# PIRA DEMONSTRATION BIBLIOGRAPHY

## AAPT SUMMER MEETING
## Philadelphia, Pennsylvania
## July-2012

LECTURE DEMONSTRATIONS WORKSHOP

### LEADERS


Brian Andersson - University of Minnesota
Cliff Bettis - University of Nebraska-Lincoln
Jerry Hester - Clemson University
Vacek Miglus - Wesleyan University
Sam Sampere - Syracuse University
Tom Senior - New Trier High School, Retired
Dale Stille - University of Iowa
Keith Warren - North Carolina State University
Stephen Irons - Yale University
Bill Berner - University of Pennsylvania
Jerry Zani - Brown University


### ADVISORS


David Maiullo - Rutgers University
David Sturm - University of Maine


### PIRA HOMEPAGE

**http://www.pira-online.org**

### UNIVERSITY OF MICHIGAN PIRA 200

http://webapps.lsa.umich.edu/physics/demolab/Content/FeaturedDemos.aspx

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# Dedicated to the Memory of Phillip Johnson

This volume is dedicated to Phil Johnson whose life brought this work to fruition.

It was Phil's vision that the demonstrations used in the physics classroom could be cataloged, given a universal number code thus eliminating a lot of confusion from school to school.  He also saw the value and need for a reference that professionals in the field could pickup and find any number of demonstration and the corresponding references to the literature on the subject.  This makes it possible to expand and enhance the demonstrations facility at any school using this volume.

I remember the first meeting at the University of Texas Austin, where he was a tireless and demanding taskmaster.  Keeping us on course and focused could be a challenge. Demonstrations that were new to any number of us would lead us off into extraneous discussions very easily, but Phil with a firm hand would get us back on track.  Phil could play just as easily as any of us and really enjoyed an evening of conviviality, the discussion more often than not wandered back to demos and how to improve them.  Talking shop is easy to do when you love your job, and Phil loved demos!

Phil was also the quintessential Big Demo man.  His demonstration show at the American Association of Physics Teachers at the University of Minnesota is a legend.  It was my first show and I learned why bother crushing a 5 gallon can when you can crush a 55 gallon drum with stunning effect.  Or was it the monkey shoot that was performed with a live professor dropped from a 25 to 30 foot scaffold into a pole vaulters foam safety pit.

Those of us who knew Phil well will find it hard to forget that quiet smile and gentle man who found it easy to laugh.  A man whose focus brought a new professionalism to the world of lecture demonstrations.  A man who by the strength of his character willed this bibliography to life.

Zigmund J. Peacock
University of Utah

# PIRA DEMONSTRATION BIBLIOGRAPHY

**This Demonstration Bibliography consists of entries from:**

| | |
|---|---|
| Demonstration Experiments in Physics | **by Richard Manliffe Sutton** |
| A Demonstration Handbook for Physics | **by G.D. Freier and F. J. Anderson** |
| Physics Demonstration Experiments at William Jewell College | **by Wallace A. Hilton** |
| Physics Demonstration Experiments | **by Harry F. Meiners** |
| The Dick & Rae Physics Demo Notebook, Vol. 1 & Vol. 2 | **by Richard B. Minnix & D. Rae Carpenter, Jr.** |
| The University of Minnesota Handbook | **( UMN )** |
| The American Journal of Physics | **( AJP )** |
| The Physics Teacher | **( TPT )** |
| The Video Encyclopedia of Physics Demonstrations | **( DISC )** |
| Physics Demonstrations, A Sourcebook for Teachers in Physics | **by Julien Clinton Sprott** |
| A Demo A Day, A Year of Physics Demonstrations | **by Borislaw Bilash II & David Maiullo** |

**Each source has a unique numbering format. This unique format is used to identify the source of each entry in the Bibliography. Examples of the unique numbering format for each reference are:**

| | |
|---|---|
| **Sut, M - 1** | Sutton |
| **F&A, Ma - 1** | Freier and Anderson |
| **Hil, M - 1d** | Hilton |
| **Mei, 8 - 2.8** | Meiners |
| **D&R, M - 108** | Dick & Rae |
| **UMN, 1A12.01** | University of Minnesota Handbook |
| **AJP 52(1), 85** | American Journal of Physics |
| **TPT 15(5), 300** | The Physics Teacher |
| **Disc 01 - 01** | The Video Encyclopedia of Physics |
| **Sprott, 1.1** | Sprott |
| **Bil&Mai, p3** | Bilash II & Maiullo |

# How to use the Physics Demonstration Bibliography

This Demonstration Bibliography contains about 11,000 entries including all of Sutton, Freier & Anderson, Meiners, Hilton, Dick and Rae, The University of Minnesota Demonstration Handbook, The American Journal of Physics ( AJP ), The Video Encyclopedia of Physics Demonstrations, articles from The Physics Teacher ( TPT ), Sprott, and Bilash II & Maiullo.

The on-line version of this Bibliography may be found at the University of Colorado at Boulder.
The URL is: http://physicslearning.colorado.edu/Pira.asp
Excel versions can be found at: http://physicslearning.colorado.edu/PiraHome/dcs/PIRADCS.html

Information in the main body of this bibliography is listed in four columns:

| Reference | Demonstration Name | PIRA DCS number | Abstract |
|---|---|---|---|

Example:

| | | | |
|---|---|---|---|
| F&A, Mb-16 | Monkey and Hunter | 1D60.30 | A compressed air gun shoots at a tin can. |

Each reference has a unique numbering format. This unique format is used in the bibliography as a means of identifying the source and entry of each reference. Some references have a similar format, so an author prefix has been added to the entries. A list of formats for the reference column in this book is:

| | |
|---|---|
| **Sut, M - 1** | Sutton |
| **F&A, Ma - 1** | Freier & Anderson |
| **Hil, M - 1d** | Hilton |
| **Mei, 8 - 2.8** | Meiners |
| **D&R, M - 108** | Dick and Rae |
| **UMN, 1A12.01** | University of Minnesota Handbook |
| **AJP 52(1), 85** | American Journal of Physics |
| **TPT 15(5), 300** | The Physics Teacher |
| **Disc 01 - 01** | The Video Encyclopedia of Physics Demonstrations |
| **Sprott, 1.1** | Julien Clinton Sprott |
| **Bil&Mai, p3** | Bilash II & Maiullo |

The **"demonstration"** name listed in the bibliography is either the name listed on the reference or, if none is given, a simple descriptive name. In cases where there are several common names for a demonstration, the committee has chosen a preferred name.

The **"abstract"** is very brief. It is not intended to be a summary of the reference. One sentence is, in general, sufficient to describe the unique characteristics, if any, of the item.

Each demonstration is listed in only one location, even if it is commonly used to illustrate several concepts.  The committee has tried to determine the most fundamental use for any demonstration and included reference pointers at other common locations of demonstration use.

The PIRA bibliography is also a dynamic reference.   The bibliography changes and expands as new technologies, demonstrations, education standards, and references emerge.  An example of this would be when a demonstration moves out of the PIRA 200, 500, or 1000.  In this case the reference that has moved out of the PIRA 200, PIRA 500, or PIRA 1000, is given the designation **"PIRA 200 - Old", "PIRA 500 - Old", or "PIRA 1000 - Old".**
The PIRA Bibliography Committee approves to all changes and additions to the Bibliography.

| | |
|---|---|
| 1A10.20 | Standards of Mass |
| 1A10.35 | Meter Stick |
| 1A40.10 | Vectors |
| 1A50.10 | Radian |
| 1A60.10 | Powers of Ten |
| 1C10.05 | Ultrasonic Ranger and Student |
| 1C10.20 | PASCO Dynamics Carts |
| 1C20.10 | Penny and Feather |
| 1C30.10 | PASCO Free Fall |
| 1D40.10 | Throw Objects |
| 1D50.10 | Ball on a String |
| 1D50.40 | Pail of Water, Pail of Nails |
| 1D60.10 | Howitzer and Tunnel |
| 1D60.20 | Simultaneous Fall |
| 1D60.30 | Monkey and Hunter |
| 1E10.10 | Bulldozer on Moving Sheet |
| 1E10.20 | Frames of Reference Film |
| 1F20.10 | Inertia Ball |
| 1F20.30 | Tablecloth Pull |
| 1F30.10 | Persistence of Motion |
| 1G10.10 | Accelerating Air / Dynamics Cart |
| 1G10.40 | Atwood's Machine |
| 1H10.10 | Push Me Pull Me Carts |
| 1J10.10 | Map of State |
| 1J11.20 | Tower of Lire |
| 1J20.10 | Bowling Ball Stability |
| 1J20.11 | Balance the Cone |
| 1J30.10 | Suspended Block |
| 1J30.25 | Rope and Three Students |
| 1J40.10 | Grip Bar |
| 1J40.20 | Torque Beam |
| 1K10.20 | Ladder Against a Wall |
| 1K10.30 | Walking the Spool |
| 1K20.10 | Friction Blocks - Surface Materials |
| 1K20.30 | Static vs. Sliding Friction |
| 1L10.10 | Cavendish Balance Video |
| 1L20.10 | Gravitational Wells |
| 1M10.20 | Pile Driver |
| 1M20.10 | Pulleys |
| 1M40.10 | Nose Basher |
| 1M40.15 | Stopped Pendulum |
| 1M40.20 | Loop the Loop |
| 1N10.20 | Egg in a Sheet |
| 1N20.20 | Spring Apart Carts |
| 1N21.10 | Carts and Medicine Ball |
| 1N22.10 | Fire Extinquisher Rocket |
| 1N22.20 | Water Rocket |
| 1N30.10 | Collision Balls |
| 1N40.24 | Air Table Collisions |
| 1Q10.10 | Inertia Wands and Two Students |
| 1Q10.30 | Ring, Disk, and Sphere Race |
| 1Q20.10 | Adjustable Angular Momentum |
| 1Q30.10 | Passing the Wheel |
| 1Q40.10 | Rotating Stool and Masses |
| 1Q40.22 | Rotating Hoberman Sphere |
| 1Q40.30 | Rotating Stool and Wheel |
| 1Q50.50 | Precessing Gyro |
| 1R10.10 | Stretching a Spring |
| 1R40.30 | Happy and Sad Balls |
| 2A10.20 | Floating Metals |
| 2B20.40 | Pascal's Vases |
| 2B30.10 | Crush the Can |
| 2B30.30 | Magdeburg Hemispheres |
| 2B35.30 | Manometer |
| 2B40.10 | Weigh Submerged Block |
| 2B40.20 | Archimedes' Principle |
| 2C10.10 | Torricelli's Tank |
| 2C20.15 | Venturi Tubes |
| 3A10.10 | Simple Pendulum |
| 3A15.10 | Physical Pendulum |
| 3A20.10 | Mass on a Spring |
| 3A40.10 | Cir. Motion vs. Mass on a Spring |
| 3A60.10 | Tacoma Narrows Film / Video |
| 3A70.20 | Coupled Pendula |
| 3B10.10 | Pulse on a Rope |
| 3B10.30 | Shive/Bell Labs Wave Model |
| 3B20.10 | Hanging Slinky |
| 3B22.10 | Melde's Apparatus |
| 3B40.10 | Doppler Buzzer |
| 3B50.40 | Moire Pattern Transparencies |
| 3B55.10 | Speaker Bar |
| 3B55.40 | Trombone |
| 3B60.10 | Beat Forks |
| 3B60.20 | Beats on Scope |
| 3C20.10 | Range of Hearing |
| 3C30.20 | DB Meter and Horn or Speaker |
| 3D30.60 | Kundt's Tube |
| 3D30.70 | Hoot Tubes |
| 3D40.20 | Singing Rod |
| 3D40.30 | Chladni Plate |
| 3D40.55 | Shattering Goblet |
| 4A30.10 | Bimetallic Strip |
| 4A30.20 | Ball and Ring |
| 4A40.30 | Smashing Rose and Tube |
| 4B20.10 | Convection Tube |
| 4B30.21 | Conduction Rods |
| 4B40.10 | Light the Match |
| 4B50.25 | Heating a Water Balloon |
| 4B60.10 | Dropping Lead Shot |

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| 4B70.20 | Expansion Cloud Chamber |
| 4C30.10 | Boiling by Cooling |
| 4C31.30 | Drinking Bird |
| 4D10.10 | Brownian Motion Cell |
| 4D20.10 | Crookes' Radiometer |
| 4D30.20 | Molecular Motion Demonstrator |
| 4E10.20 | Balloon in LN2 |
| 4E30.10 | Constant Volume Bulb |
| 4F30.10 | Stirling Engine |
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| 5A10.10 | Rods and Fur |
| 5A20.10 | Rods and Pivot |
| 5A22.25 | Soft Drind Can Electroscope |
| 5A40.10 | Charging by Induction |
| 5A40.20 | Charge Propelled Cylinder |
| 5A50.30 | Van de Graaff Generator |
| 5B10.10 | Hair on End |
| 5B10.40 | Electric Field Lines |
| 5B20.10 | Faraday's Ice Pail |
| 5B20.35 | Radio in a Cage |
| 5B30.35 | Point and Ball with Van de Graaff |
| 5C10.20 | Parallel Plate Capacitor |
| 5C20.10 | Capacitor with Dielectrics |
| 5C30.20 | Short a Capacitor |
| 5C30.30 | Light the Bulb |
| 5D10.40 | Resistance Model |
| 5D20.10 | Wire Coil in LN2 |
| 5D20.60 | Conduction in Glass |
| 5D40.10 | Jacob's Ladder |
| 5E40.25 | Lemon Battery |
| 5E50.10 | Thermocouple |
| 5F10.10 | Ohm's Law |
| 5F15.35 | Fuse with Increasing Load |
| 5F20.10 | Kirchhoff's Voltage Law |
| 5F20.50 | Series and Parallel Circuits |
| 5F30.10 | Capacitor and Light Bulb |
| 5G10.20 | Break a Magnet |
| 5G20.30 | Magnetic Domain Models |
| 5G30.10 | Paramagnetism and Diamagnetism |
| 5G50.10 | Curie Point |
| 5G50.50 | Meissner Effect |
| 5H10.20 | Oersted's Effect |
| 5H10.30 | Magnet and Iron Filings |
| 5H15.10 | Magnetic Field Around a Wire |
| 5H15.40 | Solenoid and Iron Filings |
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| 5H20.10 | Magnets and Pivot |
| 5H30.10 | Cathode Ray Tube |
| 5H40.10 | Parallel Wires |
| 5H40.15 | Interacting Coils |
| 5H40.30 | Jumping Wire |
| 5H50.10 | Model Galvanometer |
| 5J20.10 | LR Time Constant on Scope |
| 5J20.20 | Series orParallel Lamps w/Inductor |
| 5K10.20 | Induction Coil and Magnet |
| 5K10.30 | Mutual Induction Coils with Battery |
| 5K20.10 | Pendulum in Big Electromagnet |
| 5K20.25 | Magnets and Tubes |
| 5K20.26 | Faraday Repulsion Coil |
| 5K30.20 | Dissectible Transformer |
| 5K40.40 | Motor / Generator |
| 5L20.20 | RLC Resonance |
| 5N10.80 | EM Vectors |
| 5N20.10 | Tesla Coil / Induction Coil |
| 5N30.10 | Projected Spectrum w/ Prism |
| | |
| 6A01.10 | Speed of Light |
| 6A20.10 | Concave and Convex Mirrors |
| 6A40.30 | Disappearing Beaker |
| 6A42.20 | Big Plastic Refraction Tank |
| 6A44.10 | Blackboard Optics |
| 6A44.40 | Laser and Fiber Optics |
| 6A60.30 | Projected Filament w/ Lens |
| 6B10.15 | Inverse Square Model |
| 6C10.10 | Single Slit and Laser |
| 6D10.10 | Double Slits and Laser |
| 6D20.10 | Number of Slits |
| 6D30.10 | Newton's Rings |
| 6D30.20 | Soap Film Interference |
| 6D40.10 | Michelson Interferometer |
| 6F40.10 | Sunset |
| 6H10.10 | Polaroids on the Overhead |
| 6H10.20 | Microwave Polarization |
| 6H20.10 | Brewster's Angle |
| 6H30.10 | Three Polariods |
| 6H30.40 | Karo Syrup |
| 6J10.10 | Eye Model |
| 6Q10.10 | Holograms |
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| 7A10.10 | Discharging Zinc Plate |
| 7A50.40 | Vibrating Circular Wire |
| 7A60.10 | Electron Diffraction |
| 7B10.10 | Student Gratings and Line Sources |
| 7D10.10 | Geiger Counter and Samples |
| 7D30.60 | Diffusion Cloud Chamber |
| 7F10.60 | Lorentz Transformation/Time Dilation |
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| 8A10.10 | Orrery |
| 8A20.15 | Phases of the Moon |
| 8A30.30 | Retrograde Motion Model |
| 8A35.10 | Celestial Sphere |
| 8B10.50 | Sunspots on the Overhead |
| 8B10.60 | Random Walk |
| 8B40.30 | Membrane Table / Black Hole |
| 8C10.30 | Expanding Universe |

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| | **MEASUREMENT** | **1A00.00** | |
| | **Basic Units** | **1A10.00** | |
| PIRA 1000 | basic unit set | 1A10.10 | |
| Hil, M-1a | standards of mass, etc | 1A10.10 | Show models of the fundamental units of mass and length and a stop clock for time. |
| Disc 01-01 | basic unit set | 1A10.10 | Show a clock with a second sweep, meter and yard sticks, and kilogram and pound mass. |
| PIRA 200 | standards of mass | 1A10.20 | Show students 1 lb, 1 kg, 1 slug masses. |
| UMN, 1A10.20 | standards of mass | 1A10.20 | Show students 1 lb, 1 kg, 1 slug masses. |
| F&A, Ma-2 | standards of mass | 1A10.20 | Show sets of calibrated weights. |
| Sut, M-1 | table of masses | 1A10.24 | A table of masses covering the range from the universe to the electron. |
| Mei, 8-2.8 | conservation of mass | 1A10.28 | Weigh a flask with Alka-Seltzer closed and open on a crude and accurate balance to aid in conservation of mass discussion. |
| AJP 28(2),167 | TME and Glug | 1A10.29 | The Technische Mass Einheit ("metric slug") = 10 Glugs. |
| PIRA 500 | standards of length | 1A10.30 | |
| UMN, 1A10.30 | standards of length | 1A10.30 | Put out standard yard and meter. |
| F&A, Ma-1 | standards of length | 1A10.30 | Standard meter and standard yard. |
| D&R, M-016 | standard meter stick | 1A10.30 | A meter stick with painted 10 cm lengths for easy visibility. |
| AJP 34(5),419 | Airy points of a meter bar | 1A10.32 | Support a rectangular bar at the specific points in order that the distance between engravings will not be altered by deflections due to the weight of the bar. |
| AJP 57(11),988 | historical note | 1A10.33 | Very interesting history of the development of the meter. |
| AJP 52(7),607 | the new meter | 1A10.34 | Wouldn't it be nice to start off six page article on the new meter with a concise definition of the new meter? |
| PIRA 200 | meter stick | 1A10.35 | Set out a standard meter. |
| PIRA 1000 | "1 nsec" | 1A10.36 | |
| UMN, 1A10.36 | 1 "nsec" | 1A10.36 | Cut a length of meter stick to equal the distance light travels in one nsec. |
| Bil&Mai, p12 | significant digits | 1A10.37 | Modified meter sticks are used to teach about error and significant digits. |
| PIRA 1000 | body units | 1A10.38 | |
| UMN, 1A10.38 | body units | 1A10.38 | |
| D&R, M-020 | body units | 1A10.38 | Identifying parts of the body that approximate metric units. |
| PIRA 500 | clocks | 1A10.40 | |
| UMN, 1A10.40 | clocks | 1A10.40 | Set out a timer with a one second sweep, an hour glass, a metronome, etc. |
| PIRA 1000 | WWV signal | 1A10.45 | |
| UMN, 1A10.45 | WWV signal | 1A10.45 | Listen to WWV and show the signal on an oscilloscope. |
| F&A, Ma-3a | WWV signal | 1A10.45 | Listen to WWV and display on an oscilloscope. |
| Hil, M-1d | WWV | 1A10.45 | Listen to WWV and show the signal on an oscilloscope. |
| AJP 55(4),378 | WWV on your microcomputer | 1A10.46 | Use WWV to set the clock on your microcomputer and determine how fast it runs. |
| F&A, Ma-3b | Orrery | 1A10.48 | Use an Orrery to show sidereal time. |
| Hil, M-1e | Sidereal time | 1A10.49 | Two clocks on permanent display show Greenwich and Sidereal time. |
| PIRA 1000 | one liter cube | 1A10.50 | |
| UMN, 1A10.50 | one liter cube | 1A10.50 | A one liter wood cube has cm square rules on each face and removable one cm sq and one cm x one dm blocks. |
| Hil, M-20a.6 | one liter cube | 1A10.50 | Picture of a one liter cube. |
| D&R, M-028 | one liter volume | 1A10.50 | Show 1 liter liquid volume. |
| Bil&Mai, p 14 | estimating volumes | 1A10.52 | Pinto beans and a 1 L bottle are used in an activity where students measure the size of one bean and then use that figure to estimate how many beans are in a full bottle. |
| PIRA 1000 | mass, volume, and density | 1A10.55 | |

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| UMN, 1A10.55 | mass, volume, and density | 1A10.55 | Compare wood and aluminum cubes, each with 10 cm sides, (equal volume). Compare a 10 cm aluminum cube with a 10 cm sq x 4 cm lead block (equal mass). Compare a 10 cm aluminum cube with a 10 cm sq x 4 cm aluminum block (equal density). |
| TPT 34(7), 448 | volume relationship set | 1A10.57 | The relationship between the volumes of a cone, cylinder, cube, pyramid, rectangular prism, and sphere, all of equal diameter and height is explored. Or, take two cone type cups, cut one to half height, and determine how many small cups of water it takes to fill the uncut cup. |
| PIRA 1000 | Avogadro's number box | 1A10.60 | |
| UMN, 1A10.60 | Avogadro's number box | 1A10.60 | A cube with sides of 28.2 cm has a volume of 22.4 L at STP. |
| UMN, 1A10.60 | Avogadro's number box | 1A10.60 | |
| Hil, H-4a | Avogadro's number box | 1A10.60 | A 22.4 liter box to represent the volume of one mole at STP. |
| D&R, H-450, M-028 | Avogadro's number box | 1A10.60 | A 22.4 liter box representing the volume of one mole at STP. Masses of one mole of common elements may also be displayed on the box. |
| PIRA 1000 | mole samples | 1A10.65 | |
| UMN, 1A10.65 | mole samples | 1A10.65 | Show mole samples of carbon, iron, copper, zinc, etc. |
| PIRA 1000 | density samples | 1A10.70 | |
| UMN, 1A10.70 | density samples | 1A10.70 | One kg samples of lead, aluminum, water, wood each have 5 cm square bases. A one meter frame shows the size of approximately 1 kg of air. |
| PIRA LOCAL | Larry's density samples | 1A10.71 | Add abstract in Handbook.FM |
| | **Error and Accuracy** | **1A20.00** | |
| PIRA 1000 | Gaussian collision board | 1A20.10 | |
| UMN, 1A20.10 | Gaussian curve marble board | 1A20.10 | |
| Sut, A-47 | Gaussian collision board | 1A20.10 | Balls roll down a nail board into parallel chutes forming a probability curve similar to the distribution of molecular velocities. |
| D&R, M-042 | Gaussian collision board | 1A20.10 | Steel balls roll down a peg board with parallel chutes. Balls falling into chutes should form a probability curve. |
| Disc 16-12 | Gaussian curve | 1A20.10 | A commercial device for the overhead projector where ball bearings roll through an array of nails into parallel chutes. |
| PIRA 1000 | coin flip | 1A20.20 | |
| UMN, 1A20.20 | coin flips | 1A20.20 | |
| PIRA 1000 | dice | 1A20.25 | |
| UMN, 1A20.25 | dice | 1A20.25 | |
| AJP 43(8),732 | contact time measurement | 1A20.31 | Measure contact time of two hammers being struck together. A pulse generator is gated to a pulse counter while the hammers are in contact. Frequency of the pulse generator can be changed to vary accuracy. |
| Mei, 6-1 | vernier calipers | 1A20.41 | Use commercial large scale verniers to show how they work. Also mentions large coordinate systems. |
| Hil, M-1b | vernier calipers, etc | 1A20.41 | Demonstration versions of the micrometer and vernier calipers. |
| Hil, M-1c | vernier scale, slide rule for overhead projector | 1A20.42 | A slide rule and vernier scale made of clear plastic for use on the overhead projector. |
| PIRA 1000 | weight judgment | 1A20.50 | |
| Sut, M-2 | wood and brass blocks | 1A20.50 | A small heavy weight and a slightly lighter large wood block are passed around the class. |
| D&R, M-052 | weight judgement | 1A20.50 | Pass 35 mm film canisters with different masses inside to students and have them place in proper order from lightest to heaviest. |
| Mei, 6-2.5 | lead ping pong ball and foam chunk | 1A20.51 | Students judge weight of a white lead filled ping pong ball and a chunk of black foam. |
| Mei, 6-1.1 | statistics on overhead projector | 1A20.55 | Transparent Lucite probability board for the overhead projector. Construction details in the Appendix, p. 533. |
| PIRA 1000 | reaction time | 1A20.60 | |
| UMN, 1A20.60 | reaction time | 1A20.60 | Cover 3/4 of a stop clock face. Push the stop button when the hand shows. |
| F&A, Mb-1a | reaction time | 1A20.60 | A large stop clock is covered by a disc with one quadrant cut out. Stop the clock as soon as you see the hand emerge. |
| Mei, 6-2.6.1 | reaction time | 1A20.60 | Same as Mb-1a. |
| | **Coordinate Systems** | **1A30.00** | |
| PIRA 500 | XYZ Axes | 1A30.10 | |
| UMN, 1A30.10 | XYZ Axes | 1A30.10 | A stand holds large arrows. Also includes circular arrows that can be mounted on the vectors. |

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|---|---|---|---|
| AJP 35(12),x | non-orthogonal frames | 1A30.15 | A model for demonstrating the geometry of vectors in non-orthogonal frames. |
| Mei, 13-8.1 | Euler's angles | 1A30.21 | A model that demonstrates the orientation of an arbitrarily oriented set of orthogonal axes with respect to another orthogonal set which is fixed. |
| AJP 28(9),818 | Euler's angles - MITAC gyro model | 1A30.22 | Use the MITAC gyro as a classroom model to illustrate Euler's angles. |
| PIRA 1000 | polar coordinates | 1A30.30 | |
| UMN, 1A30.30 | polar coordinates | 1A30.30 | Need a demo to go with the xyz axes. |
| PIRA 500 | chalkboard globe | 1A30.40 | |
| UMN, 1A30.40 | chalkboard globe | 1A30.40 | Draw coordinates on a 20" plain globe. |
| PIRA 1000 | blackboard hemisphere | 1A30.41 | |
| UMN, 1A30.41 | blackboard hemisphere | 1A30.41 | Half of a 20" dia. blackboard sphere. |
| | **Vectors** | **1A40.00** | |
| PIRA 200 | components of a vector | 1A40.10 | Arrows define a three dimensional coordinate system. An arbitrary vector is viewed in the three planes. |
| UMN, 1A40.10 | components of a vector | 1A40.10 | |
| Mei, 6-4.3 | components of a vector | 1A40.10 | A three dimensional vector model on a large Lucite box. Diagrams. |
| D&R, S-025 | components of a vector | 1A40.10 | Several three dimensional coordinate systems used to describe effects of motion in a moving frame. Use a meter stick to locate points relative to origin. |
| Disc 01-07 | 3-D vector components | 1A40.10 | Metal arrows define a three dimensional coordinate system. An arbitrary vector is viewed in the three planes. |
| Hil, M-10a | components of a vector | 1A40.13 | A Lucite frame for introducing vectors. |
| PIRA 1000 | vector components animation | 1A40.14 | |
| Disc 01-04 | vector components | 1A40.14 | Animation. |
| Sut, M-3 | project components of a vector | 1A40.15 | A horizontal arrow is shadow projected onto two screens at 90 deg. facing the class. |
| PIRA 1000 | folding rule | 1A40.20 | |
| UMN, 1A40.20 | folding rule | 1A40.20 | A large version of the folding carpenter's rule of four 2' sections with painted arrows. |
| PIRA 1000 | tinker toys | 1A40.25 | |
| UMN, 1A40.25 | tinker toys | 1A40.25 | Put out a box of tinker toys that includes arrow tips. |
| F&A, Mb-2 | tinker toys | 1A40.25 | A set of tinker toys is set out. |
| PIRA 1000 | magnetic vector addition | 1A40.30 | |
| UMN, 1A40.30 | magnetic vector addition | 1A40.30 | |
| D&R, M-068 | magnetic vector addition | 1A40.30 | Magnetic arrows used to show vector addition. |
| PIRA 1000 | vector addition (parallelogram) | 1A40.31 | |
| D&R, M-064 | vector parallelogram | 1A40.31 | A parallelogram arrangement used to show vector addition on the chalk board. |
| Disc 01-02 | vector addition (parallelogram) | 1A40.31 | Animation. |
| PIRA 1000 | vector addition (head to tail) | 1A40.33 | |
| Disc 01-03 | vector addition (head to tail) | 1A40.33 | Animation. |
| PIRA 1000 | Vernier Vector Addition II | 1A40.35 | |
| UMN, 1A40.35 | Vernier Vector Addition II | 1A40.35 | Computer program. |
| PIRA 1000 | resultant of vectors | 1A40.40 | |
| Mei, 6-4.4 | resultant of vectors | 1A40.40 | Show the variation in the magnitude of the resultant of two vectors with a change in the angle between them on the overhead projector. Construction details in Appendix, p. 537. |
| Mei, 6-4.7 | resultant of vectors | 1A40.41 | Vector addition using elastic vectors on an open framework. |
| Mei, 6-4.5 | vector displacement | 1A40.50 | An overhead projector device uses two compass needles to show that a vector remains invariant when displaced. Diagram. |
| PIRA 1000 | vector dot products | 1A40.70 | |
| Disc 01-05 | vector dot products | 1A40.70 | Animation. |
| PIRA 1000 | vector cross products | 1A40.75 | |
| Disc 01-06 | vector cross product | 1A40.75 | Animation shows vectors superimposed on a right hand. |
| | **Math Topics** | **1A50.00** | |

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| PIRA 200 | radian disc | 1A50.10 | A flexible strip of plastic equal to the radius is bent around the edge of a circle. |
| UMN, 1A50.10 | radian | 1A50.10 | Show a flexible rod has a length equal to the radius of a large disc, then bend it around the circumference and mark off the radians. |
| Hil, M-16a | radian | 1A50.10 | A string is used to mark off radii on the circumference of a large disc. |
| Disc 05-12 | radian disc | 1A50.10 | A flexible strip of plastic equal to the radius is bent around the edge of a circle. |
| TPT, 37(4), 253 | a nostalgic demonstration of the radian | 1A50.10 | A radian disc is made out of wood and painted bright yellow, looking remarkably similar to a Pac-Man. |
| AJP 51(8),760 | sine, cosine, and circle linkage | 1A50.30 | Linkages connect a spot moving around a circle with spots moving orthogonally as the sine and cosine. |
| Mei, 6-1.2 | binary counter | 1A50.51 | Working model of a binary counter with a scale of 32. Construction details in the Appendix, p. 533. |
| AJP 32(7),645 | mechanical binary scaler | 1A50.52 | A mechanical binary scaler with flipping wood blocks. |
| AJP 47(4),379 | Dirac's strings models | 1A50.60 | Some mechanisms to demonstrate Dirac's strings where turning through 360 degrees will not bring it back to the initial configuration. |
| AJP 46(10),1015 | discrete linear transformation | 1A50.60 | Model of a discrete linear transformation where columns of water in a Plexiglas cube are allowed to flow through a matrix plate into compartments models a discrete linear transformation. |
| AJP 34(4),359 | sim. equations device | 1A50.65 | A balancing meter stick as an analog device for solving linear simultaneous equations. |
| AJP 42(5),425 | projection slide rule | 1A50.70 | Make a projection slide rule with front and back scales mounted side by side. |
| TPT 2(5),228 | integers as sum of reciprocals | 1A50.80 | A general treatment of integer values of the sum of reciprocals applicable to parallel resistors, series capacitors, spherical mirrors, thin lenses, etc. |
| | **Scaling** | **1A60.00** | |
| PIRA 200 | Powers of Ten | 1A60.10 | "Powers of Ten" is a film covering scales from the universe to sub-atomic. |
| UMN, 1A60.10 | Powers of Ten | 1A60.10 | "Powers of Ten" is a visual trip covering scales from the universe to sub-atomic. It is available in film and videodisc versions. |
| D&R, M-024 | Powers of 10 | 1A60.10 | "Powers of Ten" film and "Metric Mania", a fun transparency. |
| PIRA 1000 | scaling model for biological systems | 1A60.20 | |
| UMN, 1A60.20 | two cows | 1A60.20 | |
| AJP 45(5),498 | scaling model for biological systems | 1A60.20 | A wood "cow" with barely adequate legs stands and another scaled up by a factor of 5 collapses. |
| AJP 50(1),72 | scaling - zoological domain | 1A60.22 | The fundamentals of scaling in the zoological domain covering many animal characteristics. |
| PIRA 1000 | 2:1 scaling | 1A60.30 | |
| Disc 08-07 | 2:1 scaling | 1A60.30 | "Bridges" of the same geometry are scaled in every dimension by 2:1. Masses placed in the center of the bridges are also scaled 2:1. |
| PIRA 1000 | scaling cube | 1A60.40 | |
| UMN, 1A60.40 | scaling cube | 1A60.40 | A large cube made up of 27 smaller ones is painted black on the outside. Knock the stack apart and show the increase in surface area by the preponderance of unpainted surfaces. |
| Disc 14-16 | scaling cube | 1A60.40 | Cut a cube painted black into 27 smaller cube. When dismantled, the unpainted surfaces show the increase in surface area. |
| | **MOTION IN ONE DIMENSION** | **1C00.00** | |
| | **Velocity** | **1C10.00** | |
| PIRA 200 | ultrasonic detector and students | 1C10.05 | Have a student walk to and from a sonic ranger while observing plots of position, velocity, and acceleration. |
| UMN, 1C10.05 | sonic ranger and students | 1C10.05 | Have a student walk toward and away from a sonic ranger while observing plots of position, velocity, and acceleration on a projection of the Mac. |
| Bil&Mai, p 18 | sonic ranger and students | 1C10.05 | A record player with multiple speeds is used to pull a dynamics cart. Record the motion of the cart with a motion sensor. |
| PIRA 200 - Old | bulldozer on moving sheet/2D | 1C10.10 | A bulldozer runs at constant speed on a moving paper to show how velocities add and subtract. |
| UMN, 1C10.10 | bulldozer on moving sheet | 1C10.10 | The bulldozer on a moving sheet moves in the same or opposite direction as the moving sheet, not at a angle, to show addition and subtraction of velocities. |
| D&R, S-020 | vehicle on a moving sheet | 1C10.10 | A battery powered vehicle runs at a constant speed on a moving paper to show how velocities add and subtract. |

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| Bil&Mai, p 25 | vehicle on a moving sheet | 1C10.10 | A moving toy car is placed on a large sheet of paper. The speed of the car is measured when the sheet and car are moving in the same direction, opposite direction, and several other scenarios. |
| Disc 01-09 | bulldozer on moving sheet | 1C10.10 | Identical bulldozers run at constant speed, one on a moving paper, to show how velocities add and subtract. |
| PIRA 200 | PASCO dynamics cart | 1C10.20 | |
| PIRA 1000 - Old | PASCO dynamics cart | 1C10.20 | |
| UMN, 1C10.20 | PASCO dynamics cart | 1C10.20 | |
| Hil, M-2a | measuring constant velocity | 1C10.21 | Time a toy truck with a stop clock as it is pulled across the table at constant velocity in front of a meter stick. |
| Mei, 7-1.1 | photographing uniform motion | 1C10.22 | Take an open shutter photo of a toy tractor moving a blinky. |
| PIRA 500 | air track and glider | 1C10.25 | |
| UMN, 1C10.25 | air track and glider | 1C10.25 | |
| Disc 01-08 | constant velocity (airtrack) | 1C10.25 | Dots are superimposed on the screen every half second to mark the position of the air glider. |
| Mei, 11-1.4 | velocity -air track and glider | 1C10.26 | Measuring air track cart velocity: stopwatch and meter stick, spark recorder, photo interrupt. |
| PIRA 1000 | velocity -air track and glider | 1C10.27 | |
| UMN, 1C10.27 | velocity -air track and glider | 1C10.27 | Level air track with the Pasco photogate timer system. Use one or two timers. |
| PIRA 1000 | approaching instantaneous velocity | 1C10.30 | |
| UMN, 1C10.30 | approaching instantaneous velocity | 1C10.30 | An air cart is given a reproducible velocity by a solenoid kicker. Flags of decreasing length interrupt a photo timer. |
| Mei, 7-1.16 | approaching instantaneous velocity | 1C10.30 | A ball breaks two foils to start and stop a timer. Change spacing of gates to approach instantaneous velocity. |
| F&A, Mb-10 | strobed disc | 1C10.32 | Look at a fluorescent spot on a 1725 RPM disc with a stroboscope at multiples of the frequency to demonstrate the limiting process. |
| Mei, 7-2.1 | speed at a point | 1C10.33 | Take a picture of a light bulb pendulum with a strobed camera. |
| TPT 16(3),160 | terminal velocity | 1C10.51 | A mechanical device rolls down an incline with a terminal velocity. |
| TPT 1(2),82 | terminal velocity tube | 1C10.55 | A marble rolling down a tube of water at a slight incline reaches terminal velocity allowing slow constant velocity to be measured. |
| PIRA 1000 | muzzle velocity | 1C10.60 | |
| AJP 44(7),711 | muzzle velocity - foil | 1C10.60 | Graphite rods are broken to switch an oscillator in and out of a counter circuit. |
| AJP 45(9),882 | muzzle velocity - foil | 1C10.60 | Use the circuit in AJP 44(9),85 with the breaking foil method of measuring muzzle velocity. |
| AJP 45(9),882 | muzzle velocity - foil | 1C10.60 | Using the apparatus by Blackburn and Koenig, AJP 44,855(1976), to measure the muzzle velocity of a rifle. |
| TPT 20(3),184 | muzzle velocity - foil | 1C10.60 | The bullet passes through two aluminum foil strips. The signal is shown on an oscilloscope. |
| F&A, Mb-21 | muzzle velocity - foil | 1C10.60 | Bullet breaks two metal foils triggering a timer. |
| Mei, 7-1.2 | muzzle velocity - foil | 1C10.60 | Aluminum foil triggers 1 m apart start and stop an electronic timer. Construction details. |
| AJP 55(9),856 | muzzle velocity - photogate timer | 1C10.61 | Measure the speed of a bullet with eight crisscrossing LED beams with the detectors connected to an eight input OR gate. |
| Mei, 7-1.19 | muzzle velocity - photogate | 1C10.61 | Details of a photoelectric triggering circuit good to a few microseconds. |
| AJP 47(5),426 | time of flight | 1C10.62 | An inexpensive circuit useful in time-of-flight velocity measurements for bullet velocity with the ballistic pendulum demonstration of momentum conservation. Mechanical construction considerations are outlined. |
| AJP 51(7),602 | time of flight | 1C10.62 | An apparatus measures the time of flight of the projectile fired from the Blackwood pendulum apparatus by timing signals from two microphones. Circuits are included. |
| D&R, M-162 | time of flight | 1C10.62 | A baseball with inserted timer that starts when ball is released and stops when ball is caught or hits something. |
| Sut, E-264 | RC bullet timer | 1C10.63 | A capacitor is discharged to a ballistic galvanometer during the time the bullet passes between two gates. Diagrams and theory. |
| PIRA 1000 | muzzle velocity - disc | 1C10.65 | |
| F&A, Mb-22 | muzzle velocity - disk | 1C10.65 | An air gun is fired through two rotating cardboard discs separated by some distance. |
| Mei, 7-1.3 | muzzle velocity - disk | 1C10.65 | Shooting a bullet through two rotation discs. |
| Sut, M-70 | muzzle velocity - disk | 1C10.65 | Fire a bullet through two discs rotating on the same shaft. |
| AJP 31(7),548 | muzzle velocity - strobe photo | 1C10.66 | Sets of contacts two meters apart trigger a strobe which illuminates a spinning wheel marked with a radial line. Measure the angle on the photograph. |
| Sut, M-71 | low velocity | 1C10.71 | Project the minute hand of a clock. |

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| Sut, M-72 | velocity table | 1C10.72 | A table of velocities ranging from continental drift to the speed of light. |
| | **Uniform Acceleration** | **1C20.00** | |
| PIRA 200 | penny and feather | 1C20.10 | Drop a penny and feather in a glass tube, first full of air and then evacuated. |
| UMN, 1C20.10 | penny and feather | 1C20.10 | Drop a penny and feather in a glass tube, first full of air and then evacuated. |
| Sut, M-79 | penny and feather | 1C20.10 | Invert a large glass tube containing a feather and bit of lead. |
| Hil, M-5a | penny and feather | 1C20.10 | Dropping the feather and coin in a vacuum. |
| D&R, M-088 | penny and feather | 1C20.10 | Drop a penny and feather in an acrylic tube, first full of air and then evacuated. |
| Sprott, 1.1 | guinea and feather | 1C20.10 | In an evacuated tube objects fall at the same rate independent of their size, shape, and mass. |
| Bil&Mai, p 27 | penny and feather | 1C20.10 | How to make and use a homemade or commercial penny and feather tube. |
| Disc 01-14 | guinea and feather | 1C20.10 | Metal and paper discs are placed in identical tubes. |
| UMN, 1C20.11 | drop feather on book | 1C20.11 | |
| D&R, M-136 | drop dollar bill on book | 1C20.11 | Drop a flat dollar bill and a book simultaneously. Then place bill on top of book and drop. |
| PIRA 1000 | hammer and feather on the Moon | 1C20.12 | |
| PIRA 1000 | drop lead and cork balls | 1C20.15 | |
| UMN, 1C20.15 | cork and lead ball drop | 1C20.15 | |
| TPT 17(5),314 | drop cork & lead balls | 1C20.15 | Hint on how to drop a heavy and light object simultaneously with one hand. |
| Sut, M-80 | drop iron and wood balls | 1C20.15 | Iron and wood balls are dropped simultaneously. |
| D&R, M-120 | drop heavy and light balls | 1C20.15 | Heavy and light balls are dropped simultaneously. |
| Bil&Mai, p 33 | drop heavy and light balls | 1C20.15 | Drop heavy and light balls from the same height and see if they hit the floor at the same time. Air resistance is a factor that must be considered in very light balls such as Ping Pong balls. |
| PIRA 1000 | drop ball and paper | 1C20.16 | |
| UMN, 1C20.16 | drop ball and paper | 1C20.16 | Drop a ball and sheet of paper, then drop a ball and a wadded sheet of paper. |
| D&R, M-136 | flat and crumpled dollar bills | 1C20.16 | Drop flat and wadded dollar bills simultaneously. |
| TPT 32(9), 537 | quarters and cards | 1C20.16 | A quarter is attached near the edge of a notecard. Another quarter is attached to the center of another notecard. Both are dropped simultaneously from the same height. |
| AJP 30(9),656 | heavy and light balls pedagogy | 1C20.17 | Try asking what height the light ball must be dropped from so it hits the floor at the same time as the light. |
| TPT 35(6), 364 | freefall and air resistance | 1C20.18 | Video capture to study the effect of air resistance on a variety of objects in freefall and in two dimensions. |
| TPT 25(8), 505 | freefall and air resistance | 1C20.18 | A large light object is dropped from a height of 3 meters. Photogates are used to measure the speed of fall. |
| TPT 24(3), 153 | freefall and air resistance | 1C20.18 | Air resistance acting on a sphere analyzed with numerical analysis, strobe photographs, and videotapes. The sphere is a Ping-Pong ball. |
| TPT 43(7), 432 | freefall and air resistance | 1C20.18 | On the accuracy of computing the acceleration of free fall in air. |
| PIRA 500 | equal time equal distance drop | 1C20.20 | |
| UMN, 1C20.20 | equal time equal distance drop | 1C20.20 | Climb a ladder and drop two long strings with balls - one with equal distance intervals and the other with equal time intervals. |
| TPT 16(4),233 | equal time equal distance drop | 1C20.20 | String and Sticky Tape Series: directions for simple apparatus. |
| F&A, Mb-12 | equal time equal distance drop | 1C20.20 | Drop a long string of balls with spacing of 1,4,9,16. |
| Mei, 7-1.12 | equal time equal distance drop | 1C20.20 | Drop a string with wood blocks tied at 1,4,9,16 unit intervals. |
| Sut, M-84 | equal time equal distance drop | 1C20.20 | Drop a string with a series of lead balls attached. |
| D&R, M-094 | equal time equal distance drop | 1C20.20 | Drop a long string of balls with spacing of 1,4,9,16,etc. |
| Bil&Mai, p 29 | equal time equal distance drop | 1C20.20 | Metal nuts are tied to a string at strategic intervals. When held above a pizza pan and released the nuts are heard to strike the pan at equal time intervals. |
| Disc 01-12 | string and weights drop | 1C20.20 | Drop strings with weights. |
| PIRA 500 | inclined air track | 1C20.30 | |
| UMN, 1C20.30 | inclined air track | 1C20.30 | Place risers under one end of an air track. Use photogate timers to measure the velocity at two points. |
| Mei, 11-1.6 | inclined air track | 1C20.30 | Timing on an inclined air track: spark recording, photoelectric, periodic impact. |
| Mei, 7-1.5.1 | inclined air track | 1C20.30 | Interrupted photocell times a cart at the top and bottom of an incline. |
| Disc 01-11 | constant acceleration | 1C20.30 | Dots marking the position of the glider are superimposed on the screen as the glider accelerates down an inclined air track |
| Hil, M-3e | inclined air track | 1C20.31 | Use a stop clock and meter stick with the inclined air track. |

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| AJP 45(10),1005 | inclined air track | 1C20.35 | Data for graphs of acceleration, velocity, or displacement as a function of time is obtained from a cart on an inclined air track as it accelerates down and rebounds. Details for a timing device using two spring contacts. |
| Hil, M-15e.2 | inclined air track | 1C20.36 | Record a cart on an inclined air track with strobe photography. |
| D&R, M-108 | inclined rail and ball | 1C20.36 | Record positions of a ball at equal time intervals on an inclined channel with a strobe light. |
| PIRA 500 | blinky track | 1C20.40 | |
| UMN, 1C20.40 | blinky track | 1C20.40 | Lights that flash every second are placed along an inclined and horizontal track such that they flash at the moment the ball passes. |
| AJP 29(3),211 | acceleration "v" track | 1C20.40 | Use a 1" x 1" extruded aluminum angle for an acceleration track raceway. |
| AJP 47(3),287 | blinky track | 1C20.40 | A ball rolls down a sloped track onto a flat track. A series of lights blinking every second is mounted on the track at intervals such that the ball passes as the light blinks. |
| F&A, Mb-13 | blinky track | 1C20.40 | Lights that flash every second are spaced along an incline and horizontal track such that they are flashing at the moment the ball passes. |
| Sut, M-77 | blinky track | 1C20.40 | The original blinky track. |
| PIRA 1000 | blinky track with graphs | 1C20.41 | |
| UMN, 1C20.41 | blinky track with graphs | 1C20.41 | Two sets of magnetic arrows are transferred from the blinky track to a magnetic blackboard. The arrows graphs show the position at blinks and the change in position at blinks. |
| Disc 01-10 | rolling ball on incline | 1C20.41 | Additions to the blinky track: magnetic strips can be removed from the track showing all d's, delta d's, and delta v's. Place these strips vertically to show position, velocity, and acceleration vs time. Graphs are simulations on disc but real at U of Wash. |
| F&A, Mb-11 | blinky track - strobe photo | 1C20.42 | Use a strobe and camera to record a ball rolling down an incline and across a flat. |
| Sut, M-82 | ball on an incline | 1C20.43 | A ball is accelerated down an incline onto a horizontal track where the velocity is measured. |
| Sut, M-83 | ball on an incline with seconds pend | 1C20.43 | A seconds pendulum is released when the ball enters the horizontal track (M-82) and is placed so it knocks the ball off the track. |
| Sut, M-78 | inclined wire | 1C20.44 | A taut inclined wire forms the incline. |
| Hil, M-3d | car on an inclined wire | 1C20.44 | A long wire is stretched diagonally across the chalkboard with chalk marks at every meter. A student times a low friction car as it accelerates to various marks. |
| TPT 16(8),558 | ball on an incline | 1C20.45 | A simple demonstration using a ball bearing rolling down the grove of a plastic meter stick. Analysis included. |
| TPT 1(2),82 | slow roller on incline | 1C20.45 | A solid wheel turning on a small axis rolls down an incline. The translational velocity is slow enough to make easy accurate measurements. |
| Mei, 7-1.6 | ball on an incline | 1C20.45 | Rolling a ball down an incline starting at 1/4 the way up and all the way up. |
| Mei, 7-1.5.2 | car on an incline | 1C20.46 | A car on an incline is timed from release until the end of a measured distance. |
| Sut, M-76 | Duff's plane | 1C20.50 | A chalk ball oscillates as it rolls down a trough in a 2x6. |
| Hil, M-3c | Duff's plane | 1C20.50 | A ball leaves a trail as it oscillates back and forth while rolling down a chalk covered trough. |
| Mei, 7-1.5.8 | dynamometer | 1C20.61 | A simple dynamometer rides a cart on a track. |
| Mei, 7-1.4 | photographing acceleration | 1C20.71 | Take an open shutter strobe wheel photo of a small fan cart. |
| | **Measuring g** | **1C30.00** | |
| PIRA 200 | free fall timer | 1C30.10 | A ball is timed as it drops .5m, 1m, 1.5m, or 2m. |
| UMN, 1C30.10 | free fall timer | 1C30.10 | A ball is timed as it drops .5m, 1m, 1.5m, or 2m. |
| Mei, 7-1.17 | dropping balls | 1C30.11 | A latching relay system for turning a standard timer on and off for the dropping ball experiment. Use two independent measurements to eliminate the delay factor. |
| Mei, 7-1.18 | dropping balls | 1C30.12 | Use a photo interrupt system to time a falling ball. Details in appendix to demo 10-2.18. |
| AJP 42(3),255 | dropping balls - release | 1C30.13 | A clever device to replace the standard electromagnet release for timing a dropping ball. |
| AJP 44(9),855 | dropping balls | 1C30.13 | By replacing optical position sensors with electrical contact switches and by using an integrated-circuit timer with digital readout, the time required for a ball bearing to fall may be measured consistently to about 0.1 msec. The acceleration of gravity may then be determined to better than one part per thousand. |
| AJP 55(4),324 | accurate release mechanism | 1C30.13 | A new release mechanism with 10 ms accuracy. |
| AJP 59(6),568 | free fall timer - stopwatch mod. | 1C30.14 | Modify a commercial lap timer/stopwatch. Interface circuit and construction details. |

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| PIRA 1000 | little big ball dropper | 1C30.15 | |
| UMN, 1C30.15 | big ball dropper | 1C30.15 | |
| Hil, M-3b | dropping balls | 1C30.16 | A ball is released by an electromagnet and a clock started. The catcher stops the clock and can be set at different heights. |
| Sut, M-87 | Welch free fall apparatus | 1C30.17 | Describes an old Welch free fall apparatus. |
| PIRA 1000 | big big ball dropper | 1C30.20 | |
| UMN, 1C30.20 | tall big ball dropper | 1C30.20 | |
| Mei, 7-1.20 | dropping balls | 1C30.21 | Dropping a ball through a system of mirrors interrupts a light beam several times. Photocell output is displayed on a scope. |
| TPT 12(2),115 | induction method | 1C30.22 | Drop a magnet through several equally spaced coils of wire. Examine the induced voltage on an oscilloscope. Circuit included. |
| AJP 39(7),757 | dropping balls in air | 1C30.25 | Light and heavy balls are dropped through a multiple pass light beam and the output is shown on an oscilloscope. |
| Sut, M-85 | falling slab | 1C30.30 | A slab of wood is dropped by a ink squirter which leaves lines at equal time intervals. |
| Mei, 7-1.7 | ink jet marker | 1C30.31 | A rotating ink jet sprays a paper sleeve on a falling meter stick. |
| F&A, Mb-18 | dropping balls - photo | 1C30.33 | Take a picture of a dropping ball illuminated by a strobe. |
| Mei, 7-1.14 | dropping balls - photo | 1C30.33 | Photograph a dropping light bulb with a strobed disc. |
| PIRA LOCAL | picket fence and photogate | 1C30.35 | A calibrated picket fence is dropped through a photogate to measure "g". |
| PIRA 1000 | falling drops | 1C30.40 | |
| AJP 47(6),542 | mercury drops | 1C30.40 | A falling mercury drop generator and an electronic timing circuit conveniently and automatically generates a large number of data in a short period of time, yielding results with a high degree of precision. |
| TPT 4(2),77 | falling drops | 1C30.41 | A strobe illuminates water dripping from a faucet at an uniform rate. |
| Bil&Mai, p 35 | falling drops | 1C30.41 | Allow drops to fall from a buret. Use a stroboscope to see that the drops are accelerating. |
| AJP 48(10),888 | falling drops | 1C30.42 | A machine to make a stream of falling bubbles which are illuminated by a strobe light. |
| Mei, 7-1.15 | falling drops | 1C30.43 | Steel balls are dropped at regular intervals and illuminated with a strobe. Diagrams and pictures. |
| AJP 33(10),824 | synchrodropper | 1C30.44 | Design for a 60 Hz stable synchrodropper. |
| TPT 28(2),108 | "videostrobe" with falling drops | 1C30.46 | Use the 60 Hz refresh rate of a video monitor to strobe falling drops by adjusting the rate to 60 Hz and having the stream fall past the screen. |
| PIRA 1000 | catch a meter stick | 1C30.55 | |
| UMN, 1C20.55 | catch a meter sitck | 1C30.55 | Have one student drop a meter stick and use the distance it drops before another students catches it to determine the reaction time. |
| TPT 14(3),177 | catch a dollar | 1C30.55 | Have a student try to catch a dollar starting with the fingers at the midpoint. |
| F&A, Mb-1b | catch a meter stick | 1C30.55 | Drop a meter stick and have a student catch it. Distance can be converted to reaction time. |
| Mei, 6-2.6.2 | catch a meter stick | 1C30.55 | Drop a meter stick and have a student catch it. |
| D&R, M-098 | catch a dollar or meter stick | 1C30.55 | Try to catch a dollar bill or catch a meter stick to measure reaction time. |
| Sprott, 1.2 | reaction time, falling meter stick | 1C30.55 | Have students catch a meter stick as it is dropped. |
| Bil&Mai, p 34 | catch a dollar or meter stick | 1C30.55 | Hold a dollar bill by the top and have a student hold their open fingers over the middle of the bill. Drop the bill and see if the student can catch it. Repeat with a meter stick and measure how far the stick falls before it is caught. |
| Disc 01-13 | reaction time, falling meter stick | 1C30.55 | Have a student catch a falling meter stick and relate the distance dropped to the reaction time. |
| TPT 16(9),656 | rotating turntable | 1C30.61 | Drop a ball on a phonograph turntable. Get time from the range. |
| Mei, 7-1.13 | rotating turntable | 1C30.61 | Microswitch triggers dropping ball onto rotating turntable. |
| Sut, M-86 | pendulum timed free fall | 1C30.63 | A pendulum released from the side hits a ball dropped from the height that gives a fall time equal to a quarter period of the pendulum. |
| AJP 55(1),59 | many bounce method | 1C30.66 | Time a bouncing ball for many bounces and determine g using the coefficient of restitution. |
| | **MOTION IN TWO DIMENSIONS** | **1D00.00** | |
| | **Displacement in Two Dimensions** | **1D10.00** | |
| PIRA 1000 | ball in a tube | 1D10.10 | |
| UMN, 1D10.10 | ball in a tube | 1D10.10 | Start with a ball on a string at the bottom of a vertical tube. Hold the string while moving the tube horizontally. |
| F&A, Mb-3 | ball in a tube | 1D10.10 | A ball on a string is placed in a tube and the tube displaced. The resultant is quite apparent. |
| Mei, 6-4.12 | ball in a tube | 1D10.10 | Ball on a string in a hydrometer jar. |
| Mei, 6-4.8 | ball in a tube | 1D10.10 | A ball on a string is placed in a clear tube and the string is displaced. |

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| Sut, M-73 | ball in a tube | 1D10.10 | A bead is pulled vertically along a rod in a frame that is pulled horizontally. |
| Sut, M-74 | ball in a tube | 1D10.10 | A ball on a string is placed in a horizontal tube which is raised while holding the free end of the string on the table. |
| Disc 02-07 | velocity vector addition | 1D10.10 | The ball in a tube done horizontally on the table viewed from above with the camera. |
| TPT, 36(6),375 | vector toy | 1D10.11 | Walking toy with bob on a string that, when placed over the edge of a table, pulls the toy forward. As the toy gets closer to the edge, the angle of the pull changes. At the edge of the table, there is no component of force pulling forward, the toy stops. |
| PIRA 1000 | cycloid generator | 1D10.20 | |
| UMN, 1D10.20 | cycloid generator | 1D10.20 | A disc with a piece of chalk at the edge is rolled along the chalk tray. |
| F&A, Mb-4 | cycloid generator | 1D10.20 | A hoop with a piece of chalk fastened to the circumference is rolled along the chalk tray. |
| D&R, S-020 | cycloid generator | 1D10.20 | A hoop with a piece of chalk fastened to the circumference is rolled along the tray of a chalk board. |
| Disc 05-13 | cycloid generator | 1D10.20 | Large and small cylinders are joined coaxially. A spot on the larger cylinder moves in a cycloid when the smaller cylinder is rolled on its circumference. |
| F&A, Mb-5 | inversor | 1D10.30 | A mechanical device that transforms rotational motion into rectilinear motion. |
| F&A, Mb-6 | rotation and relative translation | 1D10.31 | A three pronged spider in a six slotted wheel. |
| F&A, Mb-8 | rotation and translation | 1D10.32 | Two blocks - one with slots and the other with pins. |
| PIRA 1000 | mounted wheel | 1D10.40 | |
| UMN, 1D10.40 | mounted wheel | 1D10.40 | A large disc marked with a radial line turns about its axis. |
| PIRA 1000 | ball on the edge of a disc | 1D10.50 | |
| UMN, 1D10.50 | ball on the edge of a disc | 1D10.50 | A ping pong ball is stuck on the edge of a vertical rotating disc. |
| TPT 2(2),81 | circular motion on the overhead projector | 1D10.55 | A device to turn a clear plastic disc at variable speed on the overhead projector. |
| Mei, 7-2.3 | balls on a disc on the overhead projector | 1D10.55 | A motorized acrylic disc with three holes for steel balls rotates on an overhead projector. |
| Hil, M-4b | measuring angular velocity | 1D10.60 | Use an electronic strobe to measure the angular velocity of a fan blade or other rotating objects. |
| Mei, 12-2.1 | disc on cart | 1D10.70 | A spinning disc mounted on a cart has a rectilinear pattern of dots. The center dot is stationary while the cart is stationary, a different dot appears stationary while moving the cart in a large circle, or while translating the cart along a track. |
| Mei, 12-2.2 | spots on a globe | 1D10.71 | An inclined globe with spots is spun, rotated in an orbit while not spinning, and both rotated and spun. The spots form parallel lines perpendicular to the various angular velocity vectors. |
| Mei, 12-2.3 | spots on a globe | 1D10.72 | A globe with random spots rests on rollers driven independently at variable speeds to show instantaneous center of rotation. |
| | **Velocity, Position, and Acceleration** | **1D15.00** | |
| ref. | showing acceleration | 1D15.01 | see 1G20.75 |
| PIRA 1000 | Hobbie film loop - AAPT | 1D15.12 | |
| UMN, 1D15.12 | Hobbie films - AAPT | 1D15.12 | |
| PIRA 1000 | kick a moving ball | 1D15.15 | |
| UMN, 1D15.15 | kick a moving ball | 1D15.15 | Kick a moving soccer ball on the floor or hit a moving croquet ball on the lecture bench with a mallet. |
| PIRA 500 | high road low road | 1D15.20 | |
| UMN, 1D15.20 | high road low road | 1D15.20 | Two balls race - one down a slight incline and the other down the same incline but including a valley. |
| AJP 51(1),132 | high road low road | 1D15.20 | Two objects start at the same velocity, one moves straight to the finish, the other traverses a valley. The problem: which wins? |
| D&R, M-418 | high road low road | 1D15.20 | Two balls race, one down a slight incline the other down the same incline but including a valley. |
| PIRA 1000 | catching the train | 1D15.30 | |
| UMN, 1D15.30 | catching the train | 1D15.30 | A ball accelerating down an incline catches and passes a ball moving at constant velocity on a horizontal track. |
| PIRA 1000 | passing the train | 1D15.35 | |
| UMN, 1D15.35 | passing the train | 1D15.35 | A ball accelerates down an incline with a stripped rope moving at constant velocity in the background. The moment the ball has the same velocity as the rope is strikingly obvious. Repeat with the rope at a different constant velocity. |
| AJP 55(5),407 | several ball and incline demos | 1D15.36 | This McDermott article contains several ball on incline races to help distinguish the concepts of position, velocity, acceleration. |

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| PIRA 1000 | Galileo's circle | 1D15.40 | |
| UMN, 1D15.40 | Galileo's circle | 1D15.40 | Several rods are mounted as cords of a large circle with one end of each rod top center. Beads released simultaneously at the top all reach the ends the rods at the same time. |
| Sut, M-89 | Galileo's circle | 1D15.40 | Small balls roll down guides that form chords of a large inclined circle. A single click marks simultaneous arrival. |
| Sut, M-88 | Galileo's circle | 1D15.40 | Beads are released simultaneously to slide along cords of a large circle. |
| PIRA 1000 | sliding weights on triangle | 1D15.41 | |
| Disc 02-09 | sliding weights on triangle | 1D15.41 | Lengths and angles of a wire frame triangle are chosen so that beads sliding down the wires traverse each side in the same time. |
| Mei, 7-2.6 | brachistochrone track | 1D15.45 | Three tracks - straight line, parabola, and cycloid are mounted together. Triggers at each end control a timer. Details. |
| PIRA 1000 | brachistochrone | 1D15.50 | |
| UMN, 1D15.50 | brachistochrone | 1D15.50 | Each end of a track forms a brachistochrone. Balls released at any height on the brachistochrones reach the middle at the same time. |
| Sut, M-93 | brachistochrone | 1D15.50 | Two balls released on opposite sides of a cycloid always meet in the middle regardless of handicap. The ball on the cycloid always beats the ball on the incline. |
| AJP 53(6),519 | brachistochrone is a tautochrone | 1D15.51 | History of the brachistochrone as a tautochrone. |
| TPT 28(8),537 | brachistochrone | 1D15.52 | On constructing a large brachistochrone. |
| AJP 53(5),490 | cycloidal slide track | 1D15.53 | Use the brachistochrone and tautochrone properties of a cycloid to make an actual slide track in amusement parks. |
| AJP 50(12),1178 | brachistochrone | 1D15.54 | Solution to the brachistochrone problem. |
| PIRA 1000 | triple track | 1D15.55 | |
| UMN, 1D15.55 | tripple track | 1D15.55 | Balls roll down an incline, brachistochrone, and parabola. The ball on the brachistochrone wins. |
| | **Motion of the Center of Mass** | **1D40.00** | |
| PIRA 200 | throw objects | 1D40.10 | A light disc contains a heavy slug that can be shifted from the center to side. Mark the center of mass. |
| UMN, 1D40.10 | throw objects | 1D40.10 | Mount battery powered lights on styrofoam shapes and throw them in the air. |
| F&A, Mp-2 | throw objects | 1D40.10 | A light wooden disc contains a heavy slug that can be shifted from the center to the side. |
| Mei, 14-2.3 | throw objects | 1D40.10 | Throw a slab of styrofoam with lights placed at the center of gravity and away from the center of gravity. |
| Mei, 12-5.1 | throw objects | 1D40.11 | A disc with a internal sliding weight has spots painted on opposite sides marking the center of mass in the two cases. |
| Hil, M-18b.2 | throw objects | 1D40.11 | Discs with movable and stationary center of mass and a "bulls eye" painted on each side, one off center. |
| Disc 03-21 | center of mass disc | 1D40.11 | Throw a disc with uniform distribution and then offset the center of mass. |
| Mei, 14-2.1 | throw hammer | 1D40.12 | Mark the center of gravity of a hammer with a white spot. Throw it in the air and attach it to a hand drill to show it rotating smoothly. |
| Mei, 9-2.1 | throw objects | 1D40.13 | A bunch of junk is tied together with strings and thrown across the room. |
| PIRA 1000 | loaded bolas | 1D40.15 | |
| UMN, 1D40.15 | loaded bolas | 1D40.15 | Some Phil Johnson humor. "This was in the Physics Teacher but I haven't got to it and I've never done it so I can't describe it well at this time". See the other 1D40.15 entries for a description. |
| TPT 30(3), 180 | bola | 1D40.15 | A description and analysis of the rotational dynamics of a bola. |
| TPT 48(4), 222 | bola | 1D40.15 | An analysis of bola motion and a simplified model bola. |
| PIRA 500 | spinning block | 1D40.20 | |
| UMN, 1D40.20 | spinning block | 1D40.20 | A large block of wood with magic markers located at and away from the center of mass. Place the block on a large sheet of paper and hit off center with a hammer. |
| F&A, Mp-17 | spinning block | 1D40.20 | A large wood block has two holes for felt tipped pens, one on the center of mass. Put the block on paper and hit it down the paper. |
| D&R, M-670 | spinning block | 1D40.20 | A 2X4 about 30 cm long has 3 holes drilled on the center line of the long axis. The center hole is at the center of mass with the other two equally spaced outward toward the ends of the block. Insert 3 different color marker pens, place the block at the end of a strip of long paper, and kick at the center of mass for parallel lines. Kick again near one end to produce one straight line plus two epicycloids. In both cases the center of mass is a straight line. |
| AJP 33(10),xiii | air supported dumbell | 1D40.21 | Two dry ice pucks on the ends of a bar form a dumbbell that rides on a sheet of plate glass. Use a cue stick to hit it on and off the center of mass. |

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| Mei, 10-2.10 | spinning block | 1D40.21 | Use a pool cue to hit a dumbbell double dry ice puck on or off the center of mass. Also shoot a .22 into a gas supported block on or off the center of mass. |
| PIRA 1000 | air table center of mass | 1D40.22 | |
| Disc 03-27 | air table center of mass | 1D40.22 | A weighted block glides across an air table. |
| AJP 31(4),299 | photographing the center of mass | 1D40.25 | Make an open lens photo of a system of two masses connected by a rod and the center of mass will be apparent. |
| AJP 58(5),495 | photographing center of motion | 1D40.25 | Photographing the center of velocity of a variety of rigid bodies. |
| Mei, 10-3.2 | spinning block | 1D40.25 | Strobed photo is taken of a irregular object translating and rotating on a air table. |
| Mei, 12-4.4 | throw the dumbell | 1D40.30 | A dumbbell with unequal masses is thrown without rotation when the force is applied at the center of mass. |
| AJP 30(6),471 | throw the dumbell | 1D40.31 | Stick unequal size corks in knitting needle, place a cord under at the center of mass, and jerk it into the air. |
| PIRA 1000 | Earth-Moon system | 1D40.35 | |
| TPT 28(6),425 | Earth-Moon system | 1D40.35 | An Earth-Moon system hanging from a string is used to demonstrate the Earth's wobble. |
| F&A, Mp-8 | Earth-Moon system | 1D40.35 | Two unequal masses are fastened to the ends of a rigid bar. Spin the system about holes drilled in the bar at and off the center of mass. |
| F&A, Mp-18 | Earth-Moon system | 1D40.35 | Pucks of different mass are held together by a string while spinning on the air table. |
| Sut, M-169 | Earth-Moon system | 1D40.35 | An Earth-Moon system is rotated from a hand drill on and off the center of gravity. |
| PIRA 1000 | air track pendulum glider | 1D40.50 | |
| UMN, 1D40.50 | air track pendulum glider | 1D40.50 | A double pendulum hangs from an air track cart with a mounted spot marking the center of mass. Set the system in oscillation and the spot will remain still or translate smoothly. |
| F&A, Mp-1 | air track pendulum glider | 1D40.50 | A pendulum with a massive bob is attached to an air cart. |
| Mei, 9-2.3 | air track pendulum glider | 1D40.50 | A heavy pendulum on a light cart. |
| Mei, 11-1.2 | air track pendulum glider | 1D40.50 | A double pendulum on an air cart has total mass equal to the cart. A marker placed on the pendulum at the center of mass is stationary as the system oscillates. |
| Sut, M-125 | momentum pendulum | 1D40.51 | A pendulum support is free to move on rollers as the pendulum swings back and forth. |
| D&R, M-486 | momentum pendulum | 1D40.51 | A pendulum support is free to move on rollers as the pendulum swings back and forth. Also can be done by standing on a roller cart and swing your hips side to side. |
| TPT 2(1),33 | momentum pendulum car | 1D40.52 | Mount a heavy pendulum on a PSSC car and then have the students imagine the pendulum scaled up to be the Earth. |
| PIRA 1000 | air track inchworm | 1D40.55 | |
| UMN, 1D40.55 | air track inchworm | 1D40.55 | A leaf spring couples two air track gliders. |
| Mei, 11-1.3 | air track inchworm | 1D40.55 | The center of mass of two carts coupled with leaf springs is marked with a light or flag. Show oscillation about the center of mass or constant velocity of c of m. |
| Mei, 9-2.2 | air track inchworm | 1D40.55 | Two carts on a track are coupled with a leaf spring and elastic. A light is mounted on the elastic at the center of mass. |
| Sut, M-126 | momentum cars | 1D40.56 | Two cars are attached together by a elastic band fastened to a motorized eccentric on one car. The point of no motion can be indicated by a pointer and changed by weighting one car. |
| Mei, 9-4.22 | rotor on a cart | 1D40.58 | Balls of equal or unequal mass can be screwed on the ends of a rod rotating horizontally about its center. The assembly is mounted on a cart on a track. The cart oscillates if the balls are of unequal mass. |
| AJP 53(10),1002 | satellite oscillation | 1D40.60 | Discussion of the LDEF satellite (30'x14'dia.) as an example where the distinction between the center of mass and center of gravity is important. |
| AJP 34(2),166 | two circle roller | 1D40.70 | Two disks, partially interlocking at right angles, roll with a wobble but with a constant height center of mass. |
| TPT 28(2),122 | non-round rollers | 1D40.71 | Two types of weird rollers: one in which the center of mass remains at a uniform distance from the surface as it wobbles down an incline, and two which although non round have a constant diameter. |
| | **Central Forces** | **1D50.00** | |
| PIRA 200 | ball on a string | 1D50.10 | Tie a lightweight ball to a string and twirl around in a vertical circle. |
| UMN, 1D50.10 | ball on a string | 1D50.10 | Tie a whiffle ball to a sting and twirl around in a vertical circle. |
| D&R, M-198 | ball on a string | 1D50.10 | Tie a lightweight ball to a string and whirl in horizontal or vertical circle. |
| PIRA 1000 | arrow on a disc | 1D50.15 | |
| UMN, 1D50.15 | arrow on a disk | 1D50.15 | Mount an arrow tangentially on the edge of a rotating disk. |
| PIRA 1000 | whirligig | 1D50.20 | |

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| UMN, 1D50.20 | whirligig | 1D50.20 | A large ball and a small ball fastened to opposite ends of a string which is threaded through a handle. |
| AJP 29(3),212 | centripetal force apparatus | 1D50.20 | Use a glass tube for the holder and rubber stoppers for the masses. |
| F&A, Mm-2 | whirligig | 1D50.20 | A large and small ball are on opposite sides of a string threaded through a handle. |
| Sut, M-138 | whirligig | 1D50.20 | Two balls - 1 kg, 100 g - are attached to the ends of a 1 m string passing through a small hollow tube.  Twirl a ball around your head. |
| D&R, M-198, M-742, & S-075 | whirligig | 1D50.20 | A string with a rubber ball on one end passes through a plastic or copper sleeve and weights are attached to a loop at the other end. |
| Disc 05-17 | ball on cord | 1D50.20 | A string with a rubber ball on one end passes through a plastic sleeve and weights are attached to a loop at the other end. |
| PIRA 500 | conical pendulum | 1D50.25 | |
| UMN, 1D50.25 | conical pendulum | 1D50.25 | A ceiling mounted bowling ball pendulum is used as a conical pendulum. |
| AJP 30(3),221 | conical pendulum | 1D50.25 | Apparatus Drawings Project No. 25: Construction of a low friction conical pendulum. |
| Mei, 8-5.3 | conical pendulum | 1D50.25 | The front axle of a bike is used for a whirligig / conical pendulum support. |
| Sut, M-160 | conical pendulum | 1D50.25 | A ball on a cord is rotated mechanically at a steady slow speed. |
| PIRA 1000 | plane on a string | 1D50.26 | |
| Disc 05-19 | plane on string | 1D50.26 | A model plane flies around on a string defining a conical pendulum. |
| Mei, 8-5.9 | conical pendulum | 1D50.27 | Motorized triple bifilar coaxial conical pendula are used to demonstrate critical period. |
| AJP 31(1),58 | conical pendulum | 1D50.28 | The main bearing of a conical pendulum is from a bicycle wheel axle. See also under whrilygig (AJP 30,221) |
| Hil, M-19L | conical pendulum | 1D50.28 | The front wheel axle of a bike is used as a good bearing for a conical pendulum where the string tension is set by a counterweight. See AJP 31(1),58. |
| TPT 1(2),81 | conical pendulum game | 1D50.29 | Swing a conical pendulum so it will strike a peg directly under the support on some swing other than the first. |
| D&R, M-784 | conical pendulum game | 1D50.29 | Swing a conical pendulum so that it will miss a miss a bottle as it swings away but hit the bottle on it's return. |
| Bil&Mai, p 136 | conical pendulum ride | 1D50.29 | Steel nuts are attached by string to the circumference of an empty wire spool.  Place the spool on a phonograph turntable set to its highest speed.  Observe the deflection.  This is a model of a carnival swing ride. |
| PIRA 1000 | carnival ride model | 1D50.30 | |
| UMN, 1D50.30 | canival ride model | 1D50.30 | A toy person is held on a vertical card at the edge of a turntable when the turntable is spun fast enough. |
| Bil&Mai, p 138 | carnival ride model - Downy ball | 1D50.30 | A Downy ball is tied to a string.  Pull the stopper of the ball outward until it locks into position.  Swing the ball slowly increasing the tangential velocity until a "pop" sound is heard indicating that the stopper has been released. |
| Disc 05-20 | roundup | 1D50.30 | A toy person stands on the inside wall of a rotating cylinder. |
| Mei, 8-5.4 | swinging up a weight | 1D50.37 | An arrangement whereby a swinging 500 g weight picks up a 1000 g weight. |
| PIRA 200 | pail of water | 1D50.40 | Swing a bucket of water in a verticle circle over your head. |
| UMN, 1D50.40 | pail of water, pail of nails | 1D50.40 | Swing a bucket of water in a vertical circle over your head. If nails are used, they can be heard dropping away from the bottom of the can. |
| F&A, Mb-29 | pail of water | 1D50.40 | A pail of water is whirled around in a vertical circle. |
| Sut, M-154 | pail of water | 1D50.40 | Swing a bucket of water over your head. |
| D&R, M-354 | pail of water | 1D50.40 | Place a test tube with mouth facing inward on the rim of a vertical bicycle wheel.  Fill with water and spin wheel.  Measure rpm when water starts to fall out of test tube to verify "g". |
| D&R, M-362 | pail of water | 1D50.40 | A plastic glass of water on a platform supported by a three point suspension is rotated horizontally or vertically without spilling.  **CAUTION**: Do not hit your leg when swinging the platform. |
| Sprott, 1.7 | pail of water | 1D50.40 | A bucket full of water is swung in a vertical circle. |
| Bil&Mai, p 130 | pail of water | 1D50.40 | A plastic glass of water on a platform supported by a three or four point suspension is rotated horizontally or vertically without spilling.  CAUTION: Do not hit your leg or anything else when swinging the platform. |
| Disc 05-21 | whirling bucket of water | 1D50.40 | Rotate a bucket of water in a vertical circle. |
| PIRA 1000 | penny on a coat hanger | 1D50.45 | |
| UMN, 1D50.45 | penny on a coathanger | 1D50.45 | |
| AJP 40(5),776 | penny on the coathanger | 1D50.45 | Place a penny on an elongated coat hanger and rotate around your finger. |
| TPT 15(1),46 | penny on the coathanger | 1D50.45 | A penny is balanced on the hook of a coat hanger.  The coat hanger is twirled around your finger and the penny doesn't fly off. |
| Sut, M-155 | penny on the coathanger | 1D50.45 | The wire coat hanger is whirled about the vertical plane by the hook without dislodging the  dime on the middle of the lower bar. |
| Hil, M-16b.3 | penny on the coathanger | 1D50.45 | Place a coin on the coat hanger and rotate it about the finger. |

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| D&R, M-362 | penny on a coathanger | 1D50.45 | Balance a penny on the hook of a coathanger and rotate. |
| Disc 05-18 | coin on coat hanger | 1D50.45 | A coin is placed on the flat of the hook of an elongated coat hanger and twirled around. |
| PIRA 1000 | balls on a propeller | 1D50.48 | |
| UMN, 1D50.48 | balls on a propeller | 1D50.48 | Balls sit in cups mounted on a swinging arm at .5 and 1.0 m. Calculate the period necessary to keep the ball in the outer cup and swing it around in time to a metronome. |
| PIRA 1000 | Welch centripetal force | 1D50.50 | |
| UMN, 1D50.50 | Welch centripetal force | 1D50.50 | The angular velocity and mass needed to stretch a spring a certain distance are compared. |
| AJP 28(6),561 | Welch centripetal force review | 1D50.50 | Uses no motor, self contained static force measurement. |
| AJP 71(2), 185 | Welch centripetal force | 1D50.50 | The center of mass correction for the usual centripital force apparatus. |
| F&A, Mm-1 | Welch centripetal force | 1D50.50 | The angular velocity and mass needed to stretch a spring a certain distance are compared. |
| AJP 34(10),981 | Welch centripetal force modification | 1D50.51 | Two modifications to the apparatus. |
| AJP 43(5),466 | Welch centripetal force | 1D50.51 | A modification to improve the Sargent-Welch 9030 centripetal force apparatus. |
| AJP 34(8),708 | Welch centripetal force modification | 1D50.51 | Improvements to the Welch centripetal force apparatus. |
| AJP 28(4),377 | variable centripetal force | 1D50.53 | A new design for the apparatus that allows any two of the three variables of mass, angular velocity, and distance to be kept constant. |
| TPT 21(3),188 | Cenco centripetal force | 1D50.53 | A relay starts the counter and clock so three hands are not needed when using the Cenco 74470 apparatus. |
| Hil, M-16e | Cenco centripetal force | 1D50.53 | Lab apparatus used as a demonstration. |
| AJP 45(5),496 | Cenco centripetal force modification | 1D50.54 | Replace the screw adjustment for the fixed end of the spring with a movable plate. |
| TPT 18(6),466 | hand rotator | 1D50.55 | Two 2000 g spring balances are mounted on a rotator. Equal masses are attached to each and readings are taken at some rotational velocity. |
| PIRA 1000 | banked track | 1D50.60 | |
| UMN, 1D50.60 | banked track | 1D50.60 | Need Demo. |
| Sut, M-144 | banked track | 1D50.60 | A steel ball rolled down an incline into a funnel reaches an equilibrium level where it revolves in a horizontal plane. |
| D&R, M-370 | carnival ride variation | 1D50.60 | A ball is placed in a Styrofoam cup or flower pot with no bottom and rotates around the inside at a constant height when the pot is swirled at the right frequency. |
| Sut, M-145 | ball in a megaphone | 1D50.62 | Throw a ball into a megaphone and it turns around and comes out the wide end. |
| TPT 11(3),173 | banked track | 1D50.65 | A turntable can be rotated at various angular frequencies. Objects can be placed at different radii. A small platform can be attached which will swing out to the correct slope for any angular velocity. A device for measuring force is also shown. |
| Sut, M-156 | puzzle | 1D50.69 | Two balls in a box must be caught in end pockets simultaneously. |
| PIRA 1000 | rolling chain | 1D50.70 | |
| UMN, 1D50.70 | rolling chain | 1D50.70 | A loop of chain is spun up on a disc and released to roll down the lecture bench as a rigid hoop. |
| F&A, Mm-3 | rolling chain | 1D50.70 | A flexible chain is spun on a motorized pulley. When it is released, it maintains rigidity as it rolls down the lecture bench. |
| Sut, M-139 | rolling chain | 1D50.70 | A loop of chain is brought up to speed on a motorized disc and when released rolls down the lecture bench over obstacles. |
| Hil, M-16c.2 | rolling chain | 1D50.70 | A loop of chain spun on a wheel and forced off remains rigid for some time. |
| D&R, M-366 | rolling chain | 1D50.70 | A loop of chain is spun up on a disc in a drill and released to roll across the floor as a rigid hoop. |
| Sprott, 1.14 | rolling chain | 1D50.70 | A loop of chain is spun up on a disc and then released. The chain retains its circular shape as it rolls across the lecture bench or over objects in its path. |
| Disc 05-24 | spinning chain | 1D50.70 | Spin a flexible chain rapidly enough that it acts as a solid object. |
| | **Deformation by Central Forces** | **1D52.00** | |
| PIRA 500 | flattening Earth | 1D52.10 | |
| UMN, 1D52.10 | flattening Earth | 1D52.10 | A hand crank spins a globe made of flexible brass hoops. |
| F&A, Mm-4b | flattening Earth | 1D52.10 | Flexible hoops flatten when spun on a hand crank rotator. |
| D&R, S-370 | flattening Earth | 1D52.10 | Flexible hoops flatten when spun on a rotator. |
| Bil&Mai, p 142 | flattening Earth | 1D52.10 | A variable speed hand drill spins flexible hoops on a steel shaft. The hoops flatten when spun. |

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| Disc 05-22 | centrifuge hoops | 1D52.10 | A flexible hoop becomes oblate as it is rotated. |
| Sut, M-147 | flattening Earth | 1D52.11 | Spin deformable balls. A clay/glycerin ball will burst, a sponge rubber ball will deform greatly. |
| Mei, 8-5.2 | empty jug by swirling | 1D52.17 | A jug will empty faster when swirled. |
| PIRA 1000 | water parabola | 1D52.20 | |
| UMN, 1D52.20 | water parabola | 1D52.20 | |
| TPT 12(8),502 | water parabola | 1D52.20 | A rectangular Plexiglas box partially filled with colored water is rotated. The parabolic shape is clearly seen. |
| F&A, Mm-8 | water parabola | 1D52.20 | A flat sided tank half full of water is rotated on a platform. |
| Mei, 8-5.5 | water parabola | 1D52.20 | A small self strobed rotating Plexiglas container is used to project the water parabola. |
| Sut, M-142 | water parabola | 1D52.20 | A glass cylinder half filled with colored water is spun on a rotating table. |
| Disc 13-17 | parabolid of revolution | 1D52.20 | A cylindrical container with some water is rotated at a constant speed. |
| PIRA 1000 | rotating water troughs | 1D52.21 | |
| Disc 13-18 | rotation water troughs | 1D52.21 | Two water containers are mounted on a rotating table. A rectangular container mounted radially shows half a parabola, and another formed in an arc of constant radius stays level. |
| Mei, 8-5.1 | rotating manometer | 1D52.23 | Tubing constructed in an "E" shape on its back is partly filled with water and rotated. |
| Sut, M-150 | rotating manometer | 1D52.24 | A U shaped manometer is mounted with one of its arms coincident with the axis of a rotating table. |
| Sut, M-143 | project mercury parabola | 1D52.26 | Spin a dish of mercury and image a light bulb on the ceiling. |
| PIRA 1000 | balls in water centrifuge | 1D52.30 | |
| UMN, 1D52.30 | balls in water centrifuge | 1D52.30 | Cork and steel balls are spun in a curved tube filled with water. |
| AJP 30(5),385 | balls in water centrifuge | 1D52.30 | Wood balls in two curved tubes, air and water filled, are rotated. |
| TPT 1(1),35 | balls in water centrifuge | 1D52.30 | Spin a bent glass tube filled with water that contains two wood or steel balls. |
| Sut, M-153 | balls in water centrifuge | 1D52.30 | Spin a bent glass tube filled with water containing cork and aluminum balls. |
| Hil, M-16d.3 | balls in water centrifuge | 1D52.30 | A glass bowl containing water, a steel ball, a cork ball is spun. |
| Hil, M-16d.1 | corks in water centrifuge | 1D52.30 | Spin a semicircular tube filled with water containing two corks. |
| F&A, Fl-7 | inertial pressure gradient | 1D52.31 | A bubble in a tube goes to the center when whirled in a horizontal circle. |
| Mei, 8-3.5 | centrifuge | 1D52.31 | A long thin tube containing a wood plug is rotated horizontal while either filled with water or empty. |
| Mei, 8-3.6 | balls in water centrifuge | 1D52.31 | A long thin tube containing a brass ball, ping pong ball, and water is rotated. |
| AJP 53(9),915 | cork and ball rotating in water | 1D52.33 | One cork is tied to the bottom, one ball is tied to the top of two cylinders full of water at the ends of a rotating bar. |
| Hil, M-16c.1 | rotating corks in water | 1D52.33 | Corks tied to the bottom of two jars full of water are first translated on a cart and then put on a pivot and rotated about the center. |
| Bil&Mai, p 132 | rotating floats in water | 1D52.33 | Fishing floats tied to the bottom of two jars full of water are attached to a large plywood circle with Velcro. Place this assembly on a Lazy-Susan, rotate, and observe the floats. |
| AJP 56(11),1046 | car picture | 1D52.34 | A picture taken from inside a car of a candle, CO2 balloon, H2 balloon as the car is driven in uniform circular motion. |
| PIRA 1000 | water and mercury centrifuge | 1D52.35 | |
| F&A, Mm-4a | mercury/water centrifuge | 1D52.35 | A globe with water and mercury on a hand crank rotator. |
| Sut, M-159 | mercury/water centrifuge | 1D52.35 | A spherical glass bowl is spun and mercury forms a equatorial band with water above and below. |
| Disc 05-23 | water and mercury centrifuge | 1D52.35 | Water and mercury spin in a glass sphere. |
| Sut, M-152 | centrifuge | 1D52.36 | Diagram for building a projection cell centrifuge. |
| F&A, Mm-7 | centrifuge | 1D52.37 | A hand cranked test tube centrifuge. |
| Sut, M-148 | the full skirt | 1D52.38 | Spin a doll with a full skirt or kilt. Cheap thrills. |
| PIRA 1000 | rotating candle | 1D52.40 | |
| UMN, 1D52.40 | rotating candle | 1D52.40 | A candle is placed on a turntable and covered with a large Plexiglas hemisphere. |
| AJP 37(4),456 | rotating candle | 1D52.40 | Make the rotating candle out of meter sticks and candles. |
| F&A, Fl-4 | central pressure gradients | 1D52.40 | A candle rotates in a chimney on a turntable. |
| Mei, 10-2.5 | rotating candle | 1D52.40 | A lighted candle in a chimney goes around on a dry ice puck string attached by a string to a pivot. |
| Sut, M-141 | rotating candle | 1D52.40 | A lighted candle in a chimney lamp on a rotating table will point to the center. |
| Hil, M-16d.2 | rotating candle | 1D52.40 | Lighted candles in chimneys are rotated about the center of mass. |
| Mei, 8-5.6 | geotropsim | 1D52.45 | Grow corn or wheat on a rotating turntable two weeks before class. |
| PIRA 1000 | paper saw | 1D52.50 | |
| UMN, 1D52.50 | paper saw | 1D52.50 | A 6" paper disc placed on a dremmel tool cuts another sheet of paper. |

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| Sut, M-140 | paper saw | 1D52.50 | Typewriter paper will cut through other paper, Bristol board will cut through wood when spun at high speeds. |
| Sut, M-149 | rubber wheel | 1D52.60 | A sponge rubber wheel with one spoke cut is rotated at high speed and viewed under stroboscopic light. |
| PIRA 1000 | rotating rubber wheel | 1D52.61 | |
| Disc 05-25 | rotating rubber wheel | 1D52.61 | A rubber wheel stretches to a larger radius when spun. |
| AJP 52(4),335 | wobbling Christmas tree toy | 1D52.70 | A Lagrangian-effective potential solution explaining the behavior of this toy. |
| TPT 3(4),173 | centripetal-centrifugal discussion | 1D52.90 | A final (?) note on the topic from the editor. |
| | **Centrifugal Escape** | **1D55.00** | |
| PIRA 500 | broken ring | 1D55.10 | |
| UMN, 1D55.10 | broken ring | 1D55.10 | A ball is rolled around the inside of a large open metal hoop. Students predict where the ball will go when it reaches the opening. |
| Bil&Mai, p 128 | broken ring | 1D55.10 | Roll a ball around a circular hoop with a gap. Ask student to predict the path of the ball when it exits the hoop. |
| Disc 05-14 | circle with gap | 1D55.10 | Roll a ball around a circular hoop with a gap. |
| PIRA 1000 | the big omega | 1D55.11 | |
| UMN, 1D55.11 | the big omega | 1D55.11 | A large wood circle with a gap is used with a bocce ball. |
| PIRA 500 | release ball on a string | 1D55.15 | |
| Sut, M-137 | cut the string | 1D55.15 | Cut the string while swinging a ball overhead. |
| Sprott, 1.8 | revolving ball and cut string | 1D55.15 | A ball swung overhead at the end of a string is cut lose and it moves tangent to the circle. |
| Bil&Mai, p 126 | release ball on a string | 1D55.15 | Swing a ball on a string in a vertical plane while facing the audience. Release the string when the ball is in the 3 or 9 o'clock position. Attach a rubber band to the string and observe the stretch of the rubber band vs. the velocity of the ball. |
| F&A, Mb-31a | slingshot | 1D55.16 | A David and Goliath type slingshot. |
| PIRA 1000 | grinding wheel | 1D55.20 | |
| UMN, 1D55.20 | grinding wheel | 1D55.20 | Watch the path of sparks flying off a grinding wheel. |
| F&A, Mb-31b | grinding wheel | 1D55.20 | Show the sparks coming off a grinding wheel. |
| Mei, 7-2.2 | grinding wheel | 1D55.20 | Sparks fly off a grinding wheel. |
| PIRA 1000 | spinning disc with water | 1D55.23 | |
| Disc 05-16 | spinning disc with water | 1D55.23 | Red drops fly off a spinning disc leaving traces tangent to the disc. |
| PIRA 1000 | falling off the merry-go-round | 1D55.30 | |
| UMN, 1D55.30 | falling off the merry-go-round | 1D55.30 | Large turntable with different surfaces. |
| F&A, Mm-6 | falling off the merry-go-round | 1D55.30 | A turntable is rotated until objects slide or tip over. |
| D&R, M-340 | falling off the merry-go-round | 1D55.30 | A turntable is rotated until objects slide off. Try the object at a different radius and same rotation speed. |
| Bil&Mai, p 134 | falling off the merry-go-round | 1D55.30 | A turntable is rotated until an object slides off. Try the object at a different radius and the same rotation speed. An old record player will also work. |
| Disc 05-15 | rotating disc with erasers | 1D55.30 | Place erasers on a disc at various radii and rotate until they fly off. |
| UMN, 1D55.31 | falling off the merry-go-round | 1D55.31 | Line up quarters radially on a rotating platform and spin at varying rates. |
| TPT 28(9),586 | train wrecks | 1D55.33 | Pictures of train wrecks at curves and some calculations. |
| Sut, M-151 | air pump | 1D55.50 | Three mutually perpendicular discs are rotated about the intersection of two and air is drawn in the poles and expelled at the equator. |
| | **Projectile Motion** | **1D60.00** | |
| PIRA 1000 | ball to throw | 1D60.05 | |
| UMN, 1D60.05 | ball to throw | 1D60.05 | Provide a large nerf ball, tennis ball, soft ball, or whatever ball is requested. |
| PIRA 200 | howitzer and tunnel | 1D60.10 | A ball fired vertically from cart moving horizontally falls back into the muzzle. |
| UMN, 1D60.10 | howitzer and tunnel | 1D60.10 | A spring loaded gun on a cart shoots a ball vertically and after the cart passes through a tunnel the ball lands in the barrel. |
| AJP 41(4),580 | howitzer and tunnel on air track | 1D60.10 | A launching system for use with an air track cart. |
| TPT 12(3),177 | howitzer and tunnel | 1D60.10 | A description of a ball launcher mounted on an air track cart. It can fire a small projectile (1/2" dia.) 10-15 ft. |
| F&A, Mb-24 | howitzer and tunnel | 1D60.10 | A car on a track shoots a ball up before it rolls under a tunnel. |
| Mei, 10-2.2 | howitzer and tunnel | 1D60.10 | A gun mounted on an air puck shoots a ball vertically. |
| Mei, 7-2.16 | howitzer and tunnel | 1D60.10 | As cart moves at constant velocity a cannon fires a billiard ball vertically. Details in Appendix, p. 545. |
| Mei, 7-2.15 | howitzer and tunnel | 1D60.10 | Instructor sits on a wheeled cart with a catapult to project a ball upward. |
| Sut, M-99 | howitzer and tunnel | 1D60.10 | A ball fired vertically from cart moving horizontally falls back into the muzzle. |
| Hil, M-6b | howitzer and tunnel | 1D60.10 | A steel ball projected upward from a moving car returns into the barrel. |

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| D&R, M-182 | howitzer and tunnel | 1D60.10 | A car on a track shoots a ball up before it rolls under a tunnel and catches it when it comes out of the tunnel. |
| Sprott, 1.3 | vertical gun on car | 1D60.10 | A car rolling across the table fires a projectile straight upward and subsequently catches it. |
| Bil&Mai, p 49 | howitzer and tunnel | 1D60.10 | Use a commercial spring cart or a spring popper toy on a battery powered car. |
| Disc 02-03 | vertical gun on car | 1D60.10 | A ball is shot up from a moving cart and falls back into the barrel. |
| Bil&Mai, p 47 | ball or toy and Rollerblades | 1D60.12 | Move across the room on Rollerblades. Throw a ball or small toy in the air and then catch it. Parabolic trajectory. |
| PIRA 1000 | howitzer and tunnel on incline | 1D60.15 | |
| UMN, 1D60.15 | howitzer and tunnel on incline | 1D60.15 | Prop up one end of the howitzer and tunnel track and start the cart from either end. |
| AJP 42(4),326 | howitzer and tunnel on incline | 1D60.15 | Perform the howitzer and tunnel on an incline with the car starting at rest. |
| AJP 43(8),732 | howitzer and tunnel inclined | 1D60.15 | Short note on inclined ballistic cart systems. |
| AJP 44(8),783 | howitzer and tunnel on incline | 1D60.15 | Some strobe pictures and drawings show the ball is always above the cart relative to the incline, but not always above the cart relative to the horizontal. |
| PIRA 1000 | vertical gun on accelerated car | 1D60.16 | |
| Disc 02-04 | vertical gun on accelerated car | 1D60.16 | Two cases: vertical gun on a car on an incline, and on a car accelerated by a mass on a string. |
| PIRA 200 | simultaneous fall | 1D60.20 | Two balls simultaneously dropped and projected horizontally hit the floor together. |
| UMN, 1D60.20 | simultaneous fall | 1D60.20 | Device to drop one billiard ball and shoot another out. |
| F&A, Mb-14 | simultaneous fall | 1D60.20 | A spring loaded device drops one ball and projects the other horizontally. |
| Sut, M-91 | simultaneous fall | 1D60.20 | Two apparatuses are described for dropping one ball and projecting another. |
| Hil, M-13b | simultaneous fall | 1D60.20 | One ball is projected horizontally as another is dropped. |
| D&R, M-158 | simultaneous fall | 1D60.20 | Two apparatuses are shown for dropping one ball and projecting another. |
| Bil&Mai, p 40 | simultaneous fall | 1D60.20 | Dice in different positions are flicked off a table with a ruler. They strike the floor at the same time. |
| Disc 02-01 | shooter/dropper | 1D60.20 | Drop one ball and simultaneously project another horizontally. |
| TPT 15(8),485 | simultaneous fall | 1D60.21 | Instructor rolls a superball off the hand while walking at a constant velocity. |
| TPT 46(9),553 | simultaneous fall | 1D60.21 | A simultaneous fall apparatus made from a broken meter stick and some blocks. |
| AJP 31(3),215 | simultaneous fall | 1D60.22 | Roll a steel ball down an incline where it hits another, momentum exchange knocks the one out, and the other drops through a slot. |
| PIRA 200 | monkey and hunter | 1D60.30 | A gun shoots at a target, released when the gun is fired. The ball hits the target in midair. |
| UMN, 1D60.30 | monkey and hunter | 1D60.30 | Light beam aiming, air pressure propelled, microswitch to electromagnet release version of monkey and hunter. |
| AJP 36(4),367 | monkey and hunter | 1D60.30 | Use a large bore air gun and wood "shell" projectile which is caught in a net. |
| F&A, Mb-16 | monkey and hunter | 1D60.30 | A compressed air gun shoots at a tin can. |
| Hil, M-13a | monkey and hunter | 1D60.30 | Shoot the tin can monkey with a blowgun and an electromagnet release. |
| D&R, M-170 | monkey and hunter | 1D60.30 | Blow a ball through a metal tube. Trip wire at muzzle opens an electromagnet which drops the monkey. |
| Sprott, 1.4 | monkey and hunter | 1D60.30 | A projectile fired at a falling target hits the target. |
| Disc 02-02 | monkey gun | 1D60.30 | The apparatus consists of a blow gun with dowel projectile and electromagnetic release. |
| TPT 15(7),368 | monkey and hunter on incline | 1D60.31 | A simple and effective version using rolling balls on an inclined table. |
| AJP 43(6),561 | monkey and hunter | 1D60.32 | Modifying the Cenco No. 75412 blowgun for bore sighting with a laser. |
| AJP 43(6),562 | monkey and hunter | 1D60.32 | A needle valve, reservoir, pressure gauge, and solenoid valve permits varying the muzzle velocity. |
| TPT 13(5),308 | monkey and hunter | 1D60.32 | Using the simultaneous fall device to shoot the monkey. |
| TPT 20(4),260 | monkey and hunter | 1D60.32 | Shoot the monkey using a rubber band propelled pencil. |
| TPT 10(4),216 | monkey and hunter | 1D60.32 | Using a 0.5 L India rubber bulb as a substitute for lungs. |
| Mei, 7-2.11 | monkey and hunter string release | 1D60.32 | A simple string release dart gun monkey and hunter. |
| Sut, M-92 | monkey and hunter | 1D60.32 | A bore sighted blowgun with electromagnetic release. |
| AJP 31(3),212 | monkey and hunter | 1D60.33 | Shoot a Christmas tree bulb weighted with a little water. |
| TPT 10(5),263 | monkey and hunter | 1D60.33 | Cut out a pop can and cover the hole with paper. |
| AJP 38(9),1160 | monkey and hunter | 1D60.34 | A magnetic switch and solenoid release. |
| AJP 50(5),470 | monkey and hunter | 1D60.34 | A simple switch using infrared optics and a single IC and transistor to release the magnet. |

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| TPT 19(8),563 | monkey and hunter | 1D60.34 | Bore sighting is used to aim the gun, an optoelectronic device is used to trigger the release. Circuit details are available from the author. |
| TPT 9(5),282 | monkey and hunter | 1D60.34 | A photo resistor is used as a switch. |
| TPT 2(7),336 | monkey and hunter | 1D60.34 | Use the PSSC cart spring to launch the projectile. Also a simple magnet switch. |
| TPT 5(6),272 | monkey and hunter | 1D60.34 | Plotting projectile motion using the overhead projector, strobe photography, and an optoelectronic circuit for triggering the monkey drop. |
| AJP 53(10),937 | monkey and hunter | 1D60.35 | Viewed from the free monkey frame, the bullet moves uniformly. Placing the hunter below the monkey can mislead students. |
| TPT 2(5),277 | monkey and hunter | 1D60.35 | Tutorial |
| AJP 43(6),562 | monkey and hunter | 1D60.36 | Investigates the effect of the method of air entry and switch friction on the accuracy of the shot. |
| TPT 13(5),298 | monkey and hunter | 1D60.38 | Sound activated electronic flash produces photographic record of the distance the target falls. |
| PIRA 500 | range of a gun | 1D60.40 | |
| UMN, 1D60.40 | range of a gun | 1D60.40 | An air powered cannon (5 psi) shoots a 5 cm dia x 10 cm projectile to better than 1% accuracy. |
| TPT 14(3),168 | range of a gun | 1D60.40 | Using the Blackwood ballistic pendulum gun, students are asked to calculate the angle necessary for them to be hit. |
| Sut, M-95 | range of a gun | 1D60.40 | Shoot at 45, then calculate 30 or 60 and place the target. |
| D&R, M-166 | range gun | 1D60.40 | Fire a spring gun at various angles. Simulate a strobe photo of the trajectory with a meter stick and weights hanging from strings. |
| Bil&Mai, p 45 | range of a gun | 1D60.40 | A dart gun with attached protractor to observe the angle is used to find the angle for maximum range. |
| Disc 02-06 | range gun | 1D60.40 | Fire a spring loaded gun at various angles. |
| Mei, 7-2.18 | range of a gun | 1D60.42 | Impact point of a slingshot projectile is predicted from the drawing force and drawing distance. |
| TPT 15(7),432 | range of a gun | 1D60.43 | Use the tennis ball serving machine to find muzzle velocity, range, etc. |
| TPT 14(4),245 | range of a gun | 1D60.44 | A softball is modified to be fired by the Cenco ballistic pendulum gun (No.75425). Calculate muzzle velocity and examine the range at various angles. |
| TPT 11(6),362 | range of a gun | 1D60.45 | Using a toy dart gun and a ball bearing weighted dart, the author gives a concise description for obtaining muzzle velocity used to predict the range at various angles. |
| AJP 29(2),x | range of a gun - gun | 1D60.46 | A toy spring-loaded gun is surprisingly precise. |
| AJP 31(2),89 | simple spring gun | 1D60.46 | A spring gun shoots a 3/4" steel ball 12 m/sec with 2% accuracy. |
| TPT 22(3),185 | range of a gun - gun | 1D60.46 | On using the Blackwood Pendulum gun as a device for finding the range of a projectile |
| TPT 28(7),477 | projectile launcher | 1D60.46 | Making a string and sticky tape launcher out of bamboo. |
| Mei, 7-2.19 | range of a gun - gun | 1D60.46 | A golf ball fired from a spring powered gun. Construction details in appendix, p. 548. |
| Mei, 7-2.20 | range of a gun - gun | 1D60.46 | A spring gun for a 3/4" steel ball. Construction details. |
| AJP 30(12),851 | range of a projected ball | 1D60.47 | Apparatus Drawings Project No. 32: Plans for a inclined tube for launching a ball. |
| PIRA 1000 | parabolic path through rings | 1D60.50 | |
| UMN, 1D60.50 | parabolic path through rings | 1D60.50 | Same as TPT 22(6),402 except the ball is shot with a spring loaded gun. |
| TPT 22(6),402 | parabolic trajectory | 1D60.50 | Four launching ramps are mounted to a large magnetic surfaced coordinate system. Magnet based metal hoops can be repositioned easily so the ball passes through all the hoops. Looks very nice. |
| TPT 2(7),336 | parabolic path through rings | 1D60.50 | A ball launched off a ramp will pass through a set of rings. |
| Mei, 7-2.13 | parabolic trajectory | 1D60.50 | Parabolic Lucite templates coincide with path of steel balls projected horizontally. |
| Mei, 7-2.7 | parabolic trajectory | 1D60.50 | Throw a piece of chalk so it follows a parabolic path drawn on the board. |
| PIRA 1000 | parabolic trajectory on incline | 1D60.55 | |
| AJP 52(4),299 | projectile range on an inclined plane | 1D60.55 | An old, simple, elegant (no calculus) solution. |
| TPT 2(6),278 | parabolic trajectories on the overhead projector | 1D60.55 | Ink dipped balls are rolled down an incline onto a tilted stage on an overhead projector. |
| F&A, Mb-20 | parabolic trajectory on incline | 1D60.55 | A tennis ball covered with chalk dust is rolled across a tilted blackboard. |
| Mei, 7-2.8 | parabolic trajectory on incline | 1D60.55 | Inked balls are rolled on a transparent tray on the overhead projector. Also Compton effect and Rutherford scattering. |
| Sut, M-96 | parabolic trajectory on incline | 1D60.55 | Fire a ball up an incline and trace the trajectory as it rolls on carbon paper. |
| Disc 02-05 | air table parabolas | 1D60.55 | Pucks are projected across a tilted air track. |
| AJP 28(9),805 | parabolic trajectory | 1D60.56 | A ball launched off a ramp strikes a vertical carbon paper moved repeatedly away and laterally by equal amounts. Unexpectedly, not dependent on g. |

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| Bil&Mai, p 41 | parabolic trajectory | 1D60.56 | Two tables are place a short distance apart. Hit a small block on one table with a larger block and see if it is possible for the small block to jump the gap and land on the second table. |
| Mei, 7-2.14 | parabolic trajectory | 1D60.56 | Inexpensive apparatus for plotting parabolic trajectory by repeatedly hitting a carbon paper. |
| TPT 16(1),33 | parabolic trajectory | 1D60.58 | A strobe picture is taken of the projectile motion of a golf ball. A method of analysis suited for a HS class is presented. |
| Hil, M-4a | photographing parabolic trajectories | 1D60.58 | Photograph a bouncing ping pong ball through a motorized slotted disc. |
| AJP 43(11),936 | falling body simulator | 1D60.59 | An analog computer simulator for falling bodies projected horizontally. |
| Mei, 7-2.17 | parabolic trajectory | 1D60.59 | Use an analog computer to calculate trajectories. |
| PIRA 1000 | parabolic trajectory | 1D60.60 | |
| UMN, 1D60.60 | parabolic trajectory | 1D60.60 | A pivoted bar with several pendula of length proportional to the square of the distance point from the pivot. |
| AJP 47(12),1097 | parabolic trajectory | 1D60.60 | Uses the balls hanging from a stick device at the blackboard. |
| F&A, Mb-17 | parabolic trajectory | 1D60.60 | A pivoted bar has pendula of length proportional to the square of the distance from the pivot point. |
| Sut, M-90 | parabolic trajectory | 1D60.60 | A stream of water matches the position of balls of lengths 1,4,9,16,... at all angles of elevation. |
| AJP 31(1),42 | parabolic trajectory - water stream | 1D60.61 | Apparatus Drawings Project No.33: The adjustable water nozzle has an arm extending in the direction of the nozzle with hanging arrows at intervals along the arm. Adjust the water pressure so the stream matches the arrow heads. |
| PIRA 1000 | water stream trajectory | 1D60.65 | |
| UMN, 1D60.65 | water trough trajectory | 1D60.65 | Hook a nozzle to the house water through an additional regulator to reduce pressure fluctuations. Shoot at varying angles into a water trough. |
| F&A, Mb-19 | parabolic trajectory | 1D60.65 | A hose aimed with a protractor demonstrates range. |
| F&A, Mb-23 | spitting trajectory | 1D60.65 | A pulser spits out regularly spaced water drops which are viewed with a strobe. A horizontal mirror shows uniform velocity and a vertical mirror shows acceleration. |
| Mei, 7-2.9 | parabolic trajectory | 1D60.65 | Project light down a horizontally discharged water stream to make the path visible. |
| Sut, M-255 | spitting trajectory | 1D60.65 | Use a tuning fork to break a stream of water directed at 45 degrees into regularly spaced drops. |
| Hil, M-13d | spitting trajectory | 1D60.65 | A horizontally projected water jet illuminated with a strobe. |
| Bil&Mai, p 43 | water stream trajectory | 1D60.65 | A steady stream of water is shot from a tube with an eye dropper nozzle. Adjust the angle for maximum range. |
| AJP 42(8),706 | water drop stream | 1D60.68 | Design for a water drop generator based on a speaker driven diaphragm. |
| Mei, 7-2.10 | water drop stream | 1D60.68 | A vibrator is used to break a horizontally projected stream of water into uniform drops. |
| Mei, 7-2.12 | dropping the bomb | 1D60.70 | A mechanism to drop a bomb in slow motion from a model airplane. |
| F&A, Mb-15 | juggling | 1D60.71 | Juggling higher trajectories requires slower hand motion. |
| AJP 49(5),483 | projectiles with analog computer | 1D60.90 | A simple analog computer is used to generate voltages representing the various parameters which are displayed on an oscilloscope. |
| | **RELATIVE MOTION** | **1E00.00** | |
| | **Moving Reference Frames** | **1E10.00** | |
| PIRA 200 | crossing the river | 1E10.10 | |
| PIRA 500 - Old | crossing the river | 1E10.10 | |
| UMN, 1E10.10 | crossing the river | 1E10.10 | Pull a sheet of wrapping paper along the lecture bench while a toy wind up tractor crosses the paper. |
| AJP 48(10),887 | crossing the river | 1E10.10 | A long sheet of paper (river) is pulled along the table by winding on a motorized shaft. A motorized boat is set to cross the river. Marking pens trace the paths. |
| Mei, 6-4.10 | crossing the river | 1E10.10 | A wind up toy is placed on a sheet of cardboard that is pulled along the table. |
| Sut, M-75 | crossing the river | 1E10.10 | A small mechanical toy moves across a rug which is pulled down the lecture table. |
| Bil&Mai, p 38 | crossing the river | 1E10.10 | A constant velocity toy moves across a moving paper river. Vector addition. |
| Disc 02-08 | bulldozer on moving sheet (2D) | 1E10.10 | The bulldozer moves across a sheet moving at half the speed of the bulldozer or at the same speed. |
| AJP 35(2),xix | toy tractor drive | 1E10.11 | On using toy tractors in kinematics demonstrations. |
| TPT 19(1),44 | moving blackboard | 1E10.15 | Using a large movable reference frame on wheels and a walking student, equations of relative speed can be deduced by non science majors. |

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| PIRA 200 | Frames of Reference film | 1E10.20 | |
| PIRA 500 - Old | Frames of Reference film | 1E10.20 | |
| UMN, 1E10.20 | Frames of Reference film | 1E10.20 | The classic film available on video disc permits use of selective parts. |
| Mei, 6-4.1 | photographing relative velocity | 1E10.22 | Toy bulldozers, blinkies, and a camera give a photographic record of relative velocities. |
| Mei, 7-3.1 | Galilean relativity | 1E10.23 | A Polaroid camera and blinky, each on a cart pushed by a toy caterpillar, show the various cases of relative motion. |
| F&A, Mb-30 | stick on the caterpiller | 1E10.31 | A small stick placed on the top tread of a toy caterpillar moves twice as fast as the toy. |
| AJP 34(1),xviii | inertial reference frames | 1E10.41 | Two X-Y axes, one on a moving cart, and "cord" vectors are painted with fluorescent paint and viewed in black light. |
| Mei, 7-3.2 | inertial reference frames | 1E10.41 | Complicated. Look it up. |
| | **Rotating Reference Frames** | **1E20.00** | |
| PIRA 500 | Foucault pendulum | 1E20.10 | |
| UMN, 1E20.10 | Foucault pendulum | 1E20.10 | A ceiling mounted pendulum swings freely. The change in path is noted at the end of the class period. |
| AJP 29(9),646 | Foucault pendulum | 1E20.10 | Suspension for a large (120# - 36') non driven Foucault pendulum. |
| F&A, Mz-6 | Foucault pendulum | 1E20.10 | A large pendulum hung from the ceiling swings for an hour. |
| Sut, M-208 | Foucault pendulum | 1E20.10 | Optical arrangement for projecting the Foucault pendulum motion. |
| Hil, M-19e | Foucault pendulum | 1E20.10 | Permanent corridor demonstration as described in Scientific American, vol 210, Feb. 64, 132-9. |
| AJP, 75 (10), 888 | Foucault pendulum | 1E20.10 | A thorough explanation of the Foucault pendulum utilizing underlying geometry on a level suitable for students not familiar with calculus. |
| AJP 76 (2), 188 | Foucault pendulum | 1E20.10 | A driving mechanism for a Foucault pendulum. Mechanism and electronic circuit are described. |
| AJP 78 (11), 1188 | Foucault pendulum | 1E20.10 | The changing plane of oscillation of a Foucault pendulum is calculated without using complicated equations or assumptions. |
| Disc 06-13 | Foucault pendulum | 1E20.10 | Look at the plane of swing at six ten minute intervals. |
| AJP 46(4),438 | short Foucault pendulum | 1E20.11 | Pictures and a circuit diagram for a well done short Foucault pendulum. |
| AJP 49(11),1004 | short Foucault pendulum | 1E20.11 | A 70 cm pendulum with a method of nullifying the precession due to ellipicity. |
| AJP 54(8),759 | Foucault pendulum | 1E20.11 | A Foucault pendulum driver for limited space exhibits. |
| AJP 46(5),419 | short, continuous Foucault pendulum | 1E20.11 | Modification of the AJP 46,384 (1978) pendulum to make it portable so it can be moved into lecture rooms for demonstration. |
| TPT 21(7),477 | Foucault pendulum | 1E20.11 | Plans for a very short (50 cm) Foucault pendulum. |
| TPT 19(6),421 | Foucault pendulum | 1E20.11 | Several novel features that can be incorporated in the design of a short Foucault pendulum to make construction and operation relatively simple. |
| TPT 28(6),362 | time lapse Foucault cycle | 1E20.12 | The author will provide a videotape of a complete time lapsed cycle of the Foucault pendulum filmed at the Center of Science and Industry in Columbus for preview and copying. |
| AJP 46(4),436 | Foucault pendulum | 1E20.13 | A 2 meter Foucault pendulum with a Charron ring drive. |
| TPT 19(2),134 | Foucault pendulum | 1E20.14 | The support wire for a 2.8 meter Foucault pendulum is lengthened by heating at the end of each swing. |
| Mei, 13-4.4 | Foucault pendulum | 1E20.14 | Foucault pendulum drive mechanisms. |
| AJP 34(7),615 | Foucault pendulum drive | 1E20.15 | An electromagnet is placed below the equilibrium position of the bob. Circuit for the drive is given. |
| Mei, 13-4.3 | Foucault pendulum | 1E20.16 | An optical projection system to show the deflection of a Foucault pendulum after 100 oscillations. |
| Sut, M-207 | Foucault pendulum | 1E20.16 | General text about the Foucault pendulum. |
| TPT 35(4), 199 | Spirograph | 1E20.17 | A "Spirograph" toy used to generate a picture of the motion of a Foucault pendulum. |
| TPT 35(3), 182 | Foucault's pendulum as a Spirograph | 1E20.17 | How a Foucault sand pendulum creates the same patterns as a "Spirograph" toy. |
| TPT 12(2), 89 | electronic Spirograph | 1E20.17 | An electronic circuit that shows "Spirograph" patterns on an oscilloscope. |
| AJP 38(2),173 | Foucault pendulum - Onnes experiment | 1E20.19 | A review of Onnes' analysis that led to the first properly functioning Foucault pendulum. More stuff. |
| TPT 28(5),264 | general and historical article | 1E20.19 | Some discussion of a current murder novel, some history of Foucault's work, etc. |
| PIRA 1000 | Foucault pendulum model | 1E20.20 | |
| UMN, 1E20.20 | Foucault pendulum model | 1E20.20 | A pendulum is mounted on a rotating turntable. |
| TPT 20(2),116 | Foucault pendulum model, etc | 1E20.20 | Build a simple model of the Foucault pendulum and demonstrate the Coriolis effect by the curved trace method. |
| F&A, Mz-7 | Foucault pendulum model | 1E20.20 | A simple pendulum supported above the center of a turntable. |
| Sut, M-209 | Foucault pendulum model | 1E20.20 | A simple pendulum hanging from a rotating platform. |
| Hil, M-19d | Foucault pendulum model | 1E20.20 | Picture of a nice Foucault pendulum model. |

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| D&R, S-035 | Foucault pendulum model | 1E20.20 | A pendulum is mounted on a clear acrylic rotating platform. Commercial model. |
| Mei, 8-5.7 | rotating frame | 1E20.21 | A monkey puppet sits on a rotating reference frame to help the student visualize a non-inertial frame. |
| Mei, 13-4.1 | Foucault pendulum model | 1E20.22 | Sit on a rotating chair with a table on your lab. A pendulum releasing ink marks a clear pattern on the paper. |
| AJP 55(1),67 | geometric model | 1E20.26 | A geometrical model helps correct some common misconceptions about the plane of oscillation of the Foucault pendulum. |
| TPT 18(6),459 | Foucault pendulum | 1E20.27 | Excellent diagram explaining the variation of rotation of the Foucault pendulum with latitude |
| AJP 46(7),725 | Foucault pendulum precession | 1E20.28 | Derivation of the Foucault pendulum period shows that no correction factor is needed for (1 m) lengths. Contradicts C.L.Strong, Sci.Am. 210,136 (1964). |
| PIRA 1000 | Foucault pendulum latitude model | 1E20.30 | |
| UMN, 1E20.30 | Foucault pendulum latitude model | 1E20.30 | See AJP 47(4),365. |
| AJP 47(4),365 | Foucault pendulum latitude model | 1E20.30 | A vibrating elastic steel wire pendulum demonstrates how the rotation of the plane of oscillation depends on the latitude. |
| AJP 37(11),1126 | Foucault pendulum latitude model | 1E20.35 | A ball on rod pendulum set at 45 degrees latitude can be driven by a solenoid inside the globe. |
| Mei, 13-4.2 | Foucault pendulum model | 1E20.35 | An electromagnet inside a globe drives a small pendulum at a selected latitude. Construction details p.592. |
| AJP 57(3),247 | Theory and two demonstrations | 1E20.40 | The concept of a locally inertial frame is used to study motion in accelerated frames. Two demonstrations are presented. |
| PIRA 1000 | rotating room | 1E20.50 | |
| AJP 43(7),567 | rotating room | 1E20.50 | Design for a rotating room that seats four at a table, and has four possible speeds. |
| AJP 58(7),668 | motion room | 1E20.50 | A rotating motion room that holds four students. |
| TPT 20(2),102 | catch on a rotating platform | 1E20.50 | Students try to play catch on a large rotating system. Other possibilities for the apparatus are discussed. |
| AJP 39(10),1129 | rotating coordinate frame visualizer | 1E20.51 | Experiments performed on a rotating frame are projected onto a screen through a rotating dove prism. Centrifugal force, coriolis force, angular acceleration, cyclones and anticyclones, Foucault pendulum, etc. |
| | **Coriolis Effect** | **1E30.00** | |
| PIRA 1000 | draw the Coriolis curve - vertical | 1E30.10 | |
| AJP 34(1),xvii | draw the Coriolis curve - vertical | 1E30.10 | Mount a rotating disk vertically, drive a pen on a cart at constant velocity in front of the disk. The speeds of the disk and cart are variable. |
| PIRA 1000 | draw the Coriolis curve | 1E30.11 | |
| UMN, 1E30.11 | draw the Coriolis curve | 1E30.11 | Place a poster board circle on a turntable move a magic marker across in a straight line. |
| F&A, Mb-28 | draw the curve | 1E30.11 | Move a magic marker in a straight line across a rotating disc. |
| Mei, 12-6.6 | draw the curve | 1E30.11 | A cart on a track with a marker passes in front of and draws on a large disc that can be rotated. |
| AJP 50(11),967 | Coriolis ink drop letter | 1E30.12 | AJP 50(4),381 should have referenced AJP 27(6),429. |
| AJP 50(4),381 | Coriolis | 1E30.12 | Turn a nearly vertical sheet as a drop of ink is running down it. |
| PIRA 1000 | Coriolis overhead transparency | 1E30.13 | |
| UMN, 1E30.13 | Coriolis overhead transparency | 1E30.13 | Same as AJP 46(7),759. |
| AJP 46(7),759 | Coriolis machine | 1E30.13 | A clear plastic disk is placed over a inertial reference frame marked with a constant velocity path. Draw marks on the plastic disk while turning through equal angles. |
| TPT 2(7),336 | Coriolis spark trace | 1E30.14 | The PSSC air puck is used to give a spark trace on a rotating table. |
| PIRA 1000 | Coriolis gun | 1E30.20 | |
| UMN, 1E30.20 | Coriolis gun | 1E30.20 | Same as Mb-25. |
| F&A, Mb-25 | Coriolis gun | 1E30.20 | A spring loaded gun at the center of a 4' disc is shot at a target first at rest and then while spinning. |
| Mei, 12-6.1 | Coriolis gun | 1E30.20 | A clamped dart gun is fired by an instructor sitting on a revolving chair into a target board. |
| Mei, 12-6.2 | Coriolis gun | 1E30.20 | A spring gun at the center of a rotating table fires into a target at the edge. |
| TPT 18(6),458 | Coriolis | 1E30.21 | Go to a merry-go-round and walk on it. You will feel a very strange "force". |
| F&A, Mb-27 | spinning Coriolis globe | 1E30.24 | A ball on a string is threaded through the pole of a spinning globe. Pull on the string and the ball moves to higher latitudes and crosses the latitude lines. |
| AJP 55(11),1010 | Coriolis dish and TV | 1E30.26 | A ball oscillates in a spherical dish at rest, and follows various curved paths when the dish is rotated at different speeds. A TV camera is mounted to the rotating frame. More. |

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| AJP 41(2),247 | Coriolis rotating platform and TV | 1E30.27 | A puck is launched on a rotating platform and the motion is followed with a TV |
| PIRA 1000 | Coriolis ball on turntable | 1E30.28 | |
| Disc 06-14 | Coriolis effect | 1E30.28 | Roll a ball across a slowly rotating turntable. |
| TPT, 37(4), 244 | Coriolis-effect demonstration on an overhead projector | 1E30.29 | Use an overhead and plastic rotating platform to illustrate Coriolis force to a large lecture. |
| F&A, Mb-26 | leaky bucket on turntable | 1E30.30 | A can with a hole is mounted above a rotating table. As the table turns, the stream of water is deflected. |
| D&R, S-040 | Toricelli column on turntable | 1E30.30 | A Toricelli column with only one hole open is filled and mounted on a rotating platform. As the table turns the stream of water is deflected. |
| Mei, 12-6.5 | drop ball on turntable | 1E30.32 | A mass falls on a disc first while it is rotating and then when it is stationary. Difference in point of impact is noted. |
| Mei, 12-6.3 | Coriolis trajectory | 1E30.33 | A ball describing an arc is released first in a stationary coordination system and then in a rotating system. |
| AJP 33(8),iii | Coriolis water table | 1E30.34 | A flat board rotates in a horizontal plane with a flexible tube full of flowing water running lengthwise. The tube deflects upon rotation. |
| TPT 3(4),171 | Coriolis water table | 1E30.34 | A flexible rubber tube with water flowing in it is stretched across a disc which can be rotated. The tube deflects when rotated. |
| Mei, 12-6.4 | Coriolis water table | 1E30.34 | A flexible rubber tube with water flowing in it is stretched across a disc which can be rotated. The tube deflects. |
| AJP 58(4),381 | rotating water flow table | 1E30.35 | Food coloring used to mark flow is introduced at the edges of a circular rotating tank with a center drain hole. A rotating overhead TV camera allows motion in the rotating frame to be viewed. |
| TPT 10(9),532 | Coriolis | 1E30.36 | A pan of water on a turntable has a recirculating pump with an inlet and exit of opposite sides of the pan. Floats above these areas rotate in opposite directions as the pan of water is spun. |
| PIRA 1000 | rotating TV camera | 1E30.50 | |
| UMN, 1E30.50 | rotation table with tv | 1E30.50 | |
| Mei, 12-6.7 | rotating TV camera | 1E30.51 | A TV camera is rotated in front of an oscilloscope displaying a slow ellipse. Vary the camera rotation. |
| Mei, 12-6.8 | vacuum cleaner | 1E30.61 | Cover the exhaust of an old vacuum: the current decreases as the RPM increases. Demonstrates transformation of vectors from a moving coordinate system to a rest frame. In one frame the torque does no work, in the other with open exhaust torque is responsible for the entire power. |
| AJP 38(3),390 | spinning dancer - Coriolis analysis | 1E30.71 | The spinning dancer, usually treated as an angular momentum problem, is used as a coriolis example. |
| | **NEWTON'S FIRST LAW** | **1F00.00** | |
| | **Measuring Inertia** | **1F10.00** | |
| PIRA 1000 | inertia balance | 1F10.10 | |
| UMN, 1F10.10 | inertia balance | 1F10.10 | A torsion pendulum has cups that can be loaded with various masses. |
| F&A, Mz-2 | inertia balance | 1F10.10 | A light torsion pendulum can be loaded with various masses. |
| Sut, M-106 | inertia balance | 1F10.10 | Torsion pendulum as an inertia balance. |
| PIRA 1000 | inertia balance - leaf spring | 1F10.11 | |
| Mei, 8-2.7 | inertia balance | 1F10.11 | A horizontal leaf spring as an inertial balance. |
| Bil&Mai, p 52 | inertia balance | 1F10.11 | Attach the inertia balance to the edge of a table with a clamp. Time the swings, add mass and time again. |
| Disc 08-24 | inertia balance | 1F10.11 | Place masses on a platform supported by horizontal leaf springs. |
| Mei, 8-2.5 | inertia oscillation | 1F10.12 | A puck between two springs rolling on Dylite beads is timed with several different masses. |
| AJP 29(6),vi | inertial equal arm balance | 1F10.13 | Publication of an unfinished demonstration, but up front about it. Shows circuit diagram for a indicator for a horizontal Roberval type balance on an acceleration cart. |
| TPT 11(5),312 | inertia balance | 1F10.13 | Measure the period of a commercially available (?) inertia balance by using a stroboscope. |
| PIRA 1000 | inertia bongs | 1F10.20 | |
| UMN, 1F10.20 | inertia bongs | 1F10.20 | Hit hanging 2"x4"x10" blocks of wood and steel with a hammer. |
| TPT 12(1),30 | inertia bongs | 1F10.20 | Two large cylinders are suspended, one wood (3Kg) and one iron (50Kg). Students compare displacements when struck by a hammer or just push the things around. |
| PIRA 1000 | foam rocks | 1F10.25 | |
| UMN, 1F10.25 | foam rocks | 1F10.25 | Hit a real rock (granite) then a foam rock (looks like granite) with a hammer. Throw a form rock at some students. |
| Disc 02-14 | foam rock | 1F10.25 | Hit a real rock and then a foam rock with a heavy mallet. |
| Mei, 8-2.6 | judging inertial mass | 1F10.30 | A blindfolded volunteer compares a mass on a string with a mass on a roller cart. |
| | **Inertia of Rest** | **1F20.00** | |

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| PIRA 200 | inertia ball | 1F20.10 | Break the string on the top or bottom of a suspended mass. |
| UMN, 1F20.10 | inertia balls | 1F20.10 | Two heavy iron balls are hung separately between lengths of string. Pull on one and jerk on the other. |
| F&A, Mc-2 | inertia balls | 1F20.10 | Two steel balls are suspended by strings with identical strings tied from their bottoms. Give a quick jerk to one and pull the other slowly. |
| Sut, M-100 | inertial ball | 1F20.10 | Break the string on the top or bottom of a suspended mass. |
| D&R, M-250 | inertia ball | 1F20.10 | Break the string on the top or bottom of a suspended mass. |
| Sprott, 1.5 | inertia balls | 1F20.10 | Pull on a string attached to the bottom of a heavy ball that is suspended by an identical string until one of the strings breaks. |
| AJP 72(7), 860 | inertia ball | 1F20.10 | Quantitative analysis of how the strings break in this demonstration. |
| Disc 02-13 | inertia ball | 1F20.10 | A mass is suspended between two cords. Pull slowly or jerk on the lower cord. |
| PIRA 1000 | bowling ball inertia balls | 1F20.11 | |
| UMN, 1F20.11 | bowling ball inertia balls | 1F20.11 | Replace the standard 6 cm balls with bowling balls for increased visibility. |
| Bil&Mai, p 56 | bowling ball inertia balls | 1F20.11 | Attach a string to a bowling ball. Pull slowly and lift the ball off the floor. Jerk and the string breaks. |
| Hil, M-6d | inertia balls | 1F20.12 | One mass is hung from a string and another mass hung below it. Jerk the lower mass to break one of the strings. |
| Mei, 8-2.1 | inertia stick | 1F20.13 | A long stick is supported from rings of filter paper at each end. Break the filter paper with a pull or the stick with a jerk. |
| D&R, M-242 | toilet paper | 1F20.14 | Toilet paper unrolls if pulled slowly, but breaks if pulled or jerked. |
| PIRA 1000 | inertia block | 1F20.15 | |
| Mei, 8-1.2 | inertia block | 1F20.15 | A 50 lb mass is mounted on rollers. A thread will pull it but a rope can be broken with a jerk. |
| UMN, 1F20.16 | inertia block | 1F20.16 | Tie a loop of 7/16" braided cotton cord through a hole in a 2"x4"x10" steel block. Pull and jerk with a hammer. |
| F&A, Mc-3 | inertia block | 1F20.16 | A length of rope is tied to a 10 lb. block. A pull with a hammer will move the block but a jerk will break the rope. |
| Sut, M-101 | inertia block | 1F20.16 | A rope is attached between a heavy iron ball and a hammer head. A fast swing of the hammer takes up the slack and breaks the rope without moving the ball. |
| D&R, M-258 | inertia block | 1F20.16 | Hang a 20 to 30 kg object with a rope. With a 3/4 inch dowel rod 1 meter long the object can be easily deflected if pushed gently but the rod will break if swung at the object. |
| AJP 46(7),710 | inertia balls - analysis | 1F20.18 | For the more advanced reader. The system may be treated as a forced harmonic oscillator and the classical results of the demonstration are verified analytically. Surprises emerge. |
| PIRA 1000 | smash your hand | 1F20.20 | |
| UMN, 1F20.20 | smash your hand | 1F20.20 | Place a lead block on your hand and hit it with a hammer. |
| F&A, Mc-1 | smash your hand | 1F20.20 | Hit a 10 lb. brick with a hammer while it rests on your hand. |
| D&R, M-254 | smash your hand | 1F20.20 | Place a 1/4 inch thick steel plate on your hand and hit it with a hammer. |
| Mei, 8-2.4 | smash your hand, etc. | 1F20.21 | Hit a 10 lb block on the hand or a 50 lb brick on the stomach with a hammer. Pound nails into a 50-75 lb wood block placed on a student's head. |
| PIRA 1000 | hit the nail on the head | 1F20.22 | |
| UMN, 1F20.22 | hit the nail on the head | 1F20.22 | Place a physics book, then a 6"x6" block of wood on a student's head and drive a nail into the block. |
| Hil, M-6e | hit the nail on the "head" | 1F20.22 | Drive a nail into a large block of wood placed on a student's head. |
| PIRA 1000 | smash block on bed of nails | 1F20.25 | |
| AJP 56(9),806 | smash the block | 1F20.25 | An analysis of smashing a block on a volunteer sandwiched between two nail beds. Safety issues are discussed. |
| TPT 14(2),119 | smash the block | 1F20.25 | A bed of nails is placed on the chest before smashing the block with a sledge. |
| Sut, M-102 | vibrograph | 1F20.26 | An optical lever arrangement for magnifying small displacements of a large mass when the table is hit with a hammer. |
| PIRA 200 | tablecloth pull | 1F20.30 | |
| PIRA 500 - Old | tablecloth pull | 1F20.30 | |
| UMN, 1F20.30 | tablecloth pull | 1F20.30 | |
| TPT 15(4),242 | the tablecloth pull | 1F20.30 | Pictures and a few hints. |
| F&A, Mc-4b | tablecloth pull | 1F20.30 | Pull the tablecloth out from under a place setting. |
| D&R, M-524 | tablecloth pull | 1F20.30 | Pull the tablecloth out from under a place setting. |
| Sprott, 1.6 | tablecloth pull | 1F20.30 | Quickly pull a cloth out from under a beaker filled with water. |
| Bil&Mai, p 54 | tablecloth pull | 1F20.30 | Pull a tablecloth from beneath a table setting. |
| Bil&Mai, p 73 | tablecloth pull | 1F20.30 | A detailed analysis of the tablecloth pull demo. |
| Disc 02-15 | tablecloth pull | 1F20.30 | Pull a low friction tablecloth from under a place setting. |
| PIRA 1000 | inertia cylinder | 1F20.33 | |

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| UMN, 1F20.33 | inertia cylinder | 1F20.33 | Stand a 3/4" x 6" aluminum cylinder on a sheet of paper. Jerk the paper out from under the cylinder. |
| F&A, Mc-4a | inertia cylinder | 1F20.33 | Jerk a sheet of paper out from under a thin steel cylinder. |
| D&R, M-222 | dollar bill and coke bottles | 1F20.33 | Jerk a dollar bill from between two coke bottles stacked mouth to mouth. |
| Bil&Mai, p 54 | dollar bill and coke bottles | 1F20.33 | Jerk a dollar bill from between two coke bottles stacked mouth to mouth. |
| PIRA 1000 | coin/card snap | 1F20.34 | |
| Mei, 8-2.3 | card/coin snap | 1F20.34 | Snap a card out from under a tall object, e.g., a shipping tag from under a balanced claw hammer. |
| Sut, M-104 | card/coin snap | 1F20.34 | Several inertia tricks. |
| Hil, M-6a | card/coin snap | 1F20.34 | Snap a piece of cardboard from under a steel ball. |
| D&R, M-226 | card/coin snap | 1F20.34 | Snap a card from under a steel ball. |
| PIRA 500 | eggs and pizza pan | 1F20.35 | |
| UMN, 1F20.35 | eggs and pizza pan | 1F20.35 | Set a pizza pan on three 2l beakers full of water, stand paper cylinders with eggs at the tops above the beakers, knock out the pizza pan. |
| Mei, 8-2.2 | blocks and broomstick | 1F20.35 | Egg on a spool, on a pie tin, on a beaker of water. Flex broom and knock out pie tin. |
| D&R, M-234 | eggs and pizza pan | 1F20.35 | Set a pizza pan on a glass of water. Set an egg on pan above the glass. Snap the pizza pan with a broomstick and the egg fall into the glass. |
| Disc 02-16 | eggs and pizza pan | 1F20.35 | Place a pizza pan on three beakers, place cardboard tubes on the pan directly above the beakers, and eggs on the tubes. Knock out the pizza pan. |
| PIRA 1000 | pen and embroidery hoop | 1F20.36 | |
| UMN, 1F20.36 | pen and embroidery hoop | 1F20.36 | |
| D&R, M-230 | pen and embroidery hoop | 1F20.36 | Balance an embroidery hoop on the mouth of a soft drink bottle, and then balance a pen on the embroidery hoop. Snap hoop sideways and pen will fall into bottle. |
| PIRA 1000 | stick on wine glasses | 1F20.40 | |
| UMN, 1F20.40 | stick on wine glasses | 1F20.40 | Stick needles in the ends of a 3/4" sq x 4' clear pine bar. Place the needles on wine glasses full of water and break the stick with an iron bar. |
| AJP, 65(6), 505-510 | transverse bending and the breaking broomstick demo | 1F20.40 | A nice explanation and guide to breaking the broomstick balanced on two wine glasses. This setup describes how to use force probes to measure and analyse the forces involved. |
| D&R, M-250 | stick on wine glasses | 1F20.40 | Wooden rod with pins in each end is placed on wine glasses full of water. Break the stick with an iron bar. |
| PIRA 1000 | shifted air track inertia | 1F20.50 | |
| UMN, 1F20.50 | shifted air track inertia | 1F20.50 | Support an air track on wheels. Move the air track under an air glider. |
| Disc 02-12 | shifted air track inertia | 1F20.50 | Move the air track under an air track glider. |
| F&A, Mc-5 | loose hammer head | 1F20.60 | A hammer handle may be tightened by pounding on the far end of the handle. |
| Sut, M-105 | inertia cart | 1F20.61 | A cart has a pivoting arm with different masses but the same volume at the ends. The greater mass lags behind as the cart is accelerated. |
| Mei, 8-1.3 | string of weights | 1F20.62 | A string of weights connected by springs shows uneven deformation when jerked. |
| Sut, M-288 | inertia of liquids | 1F20.64 | There are two horizontal glass tubes, one with a cork cylinder and the other with a lead cylinder. Strike the stopper at one end of the glass tubes with a hammer and watch the direction of the cylinders. |
| | **Inertia of Motion** | **1F30.00** | |
| PIRA 200 | persistence of motion (air track) | 1F30.10 | A single cart on the air track. |
| UMN, 1F30.10 | persistence of motion (air track) | 1F30.10 | A single cart on the air track. |
| F&A, Me-2 | air table puck | 1F30.11 | Air table with a puck. |
| F&A, Me-1 | CO2 block | 1F30.13 | A large piece of dry ice on a flat formica top wetted with alcohol. |
| PIRA 1000 | water hammer | 1F30.21 | |
| TPT 2(4),178 | water hammer | 1F30.21 | Some water in an evacuated test tube clicks when the water hits the end of the tube. |
| Sut, M-290 | water hammer | 1F30.21 | Shut off the sink faucet and a water hammer may be heard. A small tube evacuated with some water shows the effect nicely. |
| Hil, M-6c | water hammer | 1F30.21 | A tube is evacuated except for some water. When the tube is stopped suddenly, the water strikes the end of the tube with a click. |
| Disc 13-14 | water hammer | 1F30.21 | Evacuate a glass tube containing water. |
| PIRA 1000 | car on cart on cart | 1F30.30 | |
| UMN, 1F30.30 | car on cart on cart | 1F30.30 | A small car on a skateboard on a large roller cart hits a stop level with the roller cart and the skateboard and car continue to move at constant velocity. |
| Mei, 8-1.5 | cart on a cart | 1F30.30 | A smaller roller cart is placed on a larger one. when the larger is stopped, the smaller continues. |

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| Bil&Mai, p 16 | dynamics cart on a cart | 1F30.30 | A dynamics track is placed on a rolling table. A dynamics cart is placed on the track. Ask what happens to the cart when the table is pushed. Many situations are possible. |
| Bil&Mai, p 80 | dynamics cart on a cart | 1F30.30 | Place a dynamics track on a rolling table, and then a dynamics cart on the track. What happens to the dynamics cart when the table is moved across the room. |
| PIRA 1000 | nail by hand | 1F30.40 | |
| UMN, 1F30.40 | nail by hand | 1F30.40 | Follow the directions in TPT 18(1),50. |
| TPT 18(1),50 | hand pile driver | 1F30.40 | Drive a nail into wood with your bare hands. |
| PIRA 1000 | pencil and plywood | 1F30.50 | |
| UMN, 1F30.50 | pencil and plywood | 1F30.50 | Place a pencil in a brass tube hooked to a fire extinguisher. Fire the pencil into a 1/2" plywood board. |
| Disc 02-17 | pencil and plywood | 1F30.50 | Use a CO2 extinguisher to fire a pencil through a 1/2" plywood. |
| | **NEWTON'S SECOND LAW** | **1G00.00** | |
| | **Force, Mass, and Acceleration** | **1G10.00** | |
| PIRA 200 | accelerating air / Dynamics cart | 1G10.10 | |
| PIRA 500 - Old | glider, mass, and pulley on air track | 1G10.10 | |
| F&A, Md-2 | acceleration air glider | 1G10.10 | Air track cart pulled by a falling weight. |
| Mei, 7-1.5.7 | acceleration air glider | 1G10.10 | Accelerate a car on a track with a mass on a string over a pulley. |
| Hil, M-7b | glider, mass, and pulley | 1G10.10 | An air track cart is timed while pulled by a mass on a string over a pulley. |
| Bil&Mai, p 20 | dynamics cart, mass, and pulley | 1G10.10 | A mass over a pulley pulls a dynamics cart down a track. Record the motion of the cart with a motion sensor. |
| Disc 01-15 | string and weight acceleration (air) | 1G10.10 | Three cases of an air glider pulled by a falling weight. |
| PIRA 1000 | constant mass acceleration system | 1G10.11 | |
| UMN, 1G10.11 | constant mass acceleration system | 1G10.11 | A cart on the air track is accelerated by a mass on a string over a pulley and final velocity timed photoelectrically. Keep the mass of the system constant by transferring from the cart to the pan. |
| Mei, 11-1.5 | acceleration air glider | 1G10.11 | Air cart with a string over a pulley to a mass. Vary mass on both cart and hanger. |
| Mei, 10-2.1 | acceleration air glider on incline | 1G10.12 | A puck is timed as it floats up an incline pulled by a string to a weight over a pulley. |
| AJP 50(2),185 | acceleration air glider on incline | 1G10.13 | An air track cart is accelerated up an inclined track by the string, pulley and mass system. A newton scale is included on the cart to measure the tension in the string directly. An electromagnet release and photogate timer at a fixed distance are used to derive acceleration. |
| TPT 17(1),45 | acceleration glider accelerometer | 1G10.14 | An elegant pendulum accelerometer designed for the air track. Reflected laser beam is directed to a scale at one end of the track. |
| PIRA 1000 | roller cart and bunge loop | 1G10.15 | |
| UMN, 1G10.15 | roller cart and bunge loop | 1G10.15 | |
| PIRA 1000 | Strang gage | 1G10.16 | |
| Disc 01-17 | acceleration with spring (airtrack) | 1G10.16 | An air track glider is pulled by a small spring hand held at constant extension. |
| AJP 52(3),268 | constant force generators | 1G10.17 | A note that picks some nits about the hanging mass, mentions the "Neg'ator" spring. |
| AJP 57(6),543 | battery propeller force generator | 1G10.18 | Plans for a battery powered air track propeller that provides a constant force. |
| AJP 51(4),344 | constant force generator | 1G10.19 | A constant force generator for the air track based on the induction of eddy currents. It is easy to handle and can be self-made. |
| PIRA 1000 | accelerated car | 1G10.20 | |
| Hil, M-7a | acceleration car | 1G10.20 | Time the acceleration of a toy truck as it is pulled across the table by a mass on a string over a pulley. |
| AJP 29(5),294 | acceleration car and track | 1G10.21 | Apparatus Drawings Project No. 15: Large low friction acceleration carts and track for use in the lecture demonstration. |
| Mei, 8-1.1 | acceleration car | 1G10.21 | Three different pulley arrangements allow a cart to be accelerated across the table top. |
| Sut, M-108 | acceleration car | 1G10.21 | A car is accelerated by a descending weight. |
| Hil, M-3a | acceleration car, mass & pulley | 1G10.21 | Distance and time are measured as a toy truck is accelerated by a mass and pulley system. |
| PIRA 1000 | accelerated instructor | 1G10.22 | |
| UMN, 1G10.22 | accelerated instructor | 1G10.22 | |

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| Mei, 8-1.6 | acceleration car photo | 1G10.24 | Take a strobed photo of a light on a car pulled by a weight on a string over a pulley. |
| PIRA 1000 | acceleration block | 1G10.25 | |
| UMN, 1G10.25 | acceleration block | 1G10.25 | Accelerate a block of wood across the table by a mass on a string over a pulley. |
| Mei, 8-1.7 | acceleration car | 1G10.26 | A complex arrangement to accelerate a car, vary parameters, and graph results is shown. Details in appendix, p.549. |
| PIRA 1000 | mass on a scale | 1G10.30 | |
| F&A, Mf-1 | weight of a mass | 1G10.30 | Suspend a mass from a spring balance and then cut the string. |
| Hil, M-8a | mass on a scale | 1G10.30 | Hang a mass on a spring scale to show reaction of the scale to mg. |
| PIRA 200 | Atwood's machine | 1G10.40 | Two equal masses are hung from a light pulley. A small percentage of one mass is moved to the other side. |
| UMN, 1G10.40 | Atwood's machine | 1G10.40 | Place 1 kg on each side of a light pulley on good bearings. Add 2 g to one side. |
| F&A, Ms-7 | Atwood's machine | 1G10.40 | Three skeletonized aluminum pulleys are mounted together on good bearings. Many combinations of weights may be tried. |
| Sut, M-110 | Atwood's machine | 1G10.40 | Two equal masses are hung from a light pulley. A small percentage of one mass is moved to the other side. |
| Hil, M-7c | Atwood's machine | 1G10.40 | An Atwood's machine using an air pulley. |
| D&R, M-278 | Atwood's machine | 1G10.40 | Atwood's machine made of two pulleys for string separation. Spring scales hang from the ends of the string to monitor tension during acceleration. |
| Disc 01-16 | Atwood's machine | 1G10.40 | The small weight is removed after a period of acceleration and the resulting constant velocity is measured. |
| TPT, 37(2), 82 | another look at Atwood's machine | 1G10.40 | Using Atwood's machine, compare acceleration determined from experimental data with the numbers theoretically derived from Newton's law. |
| AJP 71(7), 715 | variable mass Atwood's machine | 1G10.40 | Sand flowing from a bottle makes for a variable mass Atwood's machine. |
| Sut, M-111 | Atwood's machine | 1G10.42 | Hang the weights from spring balances on each side. |
| AJP 37(4),451 | Atwood's machine | 1G10.44 | A rotation free Atwood's machine using air bearing surface and spark timer. |
| Mei, 11-2.1 | Atwood's machine | 1G10.44 | Atwood's machine using an air bearing and spark timer. |
| TPT 11(9),539 | Atwood's machine problem | 1G10.45 | More Phil Johnson humor. "One of the best nerd problems ever". The description would read: An entertaining four step Atwood's machine problem of unknown origin is solved by applying Newton's second law. |
| TPT 18(8),603 | Morin's machine | 1G10.45 | Morin's (French) alternative to Atwood's (English) machine. |
| AJP 58(6),573 | auto acceleration | 1G10.51 | On using automotive magazine test results to study kinematic relations. |
| TPT 12(8),491 | car time trials | 1G10.52 | Use student's cars to do time trials in the school parking lot. |
| | **Accelerated Reference Frames** | **1G20.00** | |
| PIRA 1000 | candle in a bottle | 1G20.10 | |
| UMN, 1G20.10 | candle in a bottle | 1G20.10 | Drop a candle burning in a large flask. |
| TPT 1(1),34 | candle in a bottle | 1G20.10 | Drop, toss up, and throw a bottle containing a lighted candle. |
| F&A, Fl-3 | gravitational pressure in circulation | 1G20.10 | Drop a Plexiglas container with a lighted candle. |
| F&A, Fl-2 | bottle and candle | 1G20.10 | Throw a jug with a lighted candle into the air. |
| Mei, 8-3.7 | candle in a bottle | 1G20.10 | A lighted candle in a glass chimney in a large container will burn for a long time unless dropped. |
| Sut, M-98 | candle in a bottle | 1G20.10 | A candle in a dropped chimney goes out after 2-3 meters due to absence of convection currents. |
| Disc 01-19 | candle in dropped jar | 1G20.10 | Drop a closed jar containing a burning candle. |
| AJP 32(1),61 | falling candle doesn't work | 1G20.11 | Hey, when these guys tried it they could drop the bottle 25 feet and the candle only went out upon deceleration. |
| AJP 34(2),172 | elevator paradox | 1G20.13 | A large hydrometer flask in a beaker of water remains at its equilibrium position as the beaker is moved up and down. |
| AJP 30(12),929 | four demos | 1G20.14 | Four demos: Drop a weight on a spring balance, drop a cup with weights on rubber bands, drop a candle in a bottle, drop or throw a tube of water containing a rising cork. |
| PIRA 1000 | ball in a thrown tube | 1G20.20 | |
| UMN, 1G20.20 | ball in a thrown tube | 1G20.20 | Invert and throw a 4' Plexiglas tube full of water that contains a cork. The rising cork will remain stationary during the throw. |
| TPT 1(1),34 | ball in a thrown tube | 1G20.20 | Throw or drop long water filled tube containing a cork. Also try a rubber stopper or air bubble. |
| F&A, Fl-6 | falling bubble | 1G20.20 | A rising bubble in a jar remains stationary while the jar is thrown. |
| Mei, 8-3.4 | ball in a thrown tube | 1G20.20 | A long thin tube with an air bubble is tossed across the room. |

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| D&R, M-102, S-215 | bubble in a thrown tube | 1G20.20 | A bubble in a water filled tube ceases to rise when tossed in the air. |
| TPT 1(1),34 | modified falling tube | 1G20.21 | Couple a lead weight and cork with a spring and put the assembly in a tube of water so the cork just floats. Drop the tube and the cork sinks. |
| Mei, 8-3.3 | ball in a falling tube | 1G20.21 | A cork remains submerged in a falling jar of water. Diagram of a mousetrap mechanism. |
| Sut, M-97 | ball in a falling tube | 1G20.22 | A ball and tube are dropped simultaneously from the ceiling. The ball strikes the bottom of the tube after hitting the floor. |
| PIRA 1000 | leaky pail drop | 1G20.30 | |
| AJP 31(5),391 | drop pail with holes | 1G20.30 | First drop a can with several vertical holes to show no flow in free fall, then rig up a pulley system to accelerate the pail greater than g (shown), and the top hole will issue the longest stream of water. |
| D&R, M-188, S-055 | leaky pail drop | 1G20.30 | Punch vertical holes near the bottom of a Styrofoam cup. When you fill it with water and drop it no water will run out. |
| TPT 1(1),34 | leaky pail drop | 1G20.30 | Punch a hole in the bottom of a can and fill it with water. When you drop it, no water will run out. |
| TPT 12(6),366 | pop the balloon | 1G20.33 | This device pops a balloon if it is not in free fall. Toss it to a student to give them a real bang. |
| Mei, 8-3.1 | vanishing weight | 1G20.34 | A strip of paper pulled from between two weights will tear except when dropped. |
| F&A, Mf-2 | vanishing weight | 1G20.36 | Weights compress the tube of an air whistle until in free fall when the whistle blows. |
| F&A, Fl-5 | Einstein's birthday present | 1G20.38 | A ball attached to a tube by a weak rubber band is pulled to the tube in free fall. |
| D&R, M-188 | Einstein's birthday present | 1G20.38 | Weights are attached to the bottom of a cup by weak rubber bands. Drape the weights over the edge of the cup and drop. They will jump inside during freefall. |
| PIRA 500 | cup and weights | 1G20.40 | |
| UMN, 1G20.40 | cup and weights | 1G20.40 | Hang 1 kg weights from heavy rubber bands extending from the center over the edge of a styrofoam bucket. Drop the thing. |
| TPT 21(8),521 | cup & weights | 1G20.40 | Further discussion of the R. D. Edge article describing dropping a styrofoam cup with weights suspended over the edge by rubber bands. |
| TPT 1(1),34 | vanishing weight - dropping things | 1G20.41 | 1) Drop a mass on a spring scale, 2) Drop an object with a second object hanging by a rubber band, 3) stretch a rubber band over the edge of a container and drop. |
| Mei, 8-3.13 | vanishing weight | 1G20.42 | A parcel scale is dropped with a bag of sand on the platform. |
| TPT 16(6),391 | elevators | 1G20.43 | A battery powered circuit is constructed in a box causes a light to glow while a spring scale is unloaded. The light will glow while a loaded spring scale is in free fall. |
| TPT 1(1),35 | drop a mass on a spring | 1G20.44 | Drop a frame with an oscillating mass on a spring and the mass will be pulled up but stop oscillating. |
| PIRA 1000 | dropped Slinky | 1G20.45 | |
| UMN, 1G20.45 | dropped Slinky | 1G20.45 | |
| Disc 01-18 | dropped Slinky | 1G20.45 | Hold a Slinky so some of it extends downward, then drop it to show the contraction. |
| Mei, 8-3.11 | vanishing weight | 1G20.46 | Drop a frame containing three different masses hanging on identical springs or a frame with a pendulum. |
| TPT 1(1),34 | dropping pendulum | 1G20.47 | Suspend a pendulum from a stick. Drop the stick when the pendulum is at an extreme and the stick and pendulum will maintain the same relative position. |
| AJP 48(4),310 | falling frame shoot | 1G20.55 | A falling cage is equipped with two guns lined up with holes in two sheets and a net to catch the ball. The balls don't go through the holes unless the cage is in free fall. |
| Sut, M-103 | elevators | 1G20.60 | Quickly raise and lower a spring balance-mass system. |
| D&R, M-106 | elevators | 1G20.60 | Quickly raise and lower a spring balance - mass system. |
| TPT 11(6),351 | elevators | 1G20.61 | Discussion of the elevator problem and a car going around a curve. |
| Mei, 8-3.12 | elevators | 1G20.62 | A rope over a ceiling mounted pulley has a weight on one side and a spring scale and lighter weight on the other side. |
| Mei, 8-3.15 | elevators | 1G20.63 | An apparatus to quantitatively demonstrate the forces acting on a passenger standing on a spring scale in an elevator. Diagrams. |
| AJP 33(8),xi | elevator | 1G20.64 | The elevator is a spring scale and potentiometer combination. |
| PIRA 500 | local vertical with acceleration | 1G20.70 | |
| UMN, 1G20.70 | accelerometer on tilted air track | 1G20.70 | The water surface of a liquid accelerometer on a tilted air track remains parallel to the angle of the air track during acceleration. |

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| TPT 28(8),546 | showing acceleration | 1G20.70 | Put a cart on an incline, mount a liquid accelerometer on the cart and mark the reference at rest, give the cart a push up the incline and observe the accelerometer as the car goes up, stops, and comes back down. |
| Mei, 8-3.8 | accelerometer | 1G20.70 | A Lucite box containing colored glycerine mounted on a cart is rolled down an incline or given a push up an incline. |
| Disc 02-11 | local vertical with acceleration | 1G20.70 | Place a liquid accelerometer on an air track glider on an inclined air track |
| AJP 31(4),302 | helium balloon accelerometer | 1G20.75 | Put two students in a car with a helium balloon. |
| Mei, 8-3.10 | accelerometer | 1G20.75 | A balloon filled with air is suspended from the top and a helium balloon from the bottom of a clear box mounted on wheels. |
| PIRA 1000 | suspended ball accelerometers | 1G20.76 | |
| TPT 2(4),176 | float accelerometer | 1G20.76 | A float in a glass of water on an accelerating cart. Also, moving in uniform circular motion. |
| Mei, 8-3.2 | accelerometer | 1G20.76 | Two flasks full of water, one has a cork ball, the other has a heavier than water ball. |
| Mei, 8-3.9 | accelerometer | 1G20.76 | An iron ball is suspended from the top and a cork ball from the bottom of a clear box filled with water mounted on wheels. |
| D&R, F-200, M-116 | linear accelerometer | 1G20.76 | A jar full of water with a heavy suspended ball is accelerated across a table. Try same experiment with a light ball suspended from the bottom of the jar. |
| D&R, F-200, M-350 | suspended ball accelerometers | 1G20.76 | Two jars full of water, one has a light ball suspended from the bottom, one has a heavy ball suspended from the top. Rotate on a turntable. |
| Disc 13-16 | accelerometers | 1G20.76 | Two jars of water, one has a light ball suspended from the bottom, the other has a heavy ball suspended from the top. |
| Mei, 8-5.8 | accelerometer | 1G20.79 | A design for a high quality accelerometer. |
| PIRA 1000 | cart and elastic band | 1G20.80 | |
| UMN, 1G20.80 | cart and elastic band | 1G20.80 | Place an accelerometer (cork on a string in a clear water filled box) on a cart and attach a strong rubber band to one end. Push the cart down the bench while holding the rubber band. |
| PIRA 1000 | acceleration pendulum cart | 1G20.85 | |
| UMN, 1G20.85 | acceleration pendulum cart | 1G20.85 | Push a skateboard across the lecture bench so an attached pendulum is displaced at a constant angle. |
| AJP 34(9),825 | accelerometer | 1G20.87 | The bubble of a spirit level moves in the direction of acceleration. |
| TPT 21(3),184 | accelerometer | 1G20.87 | Place a carpenter's level on Fletcher's trolley and use the bubble as an accelerometer. |
| Sut, M-289 | accelerometer | 1G20.88 | A discussion of "U" tube manometers for use as accelerometers. |
| | **Complex Systems** | **1G30.00** | |
| AJP 38(4),541 | Poggendorff's experiment | 1G30.11 | The reaction on an Atwood's pulley hanging from a scale is twice the harmonic mean of the suspended weights. |
| Mei, 8-1.4 | tension in Atwood's machine | 1G30.11 | Hang an Atwood's machine from a spring scale and take readings in both static and dynamic cases. |
| Sut, M-112 | double Atwood's machine problem | 1G30.12 | The mass on one side of the Atwood's machine is replaced with another Atwood's machine. |
| PIRA 1000 | mass on spring, on balance | 1G30.20 | |
| UMN, 1G30.20 | mass on spring, on balance | 1G30.20 | A mass on a spring oscillates on one side of a tared balance. |
| Sut, M-114 | mass on a spring, on balance | 1G30.20 | A large ball on a stretched spring is tared on a platform balance. The string is burned and the motion observed. |
| Hil, M-8c | acceleration on a balance | 1G30.20 | Burn the string extending a mass on a spring on a tared platform balance. |
| Mei, 8-3.14 | weigh a yo-yo | 1G30.25 | A yo-yo is hung from one side of a balanced critically damped platform scale. |
| PIRA 1000 | hourglass on a balance | 1G30.30 | |
| UMN, 1G30.30 | hourglass on a balance | 1G30.30 | An hourglass runs down on a tared, critically damped balance. |
| F&A, Mp-19 | acceleration of center of mass | 1G30.30 | A very large hourglass is placed on a critically damped balance. The deflection is noted as the sand starts, continues, and stops falling. |
| Mei, 9-4.10 | acceleration of center of mass | 1G30.30 | An hourglass full of lead shot is tared on a critically damped platform balance. The resultant force is observed as the lead shot starts, continues, and stops falling. |
| Sut, M-116 | hourglass on a balance | 1G30.30 | An hourglass on one side of a equal arm balance. |
| Mei, 9-4.13 | acceleration of center of mass | 1G30.31 | An apparatus to show transient and steady state conditions in the hourglass problem. |
| AJP 53(8),787 | the hourglass problem | 1G30.32 | Careful analysis and demonstration shows that the center of mass is actually accelerating upwards during most of the process. |
| Hil, M-8d | acceleration of center of mass | 1G30.33 | A funnel full of water is placed on a tared platform balance and the water is then released and runs into a beaker. |
| Sut, M-115 | reaction balance | 1G30.34 | One mass on an equal arm balance is supported by pulleys at the end and fulcrum. The balance is in equilibrium if the string holding the mass is held fast or pulled in uniform motion. Look it up. |

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| Mei, 9-4.12 | acceleration of center of mass | 1G30.35 | A ball is dropped in a tall cylinder filled with oil while the entire assembly is on a balance. A hollow iron ball may be released from an electromagnet on the bottom and float to the top. |
| | **NEWTON'S THIRD LAW** | **1H00.00** | |
| | **Action and Reaction** | **1H10.00** | |
| ref. | action and reaction | 1H10.01 | see 1N22. section. |
| PIRA 200 | push me pull me carts | 1H10.10 | Two people stand on roller carts and both pull on a rope or push with a long stick. |
| UMN, 1H10.10 | push me pull me carts | 1H10.10 | Two people stand on roller carts and both pull on a rope. A long stick may be substituted to allow pushing. |
| F&A, Mg-5b | rope and carts | 1H10.10 | People on two identical roller carts pull each other with a long rope. |
| D&R, M-554 | push me pull me carts | 1H10.10 | Two people on roller carts push off each other with outstretched hands. |
| Bil&Mai, p 115 | push me pull me Rollerblades | 1H10.10 | Students put on Rollerblades, hold their palms out to each other and push with equal force. Repeat with only one student pushing, a heavy student pushing a lighter student, two students pushing one student, etc. |
| Sut, M-118 | rope and carts | 1H10.11 | All the things you can do standing and running on carts with and without ropes. |
| Mei, 8-1.9 | rope and carts | 1H10.12 | Stand on a cart holding a rope passing over a pulley to a weight slightly less than static friction, then pull the rope. |
| PIRA 1000 | reaction air gliders | 1H10.15 | |
| Disc 02-18 | reaction gliders | 1H10.15 | Burn a string holding a compressed spring between two air gliders. |
| PIRA 1000 | Newton's sailboat | 1H10.20 | |
| UMN, 1H10.20 | Newton's sailboat | 1H10.20 | Propel an air glider with a battery powered fan, then attach a sail directly in front of the fan. |
| TPT 10(4),208 | Newton's sailboat | 1H10.20 | A battery powered fan and sail can be mounted on a air track cart. Three cases are demonstrated: 1) sail attached, fan not attached; 2) both sail and fan attached; 3) fan attached, no sail. |
| D&R, M-324 | fan cart with sail | 1H10.20 | A sail is placed in front of a battery powered fan on a cart. |
| Disc 02-21 | fan car with sail | 1H10.20 | A sail is placed in front of a battery powered fan on a cart. |
| TPT 10(9),448 | Newton's sailboat | 1H10.21 | A balloon provides an air source on one cart, a sail is mounted on another cart. Hold each stationary in turn. |
| PIRA 1000 | helicopter rotor | 1H10.25 | |
| Disc 02-25 | helicopter rotor | 1H10.25 | A symmetric propeller deflects air down, causing upward lift. |
| Sut, M-122 | cannon car | 1H10.30 | A small brass cannon mounted on one car fires a bullet into a wood block on another of equal mass. A string tying the carts together will result in no motion. |
| Bil&Mai, p 6 | bend a wall | 1H10.35 | A laser and a mirror on a rolling arm are used to measure the movement of a wall. |
| Bil&Mai, p 117 | bend a wall | 1H10.35 | Attach a mirror to a wall and position a laser beam to bounce off the mirror and onto the ceiling. Push on the wall near the mirror and watch the beam on the ceiling move. A student on Rollerblades can also push on the wall. |
| | **Recoil** | **1H11.00** | |
| ref. | recoil | 1H11.01 | see 1N20. and 1N21. sections. |
| PIRA 500 | floor cart and medicine ball | 1H11.10 | |
| UMN, 1H11.10 | floor cart and medicine ball | 1H11.10 | Stand on a roller cart and throw a medicine ball or styrofoam ball. |
| F&A, Mg-5c | floor cart and medicine ball | 1H11.10 | Throw a heavy medicine ball while standing on a roller cart. |
| D&R, M-300, M-312, M-324, S-330 | floor cart and medicine ball | 1H11.10 | Stand on a roller cart and throw a medicine ball to a person standing on the floor. Also do with people on two carts passing the ball between them with carts either locked together or independent. |
| Bil&Mai, p 119 | Rollerblades and medicine ball | 1H11.10 | A student on Rollerblades throws a medicine ball to a person standing on the floor. |
| PIRA 1000 | stool on conveyor | 1H11.11 | |
| Mei, 8-1.10 | stool on a conveyor | 1H11.11 | Throw a ball while on a stool mounted on a conveyor. |
| Bil&Mai, p 67 | person and skateboard | 1H11.15 | A student stands on the edge of a skateboard. As the student steps off the skateboard, the skateboard travels backward and away from the student at great velocity. |
| PIRA 200 - Old | tennis ball cannon | 1H11.20 | A cannon on wheels shoots a tennis ball. |
| UMN, 1H11.20 | tennis ball cannon | 1H11.20 | |
| D&R, M-562 | tennis ball cannon | 1H11.20 | A tennis ball cannon constructed from tin cans or PVC. |
| PIRA 1000 | liquid nitrogen cannon | 1H11.30 | |
| UMN, 1H11.30 | liquid nitrogen cannon | 1H11.30 | A liquid nitrogen powered cannon on wheels shoots heavy and light stoppers. |
| F & A, Hk-11 | liquid nitrogen cannon | 1H11.30 | A cork is shot out of a liquid nitrogen cannon. |
| F&A, Mi-2 | dry ice cannon | 1H11.30 | $CO_2$ provides the pressure to blow a cork out of a cannon on wheels. |

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| Sut, H-115 | liquid air gun | 1H11.30 | Liquid air in a bent test tube shoots a cork when the escape valve is closed. |
| Sprott, 2.11 | liquid nitrogen cannon | 1H11.30 | The rapid evaporation of liquid nitrogen exerts enough pressure to blow a cork stopper from a steel cylinder that has been sealed on one end. |
| Mei, 9-4.17 | ballistic gun | 1H11.40 | Shoot a spring loaded bifilar suspended gun. Measure the muzzle velocity by range and the recoil by adjacent scale. |
| Mei, 9-4.21 | open cannon | 1H11.41 | A hole in the back of a rail mounted gun allows the gases to escape or not to show the difference on recoil. |
| Mei, 9-4.20 | bent gun | 1H11.44 | A spring loaded gun firing a steel ball has a barrel bent 90 degrees to show recoil opposite the exit direction instead of the firing direction. |
| | **STATICS OF RIGID BODIES** | **1J00.00** | |
| | **Finding Center of Gravity** | **1J10.00** | |
| TPT 22(8),535 | center of gravity | 1J10.09 | Many examples of simple center of mass demonstrations. |
| D&R, M-662 | find the center of mass | 1J10.09 | With a rotational motion, toss an ellipse in the air with a bulls-eye at the center of mass. Also toss a baton with the same rotational motion and observe it's center of mass. |
| Bil&Mai, p 159 | find the center of mass | 1J10.09 | Toss a cardboard disc with an offset center of mass into the air with rotational motion. Bulls-eyes are drawn at the center of the disc, and at the center of mass of the disc. |
| PIRA 200 | map of state | 1J10.10 | Suspend a map of the state from holes drilled at large cities to find the "center of the state". |
| UMN, 1J10.10 | map of state | 1J10.10 | Sandwich of a map of the state between two Plexiglas sheets and suspend from holes drilled at large cities to find the "center of the state". |
| F&A, Mp-7 | map of Minnesota | 1J10.10 | A Plexiglas map of the state is suspended from several points. |
| D&R, M-466 | map of state | 1J10.10 | A map of a state is suspended from several points to find the "center of the state". |
| AJP 36(1),x | find the center of gravity | 1J10.11 | Use a chalk line on the plumb bob and snap it to make a quick vertical line. |
| PIRA 1000 | irregular object center of mass | 1J10.12 | |
| Sut, M-32 | hanging shapes | 1J10.12 | Use the plumb bob method to find the center of gravity of various geometric shapes. |
| Sut, M-31 | hanging board | 1J10.12 | Suspend an irregular board from several points and use a plumb bob to find the center of gravity. |
| D&R, M-466 | hanging board | 1J10.12 | Hang an irregular board from several points and find the center of gravity with a plumb bob. |
| Bil&Mai, p 148 | irregular object center of mass | 1J10.12 | Hang an irregular board, banana, or coat hanger from several points and find the center of gravity with a plumb bob. The banana and coat hanger will need to be taped to a sheet of heavy paper to do the demonstration. |
| Disc 03-20 | irregular object center of mass | 1J10.12 | Suspend an irregular object from several points and find the center of mass with a plumb bob. |
| F&A, Mp-13 | hanging potato | 1J10.15 | Hang a potato from several positions and stick a pin in at the bottom in each case. All pins point to the center of gravity. |
| PIRA 1000 | loaded beam - moving scales | 1J10.20 | |
| UMN, 1J10.20 | loaded beam - moving scales | 1J10.20 | Slide the scales together under a loaded beam noting the scale readings of the moving and stationary scales. |
| TPT 10(8),469 | loaded beam - moving scales | 1J10.20 | Instead of moving the masses on the beam, move the scales under the beam. Same as bringing your fingers together under the meter stick. |
| PIRA 500 | center of gravity of a broom | 1J10.25 | |
| UMN, 1J10.25 | center of gravity of a broom | 1J10.25 | Bring your fingers together under a broom the find the center of gravity. |
| F&A, Mp-15 | center of gravity of a broom | 1J10.25 | Find the center of gravity of a broom, hang a kg mass somewhere on the broom, find the new center of gravity, calculate the weight of the broom by equating torques. |
| PIRA 1000 | balance beam and bat | 1J10.26 | |
| UMN, 1J10.26 | balance beam and bat | 1J10.26 | |
| PIRA 500 | meter stick on fingers | 1J10.30 | |
| UMN, 1J10.30 | meter stick on fingers | 1J10.30 | Slide your fingers together under a meter stick and they meet at the center of gravity. Add a baseball hat to one end and repeat. |
| Sut, M-50 | friction and pressure | 1J10.30 | Slide your fingers under the meter stick to find the center of mass. |
| D&R, M-478 | meter stick on fingers | 1J10.30 | Put a finger from each hand under the ends of a meter stick. Bring fingers together to find center of mass of stick. |
| Bil&Mai, p 150 | meter stick on fingers | 1J10.30 | Slide your fingers together under a pipe and they meet at the center of gravity. Spin the pipe about this point to show this is the center of mass. |
| Disc 04-15 | meter stick on fingers | 1J10.30 | Slide your fingers under a meter stick to find the center of mass. |
| | **Exceeding Center of Gravity** | **1J11.00** | |
| PIRA 500 | leaning tower of Pisa | 1J11.10 | |

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| UMN, 1J11.10 | leaning tower of Pisa | 1J11.10 | Add a top to a slanted cylinder and it falls down. Also hang a plumb bob from the center of mass in each case. |
| F&A, Mp-9 | leaning tower of Pisa | 1J11.10 | A model of the tower constructed in sections. Adding the top will cause it to tip over. |
| Sut, M-34 | leaning tower of Pisa | 1J11.10 | Add on to the leaning tower and it falls down. |
| Hil, M-18b.1 | leaning tower of Pisa | 1J11.10 | The leaning tower of Pisa. |
| AJP, 75 (4), 367 | leaning tower of Pisa | 1J11.10 | Physics explanation with picture of an antique leaning tower of Pisa demo. |
| PIRA 1000 | toppling cylinders | 1J11.11 | |
| AJP 34(9),822 | falling cylinders | 1J11.11 | A tube, weighted at the bottom, falls when a cap is added. An upright cylinder, containing two balls, falls when a weighted cap is removed. |
| Disc 03-26 | toppling cylinders | 1J11.11 | The standard leaning tower and an upright cylinder that topples when the cap is removed. It has two balls in the tube. |
| PIRA 1000 | tipping block on incline | 1J11.15 | |
| UMN, 1J11.15 | tipping block on incline | 1J11.15 | Raise an incline plane until a block tips over. |
| TPT 16(7),506 | tipping block on incline | 1J11.15 | A very clever modification of the leaning tower of Pisa demonstration. |
| F&A, Mp-14 | tipping block on incline | 1J11.15 | A block is placed on an incline and the incline is raised until the block tips. |
| Bil&Mai, p 152 | tipping block on incline | 1J11.15 | A block is placed on an incline plane and the incline is raised until the block tips. |
| PIRA 200 | leaning tower of Lire | 1J11.20 | Stack blocks stairstep fashion until the top block sticks out beyond any part of the bottom block. |
| UMN, 1J11.20 | leaning tower of Lire | 1J11.20 | Use 6"x6"x2' wood blocks and have a student sit under the stack as it is built. |
| AJP 23(4),240 | leaning tower of lire | 1J11.20 | A note discussing the derivation of the harmonic series describing the leaning tower of Lire. |
| TPT 18(9),672 | leaning tower of Lire | 1J11.20 | Use the center of mass of a composite object to support a block beyond the edge of the lecture bench. This article emphasizes a lab approach. Ref. AJP 23,240 (1955). |
| D&R, M-490 | leaning tower of Lire | 1J11.20 | Stack meter sticks stairstep fashion until the top one sticks out beyond any part of the bottom one. |
| F&A, Mp-11 | leaning tower of Lire | 1J11.20 | Stack blocks until the top block sticks out beyond any part of the bottom block. |
| Sprott, 1.17 | leaning tower of Lire | 1J11.20 | A stack of cards illustrates the static equilibrium of a rigid body while showing an impressive overhang. |
| AJP 73(12), 1107 | stacking blocks | 1J11.21 | Three different ways to stack blocks to give the maximum amount of overhang with a given amount of blocks. |
| AJP 41(5),715 | cantilevered books | 1J11.21 | The number of books necessary to overhang 2,3,4, etc lengths. |
| Sut, M-287 | instability in flotation | 1J11.30 | A device to raise the center of mass in a boat until the boat flips. Diagram. |
| PIRA 1000 | male and female center of gravity | 1J11.40 | |
| TPT 21(1),42 | people tasks, etc. | 1J11.40 | Pictures of three center of mass objects and several person based center of mass tasks e.g., stand on your toes facing the wall, etc. |
| TPT 17(4),254 | your center of gravity | 1J11.40 | Two methods for measuring the center of gravity of a person are shown. |
| Mei, 14-3.7 | male & female center of gravity | 1J11.40 | Stand with right shoulder and foot against the wall and raise your left foot. Stand with your heels against the floor and try to touch your toes. |
| D&R, M-500, M-504 | human center of gravity | 1J11.40 | 4 human center of gravity examples. |
| Bil&Mai, p 152 | human center of gravity | 1J11.40 | A student places their toes behind a piece of tape and is asked to pick up an object on the floor 1 meter in front of them without moving their feet. Repeat the demonstration with the students heels up against a wall. |
| | **Stable, Unstab., and Neut. Equilibrium** | **1J20.00** | |
| PIRA 200 | bowling ball stability | 1J20.10 | |
| PIRA 500 - Old | bowling ball stability | 1J20.10 | |
| UMN, 1J20.10 | bowling ball stability | 1J20.10 | A bowling ball is placed in, on, and along side a large Plexiglas hemisphere. |
| PIRA 200 | balance the cone | 1J20.11 | |
| PIRA 1000 - Old | balance the cone | 1J20.11 | |
| UMN, 1J20.11 | balance the cone | 1J20.11 | |
| F&A, Mq-2 | balance the cone | 1J20.11 | A cone can show stable, unstable, and neutral equilibrium; a sphere shows only neutral equilibrium. |
| Sut, M-39 | balance the cone | 1J20.11 | A large cone shows stable, unstable, and neutral equilibrium. |
| Disc 03-19 | stability | 1J20.11 | Balance a cone, show a block is stable and a sphere is neutral. |
| PIRA 1000 | wood block stability | 1J20.12 | |
| UMN, 1J20.12 | wood block stability | 1J20.12 | A block and support have marks that show whether the center of gravity has moved up or down when the block is displaced. |
| PIRA 1000 | block on the cylinder | 1J20.15 | |

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| UMN, 1J20.15 | block on the cylinder | 1J20.15 | A rectangular block of wood is placed on a cylinder first with the width less than the radius (stable) and then with the width greater (unstable). |
| AJP 51(7),636 | block on the cylinder | 1J20.15 | An "elementary" discussion of the oscillatory properties of the block on the cylinder. |
| F&A, Mq-1 | block on the cylinder | 1J20.15 | A thin block on a cylinder is stable, a thick one is not. |
| Sut, M-40 | catenary surface | 1J20.16 | A large block is always in stable equilibrium anywhere along this catenary surface. |
| PIRA 1000 | block on curved surfaces | 1J20.17 | |
| UMN, 1J20.17 | block on curved surfaces | 1J20.17 | A block is placed on a catenary surface, a circle, and a parabola. |
| PIRA 1000 | fork, spoon, and match | 1J20.20 | |
| UMN, 1J20.20 | fork, spoon, and match | 1J20.20 | Place a spoon and match in the tines of a fork and balance the assembly on the edge of a glass. |
| TPT 10(8),464 | fork, spoon, and match | 1J20.20 | Picture of the fork, spoon, and match balanced on the edge of a glass. |
| F&A, Mp-5 | fork, spoon, and match | 1J20.20 | Stick two forks and a match together and balance on a glass while pouring out the water. |
| Mei, 14-3.8 | fork, spoon, and match | 1J20.20 | Two forks and a match can be balanced on the edge of a glass while the water is poured out. |
| D&R, M-474 | fork, spoon, and match | 1J20.20 | A fork, spoon, and match assembly are balanced on the edge of a glass. |
| PIRA 1000 | nine nails on one | 1J20.25 | |
| UMN, 1J20.25 | nine nails on one | 1J20.25 | A technique to balance ten landscape spikes on the head of a single upright spike. |
| D&R, M-458 | fourteen nail on one | 1J20.25 | A technique to balance 14 large nails on the head of a single upright nail. |
| PIRA 500 | sky hook | 1J20.30 | |
| TPT 14(8),499 | sky hook | 1J20.30 | A complete solution to the hanging belt problem. |
| TPT 15(4),241 | hanging belt | 1J20.30 | Shows a "belt hook" for the hanging belt. |
| D&R, M-470, M-474 | sky hook | 1J20.30 | The hanging belt and a hammer sky hook. |
| PIRA 1000 | spoon on nose | 1J20.32 | |
| UMN, 1J20.32 | spoon on nose | 1J20.32 | Hang a spoon on your nose. Most effective with giant food service spoons. |
| PIRA 1000 | horse and rider | 1J20.35 | |
| F&A, Mp-4 | horse and rider | 1J20.35 | A horse has an attached weight to lower the center of mass. |
| Sut, M-33 | horse and rider | 1J20.35 | Stable equilibrium of a center of gravity object. |
| Hil, M-18a.2 | horse and rider | 1J20.35 | A horse has a weight attached to lower the center of mass. |
| D&R, M-462, M-482 | horse and rider | 1J20.35 | Stable equilibrium of a center of gravity object. |
| Sut, M-36 | balancing man | 1J20.40 | Stable equilibrium of a center of gravity object. |
| Sut, M-38 | balancing man | 1J20.40 | Stable equilibrium of a center of gravity object. |
| Bil&Mai, p 154 | balancing man | 1J20.40 | A center of gravity toy is constructed from a solid rubber figure, wire, and tennis balls. |
| PIRA 500 | tightrope walking | 1J20.45 | |
| AJP 50(5),471 | tightrope walking | 1J20.45 | Design of a 10' long "low wire" and description of the physical feats possible. |
| F&A, Mp-6 | tightrope walking | 1J20.45 | A toy unicycle rider carrying a balancing pole travels along a string. |
| Disc 03-23 | clown on rope | 1J20.45 | A toy clown rides a unicycle on a wire. |
| PIRA 1000 | tightrope walking model | 1J20.46 | |
| UMN, 1J20.46 | tightrope walking model | 1J20.46 | A model of a tightrope walker shows the center of mass moves up with tipping. |
| F&A, Mp-12 | balancing a stool | 1J20.50 | Wires form a support at the center of gravity of a lab stool. |
| Mei, 14-2.2 | balancing a stool | 1J20.50 | Construct a stool so that wires crossed diagonally will intersect at the center of gravity. The stool can be oriented in any direction. |
| PIRA 1000 | chair on a pedestal | 1J20.51 | |
| Disc 03-22 | chair on pedestal | 1J20.51 | Hide heavy weights in the ends of a chair's legs so it will balance on a vertical rod placed under the seat. |
| PIRA 1000 | broom stand | 1J20.55 | |
| Disc 04-19 | broom stand | 1J20.55 | Spread the bristles and a straw broom will stand upright. |
| PIRA 500 | wine butler | 1J20.60 | |
| UMN, 1J20.60 | wine butler | 1J20.60 | Stick the neck of a wine bottle through a hole in a slanted board and the whole thing stand up. |
| TPT 14(1),39 | glass on coin, etc | 1J20.65 | Pictures show the hanging belt, pin on the point of a needle, and a jar balanced on its edge. |
| D&R, M-472 | balancing soda can | 1J20.65 | Partially fill a soda can with water and balance on its indented bottom edge. |
| PIRA 1000 | double cone | 1J20.70 | |
| UMN, 1J11.50 | double cone | 1J20.70 | As a double cone moves up an set of inclined rails, its center of gravity lowers. |

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| TPT 16(1),46 | rolling uphill | 1J20.70 | A simple version of a ball rolling up a "v". |
| F&A, Mr-1 | double cone | 1J20.70 | A double cone rolls up an inclined "v" track. |
| Sut, M-37 | double cone | 1J20.70 | Double cone and rails. |
| Hil, M-18a.3 | double cone | 1J20.70 | A double cone rolls up an inclined "v" track. |
| D&R, M-482 | double cone | 1J20.70 | As a double cone moves up a set of inclined rail it's center of gravity lowers. |
| Disc 03-24 | double cone on incline | 1J20.70 | The double cone appears to roll uphill. |
| | **Resolution of Forces** | **1J30.00** | |
| PIRA 200 | suspended block | 1J30.10 | Forces parallel and perpendicular to the plane will support the car midair when the plane is removed. |
| UMN, 1J30.10 | suspended block | 1J30.10 | A 3-4-5 triangle holding a block. Add counterweights and remove the incline. |
| F&A, Mj-2 | suspended block | 1J30.10 | The components of force of a block on an inclined plane are countered by weights. The plane is then removed. |
| Mei, 14-3.3 | suspended block | 1J30.10 | A 5-6-7 suspended block system is used to show the pulleys can be moved as long as the angle remains constant. |
| Sut, M-18 | suspended block | 1J30.10 | Forces parallel and perpendicular to the plane will support the car when the plane is removed. |
| D&R, M-272 | suspended block | 1J30.10 | Forces parallel and perpendicular to the inclined plane will suspend a cart in midair when the inclined plane is removed. |
| Disc 04-03 | load on removable incline | 1J30.10 | Place a cart on a removable 30 degree incline. |
| PIRA 1000 | normal force | 1J30.15 | |
| UMN, 1J30.15 | normal force | 1J30.15 | A block on an incline has an arrow mounted from the center of mass perpendicular to the surface with "N" on the arrowhead and another arrow hanging from the center of mass with a "g" on the arrowhead. |
| Bil&Mai, p 69 | normal force meter | 1J30.15 | Use two bathroom scales as normal force meters. |
| Bil&Mai, p 60 | normal force | 1J30.15 | Books or masses are placed on a rolling cart. Draw Free Body Diagrams of the cart rolling across a flat floor and then rolling on an incline. |
| TPT, 36(9), 556 | demonstrating normal forces with a kitchen scale | 1J30.16 | A simple and less expensive way of demonstrating normal forces. |
| Sut, M-9 | hanging the plank | 1J30.18 | A heavy plank is suspended from three spring scales in several configurations: series, parallel, and a combination. |
| PIRA 500 | tension in a string | 1J30.20 | |
| UMN, 1J30.20 | tension in a string | 1J30.20 | The weight of a mass hung from a single spring scale is compared to the weight shown on a spring scale between two masses over pulleys. |
| F&A, Ml-1 | tension in a string | 1J30.20 | A spring scale is suspended between strings running over pulleys to equal weights. |
| D&R, M-264 | tension in a string | 1J30.20 | Stretch a string over two pulleys and attach a spring scale and mass to each end. Pull down with another spring scale in the middle and compare the readings. Tension readings in the outer scales should not change. |
| TPT 9(7),387 | tension in a string | 1J30.21 | A clever story. |
| Sut, M-10 | tension in a spring | 1J30.22 | Two students pull against each other through one and then two spring scales. |
| Sut, M-8 | tension in springs | 1J30.23 | Masses are hung at the ends of a series of spring scales. |
| Bil&Mai, p 58 | tension in springs | 1J30.23 | Masses are hung from springs scales connected in series and parallel. |
| PIRA 200 | rope and three students | 1J30.25 | Two large strong students pull on the ends of a rope and a small student pushes down in the middle. |
| UMN, 1J30.25 | rope and three students | 1J30.25 | Two large strong students pull on the ends of a rope and a small student pushes down in the middle of the rope. |
| TPT 9(3),148 | rope and three students | 1J30.25 | Two football players stretch a 10 m rope while a small person pushes the middle to the floor. |
| D&R, M-268 | rope and three students | 1J30.25 | Two large students pull on the ends of a rope and a small student deflects the rope in the middle pulling the large students together. |
| Bil&Mai, p 63 | rope and three students | 1J30.25 | Two large strong students pull on the ends of a rope and a small student deflects the rope in the middle pulling the large students together. |
| Disc 04-02 | clothesline | 1J30.25 | Hang a 5 newton weight from a line and pull on one end of the line with a spring scale. |
| PIRA 1000 | rope and three weights | 1J30.26 | |
| UMN, 1J30.26 | rope and three weights | 1J30.26 | Suspend a rope over two pulleys with masses on the ends and hang another mass from the center. Measure the deflection. |
| PIRA 1000 | deflect a rope | 1J30.27 | |
| UMN, 1J30.27 | deflect a rope | 1J30.27 | Stretch a rope in a frame with a 100 newton scale measuring the tension. Pull down with a 20 newton scale. |
| PIRA 1000 | break wire with hinge | 1J30.30 | |
| UMN, 1J30.30 | break wire with hinge | 1J30.30 | Suspend a 5 kg mass from a length of wire. Break a length of similar wire by placing the same mass on the back of a large hinge. |

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| F&A, Mj-3 | breaking wire hinge | 1J30.30 | Pushing down on a slightly bent hinge will break the wire fastened to the ends. |
| Sut, M-16 | breaking wire hinge | 1J30.30 | Press down on a hinge to break a rope. |
| Sut, M-5 | pull the pendulum | 1J30.35 | A long heavy pendulum is displaced with a spring scale. |
| PIRA 1000 | horizontal boom | 1J30.40 | |
| UMN, 1J30.40 | booms | 1J30.40 | A spring scale measures the tension in the supporting rope at various loads and boom angles. |
| Disc 04-08 | horizontal boom | 1J30.40 | The tension in the wire is measured with a spring scale for two different boom structures. |
| PIRA 500 | blackboard force table | 1J30.50 | |
| UMN, 1J30.50 | blackboard force table | 1J30.50 | Scales and masses are hung in front of a large movable whiteboard. |
| F&A, Mj-1 | blackboard force table | 1J30.50 | A weight is hung on a string suspended between two spring scales. |
| Sut, M-13 | blackboard force table | 1J30.50 | The standard blackboard force table. |
| Sut, M-11 | blackboard force table | 1J30.50 | A mass is hung from the center of a cord attached to two spring scales. Start with the strings vertical, increase the angle. |
| Sut, M-12 | blackboard force table | 1J30.50 | A force table in the vertical plane |
| D&R, M-072 | force table | 1J30.50 | A horizontal force table. |
| Bil&Mai, p 22 | blackboard force table | 1J30.50 | A 5 pound exercise plate and several spring scales are used on a marker board to record three lines of force and their magnitudes. |
| Disc 04-01 | force board | 1J30.50 | This looks like a magnetic vertical force board. A circle is marked with angles every 10 degrees. |
| AJP 36(6),559 | vertical force table | 1J30.51 | A vertical force table that permits a continuous range of angles. |
| Sut, M-14 | blackboard force table | 1J30.51 | A removable frame that sets on the chalk tray. |
| Sut, M-4 | blackboard force table | 1J30.51 | A framework for doing the force table in the vertical plane. |
| AJP 41(9),1115 | force table on overhead projector | 1J30.52 | A Plexiglas force table for the overhead projector. |
| TPT 10(4),217 | force table on overhead projector | 1J30.52 | Make a large sketch of the angles using the overhead projector. |
| Hil, M-10c | standard force table, etc. | 1J30.53 | The standard force table, three dimensional force table, and torque apparatus. |
| Mei, 6-4.11 | force table | 1J30.54 | Three scales and a ring to show forces add by parallel construction. Not the usual. |
| PIRA 1000 | human force table | 1J30.55 | |
| UMN, 1J30.55 | human force table | 1J30.55 | Sit on a chair that hangs from a chain attached to load cells on each end. |
| AJP 46(7),774 | human force table | 1J30.55 | Hang from a large gallows frame on ropes attached to load cells. |
| AJP 51(6),571 | bosun chair force table | 1J30.55 | Sit on a chair suspended from two supports equipped with protractors and commercial load cells. |
| TPT 20(3),176 | blackboard force table - rubber band | 1J30.57 | Calibrate rubber bands for force vs. length, predict the mass of an object hung in a noncolinear configuration. |
| TPT 13(4),246 | blackboard force table - rubber band | 1J30.57 | A simple substitute for scales is a calibrated set of rubber bands. |
| Sut, M-15 | blackboard force table - springs | 1J30.57 | Use screen door springs in place of spring balances. |
| PIRA 1000 | sail against the wind | 1J30.60 | |
| UMN, 1J30.60 | sail against the wind | 1J30.60 | Set a mainsail on a cart so it moves toward and away from a fan. |
| AJP 40(8),1172 | sail against the wind | 1J30.60 | Use a large fan to blow at an air track glide with a sail. |
| AJP 40(4),626 | sail against the wind | 1J30.60 | A sail is mounted on an air track cart. A table fan supplies the wind. |
| AJP 28(3),259 | sail and the wind | 1J30.60 | Apparatus Drawings Project No.4: A sailboat rides in an air trough which serves as a keel. Set the angle of the sail with respect to the wind. |
| Disc 02-10 | sailing upwind (airtrack) | 1J30.60 | Use a skateboard cart with a foam core sail. |
| AJP 49(3),282 | sail a trike against the wind | 1J30.61 | A wind driven tricycle moves against the wind. |
| AJP 46(10),1004 | sail against the wind | 1J30.64 | A wind driven boat accelerates against the wind. Description and Analysis. |
| Sut, M-6 | sailboat and wind | 1J30.64 | A cork stopper boat with a keel and removable sail. |
| F&A, Mo-9 | floating cork | 1J30.65 | A stick is hung by a thread at one end with the other attached to a cork floating on water. |
| Sut, M-29 | floating cork | 1J30.65 | A stick is hung by a thread at one end with the other attached to a cork floating on water. |
| PIRA 1000 | sand in a tube | 1J30.70 | |
| UMN, 1J30.70 | sand in a tube | 1J30.70 | Place a tissue on the bottom of an open glass tube, fill with a few inches of sand, and push down on the top of the sand with a rod. |
| Sut, M-7 | sand in a tube | 1J30.70 | A couple of inches of sand held in a tube by tissue paper will support about 50 lbs. |
| D&R, F-070 | rice in a tube | 1J30.70 | Fill a small mouth jar with rice. Plunge in a screwdriver and lift the jar. Also, a couple of inches of rice held in a tube by tissue paper will resist any effort to push it through the tissue paper. |
| PIRA 1000 | stand on an egg | 1J30.75 | |

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| UMN, 1J30.75 | stand on an egg | 1J30.75 | Three eggs in a triangle pattern in foam depressions between two plates will support a person. |
| D&R, M-837 | stand on an egg | 1J30.75 | Stand or put masses on an egg in a holder that keeps the pressure in one direction. Egg will withstand 80 to 120 lbs with no trouble. |
| Disc 04-21 | egg crusher | 1J30.75 | A raw egg can be squeezed between two hard foam rubber pads with a force of over 150 lbs. |
| Sut, M-19 | rolling wedge | 1J30.80 | A light roller lifts a heavy weight as it rolls inside an inclined hinge. |
| AJP 59(5),472 | inverse catenary | 1J30.90 | A string of helium balloons tied at each end forms an inverse catenary. |
| AJP 40(2),354 | catenary analog computer | 1J30.91 | Model the catenary on a simple analog computer. |
| | **Static Torque** | **1J40.00** | |
| PIRA 200 | grip bar | 1J40.10 | A thin rod mounted perpendicular to a broom handle holds a 1 Kg mass on a sliding collar. |
| UMN, 1J40.10 | grip bar | 1J40.10 | Use wrist strength to lift a 1 kg mass at the end of a rod attached to a broom handle. |
| F&A, Mo-5 | grip bar | 1J40.10 | Use wrist strength to try to lift 1 kg at the end of a rod attached perpendicularly to a handle. |
| Mei, 14-3.1 | grip bar | 1J40.10 | A thin rod mounted perpendicular to a broom handle holds a 1 Kg mass on a sliding collar. |
| D&R, M-614 | grip bar | 1J40.10 | A student grips a croquet mallet with a hand on each side of the head. Weights are mounted at different distances on the crossbar (handle). |
| Bil&Mai, p 146 | grip bar | 1J40.10 | Make a grip bar with 1 inch PVC pipe. Have a student try to hold the bar in a horizontal position as you slide a 1 Kg mass away from the handle. |
| Disc 04-10 | torque bar | 1J40.10 | Use wrist strength to lift a weight suspended at various distances from the handle. |
| PIRA 1000 | torque wrench | 1J40.15 | |
| TPT 15(2),115 | torque wrench | 1J40.15 | Modify a Sears torque wrench so weights can be hung at different distances. |
| Disc 04-12 | torque wrench | 1J40.15 | A torque wrench is used to break aluminum and steel bolts. |
| PIRA 1000 | different length wrenches | 1J40.16 | |
| UMN, 1J40.16 | different length wrenches | 1J40.16 | |
| PIRA 200 | meter stick balance | 1J40.20 | Hang weights from a beam that pivots in the center on a knife edge. |
| UMN, 1J40.20 | torque beam | 1J40.20 | Hang weights from a beam that pivots in the center on a knife edge. |
| F&A, Mo-1 | torque beam | 1J40.20 | Weights are hung from a horizontal bar pivoted on a knife edge. |
| Sut, M-27 | torque beam | 1J40.20 | Weights are hung from a meter stick suspended on a knife edge. |
| Hil, M-18a.1 | torque beam | 1J40.20 | Weights on a meter stick supported at the center. |
| Disc 04-14 | balancing meter stick | 1J40.20 | Use a meter stick, suspended at the center, as a torque balance. |
| PIRA 1000 | hinge board | 1J40.21 | |
| Disc 04-11 | hinge board | 1J40.21 | Use a spring scale to lift a hinged board from various points along the board. |
| TPT, 36(7), 438 | torque rack demonstration | 1J40.22 | Illuminating discussion of torque using a counter-intuitive, yet simple, chalk board set-up. |
| TPT 11(7),427 | torque beam | 1J40.23 | Put a quarter (5 g) on the end of a meter stick and extend it over the edge of the lecture bench until it is just about to tip over. |
| PIRA 1000 | walking the plank | 1J40.24 | |
| UMN, 1J40.24 | walking the plank | 1J40.24 | Place a 50 lb block on one end of a long 2x6 and hang the other end off the lecture bench. Walk out as far as you can. |
| PIRA 1000 | torque wheel | 1J40.25 | |
| F&A, Mo-2 | torque disc | 1J40.25 | Weights can be hung from many points on a vertical disc pivoted at the center. |
| Sut, M-28 | torque disc | 1J40.25 | Various weights are hung from a board that can rotate freely in the vertical plane. |
| Disc 04-13 | torque wheel | 1J40.25 | Use a wheel with coaxial pulleys of 5, 10, 15, and 20 cm to show static equilibrium of combinations of weights at various radii. |
| Mei, 12-4.8 | torque disc | 1J40.26 | An apparatus to show the proportionality between torsional deflection and applied torque. |
| Mei, 14-3.5 | torque disc | 1J40.26 | Twist a shaft by applying coplanar forces to a disc. |
| PIRA 1000 | torque double wheel | 1J40.27 | |
| PIRA 1000 | opening a door | 1J40.30 | |
| UMN, 1J40.30 | opening door | 1J40.30 | |
| PIRA 1000 | opening a trapdoor | 1J40.32 | |
| UMN, 1J40.32 | opening trapdoor | 1J40.32 | |
| PIRA 500 | loaded beam | 1J40.40 | |
| UMN, 1J40.40 | loaded beam | 1J40.40 | Move a weight along a 2X4 on two platform scales. |
| F&A, Mo-7 | loaded beam | 1J40.40 | Large masses can be placed on a board resting on two platform balances. |

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| Mei, 14-3.6 | loaded beam | 1J40.40 | A model bridge is placed on two platform scales and a loaded toy truck driven across. |
| Sut, M-23 | loaded beam | 1J40.40 | A heavy truck is moved across a board supported on two platform scales. |
| Disc 04-16 | bridge and truck | 1J40.40 | A plank rests on two spring scales forming a bridge. Move a toy truck across. |
| Sut, M-26 | loaded beam | 1J40.41 | Support the loaded beam with spring scales instead of platform balances. |
| PIRA 1000 | Galileo lever | 1J40.45 | |
| UMN, 1J40.45 | Galileo lever | 1J40.45 | Same as Sutton device. |
| Sut, M-22 | Galileo lever | 1J40.45 | A simple device to demonstrate the law of moments. |
| Sut, M-21 | Galileo lever | 1J40.45 | A simple device to show the law of moments. |
| PIRA 500 | Roberval balance | 1J40.50 | |
| UMN, 1J40.50 | Roberval balance | 1J40.50 | Large Roberval balance. |
| TPT 22(2),121 | Roberval balance | 1J40.50 | A reminder and picture of the Roberval balance. Reaction to TPT 21, 494 (1983). |
| F&A, Mo-6 | Roberval balance | 1J40.50 | A large model of the Roberval or platform balance. |
| Disc 04-17 | Roberval balance | 1J40.50 | Neutral equilibrium is maintained at any position on the platform. |
| Mei, 12-4.9 | Roberval balance | 1J40.51 | A version of the Roberval balance where a rigid assembly has upper and lower arms on one side. |
| Sut, M-42 | balances | 1J40.55 | The equal-arm analytical balance and weigh bridge. |
| Sut, M-41 | balances | 1J40.56 | The steelyard. |
| PIRA 1000 | suspended ladder | 1J40.60 | |
| UMN, 1J40.60 | suspended ladder | 1J40.60 | |
| Mei, 14-3.4 | suspended ladder | 1J40.60 | Model of a ladder suspended from two pairs of cords inside an aluminum frame. |
| PIRA 1000 | hanging gate | 1J40.65 | |
| UMN, 1J40.65 | hanging gate | 1J40.65 | A gate initially hangs on hinges, then add cords and remove the hinges leaving the gate suspended in mid air. |
| TPT 12(8),503 | hanging gate | 1J40.65 | Construction and use of a model of the swinging gate. |
| PIRA 1000 | crane boom | 1J40.70 | |
| UMN, 1J40.70 | crane boom | 1J40.70 | |
| PIRA 1000 | arm model | 1J40.75 | |
| UMN, 1J40.75 | arm model | 1J40.75 | Place a spring scale on a skeleton in the place of the biceps muscle and hang a weight from the hand. |
| Disc 04-09 | arm model | 1J40.75 | Use an arm model simulating both biceps and triceps muscles to throw a ball. |
| | **APPLICATIONS OF NEWTON'S LAWS** | **1K00.00** | |
| | **Dynamic Torque** | **1K10.00** | |
| PIRA 500 | tipping block | 1K10.10 | |
| UMN, 1K10.10 | tipping block | 1K10.10 | Pull with a spring scale at various angles on the edge of a block. |
| F&A, Mo-4 | tipping block | 1K10.10 | A large wooden block is tipped over with a spring scale. |
| Mei, 14-3.2 | tipping block | 1K10.10 | A spring scale is used to show the least force required to overturn a cube. |
| PIRA 1000 | tipping blocks | 1K10.11 | |
| UMN, 1K10.11 | tipping blocks | 1K10.11 | Same as TPT 22(8),538. |
| TPT 22(8),538 | tipping block | 1K10.11 | Show the force necessary to tip over trapezoidal and weighted rectangular blocks. The students are surprised to discover the force needed is not related to the position of the center of mass. |
| PIRA 200 | ladder against a wall | 1K10.20 | Set a model ladder against a box and move a weight up a rung at a time. |
| UMN, 1K10.20 | ladder against a wall | 1K10.20 | A model ladder is set against a box and a weight moved up a rung at a time. |
| F&A, Mo-8 | forces on a ladder | 1K10.20 | A small model ladder is placed against a box. |
| Disc 04-18 | ladder forces | 1K10.20 | A real ladder leans against the wall. Animation shows the forces as the ladder moves. |
| PIRA 1000 | forces on a ladder - full scale | 1K10.25 | |
| UMN, 1K10.25 | forces on a ladder - full scale | 1K10.25 | Mount a set of wheels at the top of a ladder, place some shoes at the bottom to decrease friction and climb the ladder until you fall down. |
| Sut, M-30 | forces on a ladder - full scale | 1K10.25 | Wheels are attached to the top of a ladder and the bottom slides on the floor. Climb up the ladder and fall down. |
| PIRA 200 | walking the spool | 1K10.30 | Pull at various angles on the cord wrapped around the hub of a spool to move the spool forward or back. |
| UMN, 1K10.30 | walking the spool | 1K10.30 | Pull on the cord wrapped around the hub of a spool at various angles to make the spool move forward or back. |
| F&A, Mo-3 | walking the spool | 1K10.30 | Pull on a cord wrapped around the axle of a large spool. The spool can be made to go forward or backward depending on the angle. |

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| Sut, M-24 | walking the spool | 1K10.30 | A string is pulled off the inner axis of a spool at different angles, changing the direction the spool rolls. |
| Hil, M-10d | walking the spool | 1K10.30 | A string wound around the center of a spool is pulled at different angles causing the spool to change directions. Diagram and analysis. See TPT 2(3),139. |
| D&R, M-618 | walking the spool | 1K10.30 | A string is pulled off the inner axis of a spool at different angles changing the direction the spool rolls. |
| Sprott, 1.15 | walking the spool | 1K10.30 | A wooden spool can be made to move in different directions by pulling at different angles on the string attached to the hub. |
| Disc 06-07 | spool with wrapped ribbon | 1K10.30 | The sides of the spool are made of clear Plexiglas. |
| Mei, 12-5.3 | walking the spool x three | 1K10.31 | Three rolling spools where the outer discs ride on rails and the center section with the string is larger, smaller, and the same size as the outer discs allowing one to always pull horizontally. |
| PIRA 1000 | pull the bike pedal | 1K10.40 | |
| UMN, 1K10.40 | pull the bike pedal | 1K10.40 | Lock the front wheel, remove the brake, add training wheels, and pull backwards on the pedal in the down position. |
| Mei, 12-4.3 | pull the bike pedal | 1K10.40 | Pulling backward on a pedal (in the down position) of a brakeless bike will cause the bike to go back unless the length of the pedal crank is increased. |
| Sut, M-25 | pull the bike pedal | 1K10.40 | Pull backward on a pedal at its lowest point and the bike will move backward. |
| PIRA 1000 | traction force roller | 1K10.41 | |
| UMN, 1K10.41 | traction force roller | 1K10.41 | Pull on a string wrapped around the circumference of a cylinder on a roller cart. Pull on a yoke attached to the axle of the same cylinder on the roller cart. |
| AJP 34(3),xxix | traction force roller | 1K10.41 | A large pulley on a roller cart is drawn either by a string wrapped around the circumference or by a yoke attached to the axle. |
| F&A, Ms-6 | traction force roller | 1K10.41 | A large pulley can be drawn by either pulling on the axle or on a string wrapped around the perimeter. Try each case while the pulley is resting on a roller cart. |
| PIRA 1000 | extended traction force | 1K10.42 | |
| UMN, 1K10.42 | extended traction force | 1K10.42 | Pull on a string wrapped around the circumference of a cylinder placed on an air track glider. |
| TPT 28(9),600 | extended traction force | 1K10.42 | A string wound around a cylinder, hoop, and spool is pulled while the objects are on a roller cart and the reaction force direction is surprising. |
| PIRA 1000 | rolling uphill | 1K10.50 | |
| UMN, 1K10.50 | rolling uphill | 1K10.50 | A disc with a nonuniform mass distribution is placed on an incline so it rolls uphill. |
| F&A, Mp-3 | rolling uphill | 1K10.50 | A loaded disc is put on an inclined plane so it rolls uphill or rolls to the edge of the lecture bench and back. |
| Sut, M-35 | rolling uphill | 1K10.50 | A large wood disc weighted on one side will roll uphill or to the edge of a table and back. |
| Disc 03-25 | loaded disc | 1K10.50 | A loaded disc can roll up an incline. |
| AJP 28(9),819 | teaching couples | 1K10.80 | Start with two index fingers rotating a meter stick about the center of mass, use it to go into couples. Read it. |
| Sut, M-20 | free vector | 1K10.81 | A strong magnet on a counterbalanced cork always rotates about the center of mass no matter where the magnet is placed. |
| Mei, 10-2.8 | couples | 1K10.82 | An arrangement to apply equal forces to opposite sides of a pulley mounted on a dry ice supported steel bar. |
| AJP 28(1),76 | air jet couple | 1K10.83 | Air from a balloon is released through two nozzles offset from the center of mass. The assembly is free to rotate on a block of dry ice. |
| TPT 5(3),138 | saw-horse on teter-totter | 1K10.90 | The Phil Johnson humor continues with "Good luck trying to demonstrate this one". The description is: A man sits on one side of an unbalanced teeter-totter but is able to bring it into equilibrium by applying a torque to a bar placed across his shoulders. Hint: See the article picture. |
| | **Friction** | **1K20.00** | |
| AJP 70(9), 890 | friction | 1K20.01 | A guide to the literature on the fundamental orgins of friction. |
| PIRA 1000 | washboard friction model | 1K20.05 | |
| UMN, 1K20.05 | washboard friction model | 1K20.05 | |
| PIRA 200 | friction blocks - surface material | 1K20.10 | Pull a block with four different surfaces with a spring scale. |
| UMN, 1K20.10 | friction blocks - surface material | 1K20.10 | A set of blocks with different surfaces are pulled with a spring scale. |
| F&A, Mk-1 | friction blocks | 1K20.10 | Pull blocks across the lecture bench with a spring scale. |
| D&R, M-340 | friction blocks - surface material | 1K20.10 | A block with 4 different surfaces is pulled along a table with a spring scale. |
| AJP 72(10), 1335 | friction blocks | 1K20.10 | Why this experiment gives inconsistent results and a look at some of the factors that contribute to those results. |

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| AJP 75 (12), 1106 | friction | 1K20.10 | A sequence designed for teaching about friction between solids using both experiments and models. |
| Bil&Mai, p 24 | friction blocks | 1K20.10 | Attach a block to a spring scale with a string. Record the minimum force needed to pull the block with a constant velocity when the string is parallel to the table and then at different angles. |
| Bil&Mai, p 71 | friction blocks - surface materials | 1K20.10 | Tread for a good tire and a bald tire are attached to different blocks. Drag the blocks across the floor and see which is harder to pull. |
| Disc 03-05 | surface dependence of friction | 1K20.10 | Place brass blocks on an incline with four surfaces: teflon, wood, sandpaper, and rubber. |
| Bil&Mai, p 75 | tug of war | 1K20.11 | Observe the relative motion of two battery operated toy cars engaged in a tug of war with and without friction, or with one car having more friction than the other. |
| Mei, 8-4.9 | friction blocks | 1K20.12 | Several ways to move a surface under a fixed block. |
| AJP 73(9), 812 | friction blocks | 1K20.13 | A look at why the coefficient of friction might increase with an increase in sliding speed for certain materials. |
| AJP 33(2),161 | sliding friction machine | 1K20.13 | A spring scale is attached to an object on a rotating table. |
| TPT 14(6),373 | friction blocks | 1K20.13 | A device includes both sliding surface and mounted spring scale. |
| TPT 12(6),367 | friction blocks | 1K20.13 | A block is constructed with an built-in apparatus to measure coefficient of friction directly. |
| Mei, 8-4.11 | friction blocks | 1K20.13 | An apparatus pulls a block at a constant speed and measures the frictional force. Details in appendix, p.550. |
| Mei, 8-4.10 | friction blocks | 1K20.13 | A block rests on a turntable and the string goes to a dynamometer. |
| Bil&Mai, p 96 | friction blocks | 1K20.13 | A block rides on a pendulum platform. When the platform hits the edge of a table the block continues on for a short distance before being stopped by friction. Calculate the work done by friction. |
| TPT, 36(8), 464 | measuring coefficient of friction of a low-friction cart | 1K20.14 | Use a sonic range probe to monitor the acceleration of a dynamic cart rolling up and down an inclined plane. |
| PIRA 500 | weight dependence of friction | 1K20.15 | |
| UMN, 1K20.15 | weight dependence of friction | 1K20.15 | Pull a friction block with a spring scale, add a second equal block to the first and repeat. |
| Disc 03-04 | weight dependence of friction | 1K20.15 | Add mass to a board pulled along the table with a spring scale. |
| TPT 18(8),559 | friction blocks | 1K20.16 | A loaded cart rolls down an incline and hits a barrier. The load continues sliding on a second incline until it stops. The mass on the slider is varied to show stopping distance independent of mass. |
| TPT 11(8),453 | friction blocks | 1K20.17 | Two additional points relating to Geoffery Fox's "Stumpers" column TPT. 11, 288 (1973). |
| PIRA 500 | area dependence of friction | 1K20.20 | |
| UMN, 1K20.20 | area dependence of friction | 1K20.20 | A friction block has a rectangular shape with one side twice as big as the other. One of the smaller sides is routed out to 1/5 the area. |
| Sut, M-49 | friction blocks | 1K20.20 | Friction independent of area of contact - cut a block to form a prism whose cross section is an irregular polygon. |
| Disc 03-03 | area dependence of friction | 1K20.20 | A 2X12 is pulled along the bench top while resting on either the narrow or wide face. |
| PIRA 200 | static vs. sliding friction | 1K20.30 | Use a spring scale and block to show that static friction is greater than sliding friction . |
| Disc 03-02 | static vs. sliding friction | 1K20.30 | Show that static friction is greater than sliding friction with a spring scale and block. |
| PIRA 500 | angle of repose | 1K20.35 | |
| UMN, 1K20.35 | angle of repose | 1K20.35 | An incline plane is lifted until a block begins to slide. |
| TPT 17(9),593 | angle of repose | 1K20.35 | Using the familiar suspended incline block apparatus to examine normal and frictional forces in sliding up and down the plane. |
| F&A, Mk-4 | angle of repose | 1K20.35 | An inclined plane is raised until a block starts to slide. |
| D&R, M-336 | angle of repose | 1K20.35 | An inclined plane is lifted until a block begins to slide. |
| Sprott, 1.9 | angle of repose | 1K20.35 | Show the effect of material on critical sliding angle. |
| AJP 46(8),858 | tire friction | 1K20.37 | The automobile tire is a misleading example of static and sliding friction. |
| AJP 48(3),253 | tire skid equation | 1K20.37 | Motivated by being an expert witness, the approximate expression for sliding friction coefficient as a function of speed was developed from published tables. |
| Mei, 8-4.3 | angle of repose | 1K20.37 | A plastic small parts drawer on a sanded aluminum surface allows weight to be added easily. |
| Hil, M-11a | angle of repose | 1K20.37 | Using the incline plane for various friction demos. |
| AJP 53(9),910 | how dry friction really behaves | 1K20.38 | A note arguing that the main rules of thumb about friction are wrong and the less said about friction the better. |
| Mei, 8-4.8 | angle of repose | 1K20.38 | A tribometer with a meter stick mounted vertically 1 m from the hinge gives a reading of coefficient of friction directly. |
| Mei, 8-4.4 | angle of repose | 1K20.39 | Glass - glass angle of repose with oil and oil/water. |

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| Sut, M-48 | angle of repose | 1K20.39 | The standard inclined plane and blocks + an interesting towel on a glass tube demo. |
| PIRA 500 | front and rear brakes | 1K20.40 | |
| UMN, 1K20.40 | front and rear brakes | 1K20.40 | A model car is rolled down an incline with either front or rear brakes locked. |
| TPT 28(8),522 | front and rear brakes | 1K20.40 | Construction details for a model car in which pulling a pin applies front, rear, or both sets of brakes to a car rolling down an incline. |
| F&A, Mk-3 | front and rear brakes | 1K20.40 | A car slides down an incline with either front or rear wheels locked. |
| Mei, 8-4.7 | front and rear brakes | 1K20.40 | A car rolls down an incline with either front or rear wheels locked. |
| Sut, M-53 | front and rear brakes | 1K20.40 | A toy car is modified so either the front or rear brakes can be locked. Slide down the incline plane for each case. |
| D&R, M-622 | front and rear breaks | 1K20.40 | A toy car slides down an incline with either front or rear wheels locked. |
| Disc 03-06 | stability of rolling car | 1K20.40 | A toy car slides down an incline with either front or rear wheels locked. |
| PIRA 1000 | friction roller | 1K20.42 | |
| UMN, 1K20.36 | friction roller | 1K20.42 | A cylinder in a yoke can be rolled or locked and slid as it is pulled by a spring scale. |
| F&A, Mk-2 | friction roller | 1K20.42 | A cylindrical roller is pulled or slid across the lecture bench with a spring scale. |
| Mei, 8-4.5 | friction roller | 1K20.42 | A cylinder is pulled along and perpendicular to its axis by a yoke with a spring scale. |
| AJP, 75 (6), 571 | rolling friction | 1K20.42 | A simple setup for measuring the rotational speed dependent coefficient of rolling friction using easily acquired equipment and apparatus. |
| PIRA 1000 | frictional force rotator | 1K20.45 | |
| UMN, 1K20.45 | frictional force rotator | 1K20.45 | |
| AJP 50(7),631 | frictional force rotator | 1K20.45 | This article shows how to rotate a friction vector to make its component in a given direction as small as desired. Everyday unconscious applications of this method are presented along with some new demonstration equipment. |
| AJP 51(9),804 | cross friction | 1K20.46 | Push a block across the slope of an incline and the block will move with a straight line trajectory. Knock a coin across and it will move in a curved path but all stopping points will be in a straight line. |
| TPT 3(1),23 | squeaky chalk | 1K20.55 | You don't have to break chalk to eliminate squeaking, only understand friction and hold the chalk accordingly. |
| Sut, M-51 | angle of friction with pencil | 1K20.55 | Tilt a pencil until it slides along the table. |
| TPT, 37(3), 184 | why does it work? | 1K20.56 | Friction and mass conspire to cause a counter-intuitive effect between rubber and steel balls. |
| Mei, 8-4.6 | sliding chain | 1K20.60 | Hang a chain over the edge of the table until the weight of the chain makes it slide. |
| PIRA 1000 | falling flask capstan | 1K20.70 | |
| UMN, 1K20.70 | falling flask capstan | 1K20.70 | Attach a 4 liter r.b. flask at the other end of a ball on a string and drape the flask over a horizontal rod 4' high. Let go of the ball. |
| AJP 59(10),951 | falling keys capstan | 1K20.70 | A short analysis of the falling key capstan. |
| TPT 28(6),390 | falling keys capstan | 1K20.70 | Hang a set of keys from a string draped over a pencil and when the string is released, the keys don't hit the floor. |
| AJP 59(1),80 | discussion of the capstan | 1K20.71 | Friction experiments with the cord wrapped around a cylinder. Discussion of the donkey engine and capstan with a digression on sea chanties. |
| AJP 49(11),1080 | capstan on a force table | 1K20.71 | Tap a hole in the center of a force table and insert a bolt to use as a capstan. |
| TPT 14(7),432 | capstan | 1K20.71 | Theory of the capstan along with discussion of applications. |
| Sut, M-52 | capstan | 1K20.71 | Show the frictional force vs. the number of turns around a rod. |
| Sut, M-54 | friction pendulum | 1K20.74 | A ball is suspended by a loop of string over a slowly turning horizontal wooden bar. A large amplitude results. |
| TPT 17(6),386 | going up a tree | 1K20.76 | The Phil Johnson humor continues with: "Very clever device. Look it up as it's hard to describe". A description would be: A string passes through 2 straws attached to a piece of cardboard. Hang the middle of the string off a nail in a wall. Hold both ends of the string taut, pull on each end of the string alternately, and the cardboard will climb the string. |
| Mei, 8-4.12 | Snoek effect | 1K20.80 | The Phil Johnson humor continues with: "If you don't know about the Snoek effect, don't ask me - I had to read up on it too". A description would be: A tantalum wire torsion pendulum with electrically insulated ends is constructed. Running a current from a variac into the wire changes the oxygen diffusion, thus changing the amount of damping. |
| AJP 37(6),665 | WWII torpedo story | 1K20.85 | Friction caused dud torpedo in WWII. |
| PIRA 1000 | air track friction | 1K20.90 | |
| Disc 03-01 | air track friction | 1K20.90 | Show there is little friction on an air track. |
| TPT 11(6),362 | teflon cookie sheet | 1K20.95 | Cut up a teflon coated cookie sheet for an inexpensive teflon surface. |

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| Mei, 8-4.1 | teflon pulley | 1K20.95 | Teflon sheet bent around corner replaces a pulley. |
| Mei, 8-4.2 | Dylite beads | 1K20.95 | Dylite beads on a rimmed glass surface (window pane) provide a low friction surface. |
| | **Pressure** | **1K30.00** | |
| PIRA 200 - Old | bed of nails | 1K30.10 | Lie down on a bed of 16d nails on 1" centers. |
| UMN, 1K30.10 | bed of nails | 1K30.10 | Lie down on a bed of 16d nails on 1" centers. |
| F&A, Ml-2 | bed of nails | 1K30.10 | The instructor lies on a large board with nails at 1" centers. |
| D&R, F-035 | bed of nails | 1K30.10 | Lie down on a bed of 16 penny nails on 2 cm centers. |
| D&R, F-037 | stand on balloons/light bulbs/cups | 1K30.10 | Inexpensive alternatives to the bed of nails using 24 balloons and an overturned table, standing on a board placed on three 25 watt light bulbs in a triangular arrangement, or 24 plastic soft drink cups and an overturned table. |
| Disc 04-20 | bed of nails | 1K30.10 | Break a block on the chest of a person lying on a bed of nails. |
| PIRA 1000 | pop the balloons | 1K30.20 | |
| UMN, 1K30.20 | pop the balloons | 1K30.20 | A disc with points on one side can be placed on balloons so either the points or flats rest on the balloons. |
| | **GRAVITY** | **1L00.00** | |
| | **Universal Gravitational Constant** | **1L10.00** | |
| AJP 59(1),84 | falling apple story | 1L10.01 | Quotes from the original accounts of the falling apple and Newton. |
| PIRA 200 | Cavendish balance film loop | 1L10.10 | Time lapse of the Cavendish experiment. |
| UMN, 1L10.10 | Cavendish balance film loop | 1L10.10 | Time lapse of the Cavendish experiment. |
| PIRA 1000 | Cavendish balance model | 1L10.20 | |
| UMN, 1L10.20 | Cavendish balance model | 1L10.20 | A model of the Cavendish balance with sliding masses. |
| F&A, Mn-1 | Cavendish balance model | 1L10.20 | Model of the Cavendish balance. |
| PIRA 500 | Cavendish balance | 1L10.30 | |
| UMN, 1L10.30 | Cavendish balance | 1L10.30 | Set up the standard Cavendish balance with a laser beam. |
| TPT 10(8),477 | Cavendish balance | 1L10.30 | A platform is used to decouple the Cavendish balance from the building vibrations. |
| Mei, 8-8.7 | Cavendish balance | 1L10.30 | Quite a bit of discussion about the Klinger KM 1115 gravitational torsion balance. |
| Sut, M-128 | Cavendish balance | 1L10.30 | Standard Cavendish experiment with lead balls and optical lever detection. |
| Hil, M-9b | Cavendish balance | 1L10.30 | Mount the Cavendish balance permanently in the classroom and adjust hours before the experiment. |
| Disc 07-23 | Cavendish balance | 1L10.30 | The commercial device with video over a 1 1/2 hour period. |
| AJP 34(2),xv | Cavendish balance - damping | 1L10.33 | A small ball bearing attached to the bottom of the vane dips into a cup containing silicon oil. |
| AJP 55(4),380 | Cavendish balance wire replacement | 1L10.34 | Use amorphous metallic ribbon as a wire replacement which gives a higher spring constant and is more durable. |
| AJP 33(11),963 | do-it-yourself Cavendish balance | 1L10.35 | A simple Cavendish balance built by sophomore students. |
| AJP 57(5),417 | modified torsion balance | 1L10.36 | A very small suspension wire is used allowing the linear accelerations to be measured directly. |
| AJP 51(10),913 | resonance Cavendish balance | 1L10.41 | The Cavendish balance is driven into resonance by swinging the external mass. Suitable for corridor demonstration. |
| AJP 49(7),700 | servo mechanism Cavendish balance | 1L10.42 | Abstract from the apparatus competition. |
| AJP 51(4),367 | servo mechanism Cavendish balance | 1L10.42 | The torsion bar does not appreciably rotate. A simple electronic servomechanism is used to maintain rotational equilibrium as an external mass is introduced. The resulting servo correction voltage is proportional to the torque introduced by gravity. This effect can be observed in tens of seconds. |
| AJP 54(11),1043 | Cavendish balance compensation | 1L10.43 | Modify the Leybold Cavendish balance with a electromagnetic servosystem of damping that reduces the settling time to a few minutes. |
| AJP 55(9),855 | automatic recording Cavendish | 1L10.45 | The reflected laser light from the Cavendish balance falls on a two-element photodiode mounted on a strip chart recorder with appropriate electronics to keep the spot centered on the diode. |
| PIRA 1000 | gravitational field model | 1L10.50 | |
| UMN, 1L10.50 | gravitational field model | 1L10.50 | |
| | **Orbits** | **1L20.00** | |
| PIRA 200 | gravitational well - rubber diaphragm | 1L20.10 | |
| PIRA 1000 - Old | gravitational well - rubber diaphragm | 1L20.10 | |
| Mei, 8-8.2 | gravitational well | 1L20.10 | On making a rubber diaphragm type potential well. |

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| D&R, M-822, S-065, & S-075 | gravitational wells | 1L20.10 | A potential well made of a clothes basket and rubber sheet. Also large and small commercial models of 1/R cones. |
| AJP 70(1), 48 | gravitational well - rubber diaphragm | 1L20.10 | Measurement of the shape that results when a heavy ball is placed upon a flat rubber sheet. Also analyzes the orbits of marbles and coins as they roll across the surface. |
| AJP 70(10), 1056 | gravitational well - rubber diaphragm | 1L20.10 | Additional comments on AJP 70(1), 48. |
| Bil&Mai, p 364 | gravitational well - rubber diaphragm | 1L20.10 | A potential well made from a large embroidery hoop and Spandex. |
| Mei, 8-8.1 | gravitational well on overhead projector | 1L20.12 | Making a Lucite 1/R surface for use on the overhead projector. |
| Sut, M-131 | elliptic motion | 1L20.14 | A ball rolling in a funnel or cone. |
| TPT 14(8),506 | gravity surface | 1L20.16 | Using the Playskool Baby Drum Drop as a gravity surface. |
| AJP 30(7),531 | orbits in a wineglass | 1L20.17 | A properly shaped wine glass is used with ball bearings to show radius to orbit period, orbit decay, etc. |
| Mei, 15-1.16 | orbits in a spherical cavity | 1L20.18 | Derivation of the period of a ball orbiting in a spherical cavity. Strobe photography verifies as a demo. |
| Mei, 8-8.3 | rotating gravitational well | 1L20.30 | A ball placed in a rotating potential well demonstrates the path of a satellite. Use a variable speed motor to show escape velocity. |
| Hil, M-17e | escape velocity | 1L20.31 | A Fake. Pour water into a can with a hole in it and then twirl around until "escape velocity" is reached. Show no water remains. |
| D&R, M-815 | escape velocity | 1L20.31 | A spoof using a can with a hole in it that is twirled until " escape velocity" is reached. |
| Mei, 8-8.9 | satellites | 1L20.32 | A very complex satellite simulator. |
| TPT 16(5),316 | spin-orbit coupling | 1L20.35 | A spinning ball orbits in a watch glass with increasing radii until it escapes. |
| PIRA 1000 | film "Motion of Attracting Bodies" | 1L20.36 | |
| UMN, 1L20.36 | "Motion of Attracting Bodies" film | 1L20.36 | Meeks film, 6:30 min. Computer animated. Covers Newton's laws, Earth's gravity variations, satellite and binary orbits. |
| PIRA 1000 | conic sections | 1L20.40 | |
| UMN, 1L20.40 | conic sections | 1L20.40 | A dissectible cone is cut several ways to give a circle, ellipse, parabola, and hyperbola. |
| Disc 07-21 | sections of a cone | 1L20.40 | The standard wood cone. |
| Hil, M-17b | drawing ellipses | 1L20.45 | The two nail and string method for ellipse drawing. |
| PIRA 1000 | ellipse drawer | 1L20.50 | |
| UMN, 1L20.50 | ellipse drawer | 1L20.50 | An aluminum bar with adjustable pegs and a loop of string for drawing the ellipse. |
| D&R, S-400 | ellipse drawing aids | 1L20.50 | A variety of acrylic ellipses with wooden handles for use on the chalk board. |
| Disc 07-22 | ellipse drawing board | 1L20.51 | The two nail and string method of drawing on paper. |
| AJP 44(4),348 | orbit drawing machine | 1L20.55 | Design for orbit drawing machines for use on the overhead projector. A simple one draws elliptical orbits only, an elaborate one draws general Coulomb orbits. |
| Mei, 10-2.15 | dry ice puck orbits | 1L20.61 | A dry ice puck on a large table is tethered through a hole in the center to a vacuum ping pong ball device under the table that gives an inverse square law force. Construction details p.573. |
| Mei, 10-2.16 | dry ice puck Kepler's law | 1L20.62 | A dry ice puck has a magnet mounted vertically with a second one below the table which may be inverted to show both attraction and repulsion. |
| Hil, M-17c | dry ice puck Kepler's law | 1L20.62 | A strong magnet is placed under the air table and a magnetic puck with a light is photographed. |
| Hil, M-17d | air table Kepler's laws | 1L20.62 | With a strong magnet below the table, take strobe photos of a magnetic puck to demonstrate equal areas. TPT 8(4),244. |
| Mei, 10-2.17 | dry ice puck Kepler's law | 1L20.63 | Motor at the center of the table with a special pulley arrangement. |
| AJP 34(11),1063 | areal velocity conservation | 1L20.64 | Analyze a strobe photograph of one cylindrical magnet on dry ice approaching another and deflecting. |
| AJP 37(11)1134 | fancy air puck Kepler's law | 1L20.65 | The puck has a variable thruster and is of variable mass. A Peaucellier linkage is used to apply central force. |
| AJP 29(8),549 | "gravity" with magnetic field | 1L20.66 | Drop a ball near a magnetron magnet and watch it curve around about 150 degrees. |
| Sut, M-130 | inverse square law motion | 1L20.69 | Pointer to A-62, A-63. Very crude models of planetary motion. |
| PIRA 1000 | film "Planetary Motion and Kepler's Laws" | 1L20.71 | |
| UMN, 1L20.71 | "Planetary Motion and Kepler's Laws" | 1L20.71 | Meeks film, 8:45 min. Computer Animated. Shows orbits of the planets, covers Kepler's second and third laws. |
| | **WORK AND ENERGY** | **1M00.00** | |
| | **Work** | **1M10.00** | |

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| PIRA 1000 | shelf and block | 1M10.10 | |
| UMN, 1M10.10 | shelf and block | 1M10.10 | Lift a block up and set it on a shelf. |
| Bil&Mai, p 78 | shelf and block | 1M10.10 | Lift a block up and set it up on a shelf or a table. |
| PIRA 1000 | block on table | 1M10.15 | |
| UMN, 1M10.15 | block on table | 1M10.15 | |
| PIRA 1000 | carry a block | 1M10.16 | |
| UMN, 1M10.16 | carry a block | 1M10.16 | Just carry a block around. |
| Bil&Mai, p 78 | carry a block | 1M10.16 | Just carry a block around. |
| PIRA 200 | pile driver | 1M10.20 | Drive a nail into a block of wood with a model pile driver. |
| UMN, 1M10.20 | pile driver | 1M10.20 | A model pile driver pounds a nail into wood. |
| F&A, Mv-1 | pile driver | 1M10.20 | A 10 lb block guided by side rails falls onto a nail in wood. |
| Sut, M-133 | pile driver | 1M10.20 | Drive a nail into a block of wood with a model pile driver. |
| Bil&Mai, p 83 | pile driver | 1M10.20 | Start a nail in a piece of wood. Place a long transparent fluorescent light disposal tube over the nail and drop a 1000 g. mass into the tube. Measure how far the nail is driven into the wood. |
| Disc 03-07 | pile driver | 1M10.20 | Drop a weight onto a nail in wood. |
| PIRA 1000 | pile driver with pop cans | 1M10.25 | |
| UMN, 1M10.25 | pile driver with soda cans | 1M10.25 | Smash pop cans with a pile driver. |
| F&A, Mv-3 | work to remove tape | 1M10.99 | Pull off a piece of tape stuck to the lecture bench. |
| | **Simple Machines** | **1M20.00** | |
| PIRA 1000 | simple machine collection | 1M20.01 | |
| Disc 04-06 | simple machines | 1M20.01 | A collection of simple machines is shown. |
| PIRA 200 | pulleys | 1M20.10 | |
| PIRA 500 - Old | pulleys | 1M20.10 | |
| UMN, 1M20.10 | pulleys | 1M20.10 | An assortment of large pulleys can be rigged several ways. |
| Sut, M-45 | pulleys | 1M20.10 | Demonstrate what you have. |
| PIRA 1000 | pulley advantage | 1M20.11 | |
| UMN, 1M20.11 | pulley advantage | 1M20.11 | Place a mass on a string over a pulley and hold a spring scale at the other side. Repeat with a mass hanging from a single pulley in a loop of string. |
| Disc 04-04 | pulley advantage | 1M20.11 | Hang a 10 newton weight on a string passing over a pulley and measure the force with a spring scale, then hang the weight from a free running pulley. |
| TPT 16(9),645 | pulleys | 1M20.13 | Pedagogy. Good diagram. |
| PIRA 1000 | pulley and scales | 1M20.15 | |
| UMN, 1M20.15 | pulley and scales | 1M20.15 | Same as encyclopedia disc 04-05. |
| Disc 04-05 | pulley and scales | 1M20.15 | This is a counter intuitive demonstration. A frame containing a spring scale and pulley hangs from another spring scale. Look it up. |
| PIRA 500 | bosun's chair | 1M20.20 | |
| UMN, 1M20.20 | bosun's chair | 1M20.20 | Use a single pulley to help the instructor go up. |
| AJP 44(9),882 | bosun's chair | 1M20.20 | Using a block and tackle, the lecturer ascends. Full of pedagogical hints on how to do this effectively. |
| Sut, M-46 | bosun's chair | 1M20.20 | The instructor "lifts himself up by the bootstraps". |
| PIRA 1000 | monkey and bananas | 1M20.25 | |
| UMN, 1M20.25 | monkey and bananas | 1M20.25 | A wind up device and equal mass are placed at either ends of a string placed over a pulley. |
| AJP 33(4),348 | monkey and bananas | 1M20.25 | A yo-yo and counterweight are suspended over a pulley. The counterweight and yo-yo rise and fall together. |
| AJP 33(8),662 | monkey and the coconut | 1M20.25 | A steel yo-yo and steel counterweight suspended over two low friction bearings. |
| Mei, 12-5.4 | climbing monkey | 1M20.25 | A yo-yo and a counterweight are on opposite sides on a pulley. As the yo-yo goes up and down, so does the counterweight. |
| Hil, M-8e | climbing monkey | 1M20.25 | A steel yo-yo on one side of a pulley and a counterweight on the other. As the yo-yo goes up and down, so does the counterweight. |
| Sut, M-113 | climbing monkey | 1M20.26 | Two equal masses are hung over a pulley, one of which is equipped with a cord winding mechanism. |
| Sut, M-44 | windlass | 1M20.27 | A model windlass is described. |
| F&A, Mb-7 | climbing pirate | 1M20.28 | String is wrapped around two different sized pulleys on a common axis. |
| Sut, M-47 | fool's tackle | 1M20.29 | A diagram of the "fools tackle" is shown. |
| PIRA 500 | incline plane | 1M20.30 | |
| UMN, 1M20.30 | incline plane | 1M20.30 | |
| Mei, 6-3.1 | screw and wedge | 1M20.30 | A long triangular piece of sailcloth is wound around a mailing tube to show the relationship between a screw and a wedge. Diagram. |
| PIRA 1000 | big screw as incline plane | 1M20.35 | |
| UMN, 1M20.35 | big screw | 1M20.35 | A large wood screw and nut (6"-1) show the relationship between a screw and incline. |

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| TPT 33(1), 28 | screw threads | 1M20.36 | How the torque required to compress a spring is different when using a course thread vise vs. a fine thread vise. |
| PIRA 1000 | levers | 1M20.40 | |
| UMN, 1M20.40 | levers | 1M20.40 | Show the three classes of levers with a mass, bar, pivot, and spring scale. |
| Sut, M-43 | levers | 1M20.40 | The three classes of simple levers. |
| D&R, M-614 | levers | 1M20.40 | A first class lever with movable pivot. Can also be used as a seesaw and brought in to balance with the appropriate mass/distance ratio's on each side of the pivot. |
| Disc 04-07 | levers | 1M20.40 | A torque bar, spring scale, and pivot are used to illustrate the three classes of levers. |
| PIRA 1000 | body levers | 1M20.45 | |
| TPT 16(6),403 | body levers | 1M20.45 | Construction and use of a device representing body levers. |
| Hil, M-14c | wheel and axle | 1M20.60 | The PIC-Kit used for demonstrating simple machines. |
| Mei, 6-3.2 | black box | 1M20.99 | Hide a mechanism in a box and try to deduce what is inside. |
| | **Non-Conservative Forces** | **1M30.00** | |
| PIRA 1000 | air track collision/sliding mass | 1M30.10 | |
| UMN, 1M30.10 | air track collision/sliding mass | 1M30.10 | An air cart with a mass that can be locked or free hits the end of the track. |
| F&A, Mw-1 | air track collision/sliding mass | 1M30.10 | Compare the bounce of an air cart on an inclined air track with a mass that is attached tightly and loosely. |
| Sut, M-109 | negative acceleration due to friction | 1M30.15 | A pendulum hits a tabletop, transferring a wood block rider to the tabletop. Potential to kinetic energy is wasted in friction. |
| ref. | ref. friction blocks | 1M30.16 | see 1K20.16. |
| Hil, M-14e | the woodpecker | 1M30.30 | A toy bird slides down a rod giving up energy to friction and pecking. A "loose clamp" on the ringstand demo is also shown. |
| | **Conservation of Energy** | **1M40.00** | |
| PIRA 200 | nose basher | 1M40.10 | A bowling ball pendulum is held against the nose and allowed to swing out and back. |
| UMN, 1M40.10 | nose basher | 1M40.10 | Hold a bowling ball suspended from the ceiling against your nose and let it swing. |
| TPT 22(6),384 | nose basher, etc | 1M40.10 | Use bowling balls for the nose basher, drop out or project out of upper floor windows, collisions. |
| F&A, Mr-6 | nose basher | 1M40.10 | A large pendulum bob is suspended from the ceiling. Do the nose basher. |
| Mei, 9-1.2 | nose basher | 1M40.10 | Head against the blackboard, long pendulum. |
| Hil, M-14b | nose basher | 1M40.10 | Hold a bowling pendulum to the nose and let it go. |
| D&R, M-414 | nose basher | 1M40.10 | Hold a bowling ball suspended from the ceiling against your nose and let it swing out and back. |
| Sprott, 1.10 | nose basher | 1M40.10 | A bowling ball is suspended from the ceiling with thin wire. Hold it against your nose and let is swing out and back. |
| Bil&Mai, p 89 | nose basher | 1M40.10 | A bowling ball pendulum is held against the nose and allowed to swing out and back. |
| Disc 03-14 | nose basher / bb pendulum | 1M40.10 | A bowling ball pendulum is held against the nose and allowed to swing out and back. |
| Mei, 9-1.7 | recording pendulum motion | 1M40.11 | A complicated device uses a spark timer to record interchange of kinetic and potential energy in a swinging pendulum. |
| AJP 36(7),643 | additional references | 1M40.12 | A letter noting that AJP 35(11),1094 has been published many times. |
| AJP 35(11),1094 | weight of a pendulum | 1M40.12 | Suspend a pendulum from a double beam balance with a small block placed under the opposite pan to keep the system level. Swing the pendulum so it just lifts a weight off the stopped pan. |
| Sut, M-17 | swinging on the halyards | 1M40.12 | Swinging on the halyards to hoist a sail. |
| Sut, M-146 | break a pendulum wire | 1M40.12 | Suspend a heavy bob on a weak wire. As the ball descends in its swing, the wire breaks. |
| AJP 41(9),1100 | burn the pendulum wire | 1M40.13 | A Saran wrap pendulum support is burned to release the bob as it reaches the bottom of its swing. Measure the range of the bob. |
| PIRA 200 | stopped pendulum | 1M40.15 | A pendulum started at the height of a reference line reaches the same height when a stop is inserted. |
| UMN, 1M40.15 | stopped pendulum | 1M40.15 | A pendulum is started at the height of a reference line and returns to that height even when a stop is inserted. |
| F&A, Mr-3 | stopped pendulum | 1M40.15 | A pendulum swing is started at the height of a reference line. A stop is inserted and the bob still returns to the same height. |
| D&R, M-414 | stopped pendulum | 1M40.15 | A pendulum started at the height of a reference line reaches the same height when a stop is inserted. |
| AJP 71(11), 1115 | stopped pendulum | 1M40.15 | The period of the interrupted pendulum is highly nonisochronous if the interruption is not located on the main verticals axis that contains the point of the suspension. |

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| Bil&Mai, p 94 | stopped pendulum | 1M40.15 | A pendulum started at the height of a reference line reaches the same height when a stop is inserted. |
| Disc 03-13 | Galileo's pendulum | 1M40.15 | Intercept the string of a pendulum by a post at the bottom of the swing. |
| Sut, M-132 | blackboard stopped pendulum | 1M40.16 | Do the stopped pendulum on the blackboard. |
| PIRA 200 | loop the loop | 1M40.20 | A ball rolls down an incline and then around a vertical circle. |
| UMN, 1M40.20 | loop the loop | 1M40.20 | A ball rolls down an incline and around a loop. Vary the initial height of the ball. |
| AJP 30(5),336 | loop the loop | 1M40.20 | Apparatus Drawings Project No. 26: The vertical circle is made by flexing a thin stainless steel strip in a framework of Plexiglas. |
| TPT 15(6),368 | loop the loop | 1M40.20 | How to make an inexpensive loop the loop from vinyl cove molding. |
| F&A, Mm-5 | loop the loop | 1M40.20 | A steel ball is rolled down an angle iron bent to form a incline and loop. |
| Mei, 12-5.7 | loop the loop | 1M40.20 | An apparatus to do the loop the loop quantitatively. Construction details in appendix, p.589. |
| Sut, M-157 | loop the loop | 1M40.20 | A ball rolls down an incline and then around a vertical circle. |
| Hil, M-16b.2 | loop the loop | 1M40.20 | Standard loop the loop. |
| D&R, M-422, M-674 | loop the loop | 1M40.20 | Ball rolls down an incline and then around a vertical circle. Also, Hot Wheels track. |
| Bil&Mai, p 140 | loop the loop | 1M40.20 | A golf ball is rolled down a bookshelf track bent to form an incline and loop. |
| Disc 06-09 | loop the loop | 1M40.20 | A rolling ball must be released at 2.7 times the radius of the loop. |
| AJP 42(2),103 | water loop the loop | 1M40.21 | A water stream "loop the loop" demonstrates the effect of centripetal forces much more dramatically than when a ball is used. |
| PIRA 1000 | reverse loop the loop | 1M40.23 | |
| UMN, 1M40.23 | reverse loop the loop | 1M40.23 | The reverse loop-the-loop is placed on a cart hooked to a falling mass that produces an acceleration just large enough to make the ball go around backwards into the cup. |
| AJP 29(1),48 | reverse loop-the-loop | 1M40.23 | With a little practice, one can pull a reverse loop-the-loop with a large and prolonged acceleration. Plans and procedures. |
| Mei, 12-5.5 | reverse loop the loop | 1M40.23 | In the reverse loop-the-loop a ball rolls up an incline and around a loop into a cup as the whole apparatus is accelerated. |
| AJP 55(9),826 | loop the loop with slipping analysis | 1M40.24 | Analysis of loop the loop, also dealing with slipping. |
| PIRA 1000 | energy well track | 1M40.25 | |
| Disc 03-12 | energy well track | 1M40.25 | A ball can escape the energy well when released from a point above the peak of the opposite side. |
| PIRA 1000 | ball in a trough | 1M40.30 | |
| UMN, 1M40.30 | ball in a track | 1M40.30 | A ball rolls in an angle iron bent into a "v" shape. |
| Mei, 7-1.5.9 | ball in a trough | 1M40.30 | Roller coaster car on a track runs down one track and up another of a different slope. |
| Bil&Mai, p 91 | ball in a track | 1M40.30 | A ball rolls in an angle iron bent into a "v" shape. |
| Mei, 9-1.6 | deformed air track | 1M40.31 | Deform a 5 m air track into a parabola (1") at center and show oscillations both with the track leveled and with one end raised. |
| Mei, 11-1.7 | air track potential well | 1M40.31 | Curve an air track into an arc of a vertical circle. |
| Hil, M-14a | ball in curved tracks | 1M40.32 | Balls are rolled down a series of curved tracks of the same height but different radii. |
| PIRA 1000 | triple track | 1M40.33 | |
| UMN, 1M40.33 | adjustable track | 1M40.33 | |
| F&A, Mr-2 | ball in a track | 1M40.33 | A large steel ball rolls on a bent angle track with differing slopes. |
| Disc 03-15 | triple track energy conservation | 1M40.33 | Balls released from three tracks with identical initial angles rise to the same height independent of the angle of the second side of the "v". |
| PIRA 1000 | roller coaster | 1M40.35 | |
| UMN, 1M40.35 | roller coaster | 1M40.35 | A ball rolls down a track with four horizontal sections of differing heights. The velocity is measured at each section. |
| AJP 59(3),283 | roller coaster experiment | 1M40.35 | Optoelectrical detectors measure the speed of a ball at specific points on a roller coaster track. Could be adapted for lecture demonstration. |
| PIRA 500 | ballistic pendulum with .22 | 1M40.40 | |
| UMN, 1M40.40 | ballistic pendulum | 1M40.40 | Shoot a .22 into a block of wood mounted as a pendulum. A slider device measures recoil. |
| F&A, Mi-3 | ballistic pendulum | 1M40.40 | A .22 is fired into a suspended wood block. The recoil distance is used to determine the rise of the block. |
| Mei, 9-5.15 | ballistic pendulum | 1M40.40 | Shoot a .22 straight up into a suspended block of wood. |
| Sut, M-124 | ballistic pendulum | 1M40.40 | The standard rifle ballistic pendulum setup. |
| Hil, M-15a.3 | ballistic pendulum | 1M40.40 | Fire a air-gun into a wood block with a paraffin center. |
| PIRA 1000 | Beck ballistic pendulum | 1M40.41 | |
| AJP 53(3),267 | modify the ballistic pendulum | 1M40.41 | Ignoring rotational dynamics results in a large error. Convert to a rotational dynamics device with an additional metal sleeve. |

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| AJP 36(12),1161 | Beck ballistic pendulum | 1M40.41 | Comprehensive review of the Beck ballistic pendulum. |
| Hil, M-13c | ballistic pendulum | 1M40.41 | The commercial ballistic pendulum. |
| Disc 05-11 | ballistic pendulum | 1M40.41 | The commercial swinging arm ballistic pendulum. |
| AJP 32(3),229 | ballistic pendulum | 1M40.42 | A catapult/ballistic pendulum made of inexpensive materials. |
| AJP 40(3),430 | bow and arrow ballistic pendulum | 1M40.43 | The relation between bending of the bow and the velocity of the arrow was found to be linear. |
| TPT 17(6),393 | bow and arrow ballistic pendulum | 1M40.43 | Plans for a coffee can target for a bow and arrow ballistic pendulum. Includes slider. |
| Bil&Mai, p 81 | bow and arrow ballistic pendulum | 1M40.43 | A bathroom scale is used to measure the force needed to draw a bow to certain positions. Graph the results and propose a method to determine how much work was done. |
| AJP 36(6),558 | blow gun ballistic pendulum | 1M40.45 | Find the velocity of the dart fired from a blowgun by measuring the fall from the aiming point to the hit point on the target block. |
| AJP 31(9),719 | vertical ballistic pendulum | 1M40.47 | A ball is dropped into a box of sand suspended from a spring and the extension of the spring is measured. |
| AJP 38(4),532 | trouble with the ballistic pendulum | 1M40.49 | An analysis of the error introduced with non-parallel ropes. |
| TPT 11(7),426 | ballistic pendulum tutorial | 1M40.49 | Good tutorial on the ballistic pendulum. |
| PIRA 500 | big yo-yo | 1M40.50 | |
| UMN, 1M40.50 | big yo-yo | 1M40.50 | A large disc is hung from bifilar threads wrapped around a small axle. |
| AJP 41(11),1295 | big yo-yo | 1M40.50 | A shop drawing of axles with three different radii used to make a big yo-yo out of a force table. |
| F&A, Ms-2 | big yo-yo | 1M40.50 | A large (2') disc is suspended from a small axle so the string unwinds on the way down and rewinds on the way up. |
| Mei, 12-5.2 | big yo-yo | 1M40.50 | Two large discs hung from bifilar thread wrapped around a small axle. |
| Sut, M-164 | big yo-yo | 1M40.50 | A large yo-yo is made by suspending a large spool from two threads wrapped around opposite ends of the axle. |
| Hil, M-19b.2 | big yo-yo | 1M40.50 | A picture of a commercial Maxwell's wheel. |
| Disc 06-08 | Maxwell's yoyo | 1M40.50 | Release a large yo-yo and it will bottom out and wind up again. |
| TPT 28(2),92 | cheap and simple yo-yos | 1M40.51 | Yo-yos made with cardboard sides and paper towel centers routinely gave time of fall within 1% of predicted |
| Mei, 9-5.11 | swinging arm | 1M40.55 | A ball is dropped into a pivoting capturing arm from the height required to make it just complete one revolution. |
| F&A, Mt-8 | spinner and pendulum | 1M40.56 | A ball suspended as a bifilar pendulum hits a ball of equal mass free to rotate in a horizontal circle. |
| Mei, 9-1.1 | Pany device | 1M40.57 | A complicated apparatus converts elastic potential energy (spring) into rotational potential energy and back. |
| PIRA 500 | height of a ball | 1M40.60 | |
| UMN, 1M40.60 | height of a ball | 1M40.60 | Same as AJP 29(10),709. |
| AJP 29(10),709 | height of a ball | 1M40.60 | Rotate a 15.3 in radius bar at 1, 2, or 3 rev/sec, a mechanism releases a ball at the end of the bar at the moment the ball is traveling vertically. The ball rises 1, 4, or 9 ft. |
| Mei, 9-1.4 | height of a ball | 1M40.60 | A device to project a ball upward at different known velocities to show dependence of kinetic energy on the square of velocity. |
| PIRA 1000 | 1-D trampoline | 1M40.61 | |
| UMN, 1M40.61 | 1-D trampoline | 1M40.61 | A horizontal string passes over a pulley down to a spring fixed at one end. Place a spitball at the center of the horizontal section and pull it down until the spring extends unit lengths. Compare the heights the spitball reaches. |
| PIRA 1000 | x-squared spring energy dependence | 1M40.63 | |
| Disc 03-10 | x-squared spring energy dependence | 1M40.63 | Measure the height of recoil of an air track glider on an incline after compressing a spring to different lengths. |
| PIRA 1000 | spring ping pong gun | 1M40.64 | |
| D&R, M-288 | spring gun - dart gun | 1M40.64 | Two identical dart guns, shoot a standard dart with one, and a dart with a marble epoxied to the end with the other. Aim up, down, or horizontal, and ask which dart will reach the target first. |
| Bil&Mai, p 64 | spring gun - dart gun | 1M40.64 | Two identical dart guns, shoot a standard dart with one, and a dart with a marble epoxied to the end with the other. Aim up, down, or horizontal, and ask which dart will reach the target first. |
| Disc 03-08 | spring ping pong gun | 1M40.64 | A spring gun shoots standard and loaded ping pong balls to different heights. |
| PIRA 1000 | height of a spring launched ball | 1M40.65 | |
| AJP 31(5),392 | height of a spring-launched ball | 1M40.65 | A 3/4" steel ball is launched upward by a "stopped spring" (shown), from which the initial velocity is calculated. |

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| Bil&Mai, p 87 | height of a spring launched ball | 1M40.65 | Place a golf ball on a depressed spring and then release. The ball will be launched upward about 30 cm. Redo the demonstration with a Ping Pong ball which goes much higher. |
| PIRA 1000 | mechanical jumping bean | 1M40.66 | |
| UMN, 1M40.66 | mechanical jumping bean | 1M40.66 | Same as TPT 1(3),108. |
| TPT 1(3),108 | mechanical jumping bean | 1M40.66 | A mailing tube jumps when a hidden mass moves upward under rubber band power. |
| Mei, 9-3.3 | jumping tube | 1M40.66 | A spring loaded tube jumps two or three times its own height when triggered. Diagram. |
| PIRA 1000 | spring jumper | 1M40.67 | |
| D&R, M-406 | spring jumper | 1M40.67 | Compress a spring under a toy held down by a suction cup. |
| Disc 03-09 | spring jumper | 1M40.67 | Compress a spring under a toy held down by a suction cup. |
| AJP 53(11),1114 | muzzle velocity - spring constant | 1M40.68 | A method of using the potential energy of the cocked spring to calculate the muzzle velocity. (15% of the energy is lost.) |
| AJP 28(7),679 | rachet for inelastic collisions | 1M40.69 | A ratchet mechanism locks a spring in the compressed position giving an inelastic collision with the decrease in kinetic energy stored for later release by tripping the ratchet. |
| Mei, 9-1.8 | dropping bar | 1M40.71 | Lift a horizontal bar suspended from two springs and drop it through a photocell to measure velocity. Examine the exchange between gravitational, elastic potential, and kinetic energy. |
| TPT 13(3),169 | tension in wire when one mass swings | 1M40.72 | A spring scale is suspended between two masses. Set one swinging- a lot of physics. |
| Mei, 11-1.12 | air track cart and falling mass | 1M40.74 | A mass m attached to a cart M with a string and pulley. Compare kinetic energy gained by m+M with potential energy lost by M. |
| PIRA 1000 | obedient can | 1M40.75 | |
| Sprott, 1.11 | obedient can, come-back can | 1M40.75 | A can rolls across a table, stops then comes back to where it started due to energy it stores winding an elastic band as the can rolls out. |
| Mei, 11-2.3f | air disc | 1M40.76 | A falling weight spins an air bearing supported rotating disc. Compare rotational (disc) and translational (weight) kinetic energy with potential energy. |
| AJP 53(10),962 | push-me-pull-you sternwheeler | 1M40.80 | Both upstream and downstream motion is possible in a system with a water stream running between the rails and a waterwheel mounted on the rear axle of the cart. |
| Mei, 9-1.3 | sloping cart | 1M40.85 | This is a counter intuitive demo. Nothing happens when a brick is placed on a slanted cart. |
| PIRA 1000 | rattleback | 1M40.90 | |
| UMN, 1M40.90 | rattleback | 1M40.90 | |
| TPT, 37(2), 80 | curious Celts and riotous rattlebacks | 1M40.90 | The rattleback enigma further explored by making them out of plastic spoons. |
| PIRA 1000 | high bounce paradox | 1M40.91 | |
| Bil&Mai, p 85 | high bounce paradox | 1M40.91 | Flip a half racquetball inside out and drop on the floor. It bounces back higher than the height from which it was dropped. |
| Disc 03-11 | high bounce paradox | 1M40.91 | Flip a half handball inside out and drop on the floor. It bounces back higher than the height from which it was dropped. |
| F&A, Mp-10 | acrobat | 1M40.93 | Phil Johnson's response to this demo was: "?????????????". In actuality this is a toy with an acrobat figure ( double or triple pendulum ) with a rubber band through the hands and connected to two vertical flexible supports. Flex the supports and the acrobat does amazing tricks. |
| TPT 39(8), 471 | trebuchet | 1M40.95 | The dynamics, design, and some improvements that can be made to the classical trebuchet to maximize projectile range. |
| TPT 32(8), 476 | trebuchet | 1M40.95 | The trebuchet as an example of medieval energy conservation. |
| TPT 24(9), 556 | catapult | 1M40.97 | Students chose between two catapult designs to launch eggs over a wall while maximizing distance beyond the wall. |
| TPT 47(9), 574 | siege engines / onager | 1M40.99 | The classic onager siege engine and three improvements that can maximize projectile range. |
| | **Mechanical Power** | **1M50.00** | |
| PIRA 1000 | Prony brake | 1M50.10 | |
| UMN, 1M50.10 | Prony brake | 1M50.10 | Turn a large hand cranked pulley with the belt fastened to two spring scales. |
| F&A, Mv-2 | Prony brake | 1M50.10 | A belt fastened to two spring scales is strung under tension around a large hand cranked pulley. |
| Mei, 12-4.1 | Prony brake | 1M50.10 | How to make a self adjusting Prony brake that provides constant torque. |
| Mei, 12-4.2 | Prony brake | 1M50.10 | Each end of the belt for a Prony brake is attached to a spring scale. |
| Sut, M-135 | Prony brake | 1M50.10 | Measuring your horsepower by Prony brake and running up stairs. Hints on making a human sized Prony brake. |

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| Sut, M-134 | Prony brake | 1M50.10 | Measuring delivered horsepower by turning a pulley under a stationary belt attached to spring scales at each end. |
| Bil&Mai, p 93 | Prony brake - stairs | 1M50.10 | Measure your horsepower by running up stairs. |
| Disc 03-18 | Prony brake | 1M50.10 | Rotate a shaft against a constant frictional resistive force. |
| Sut, M-136 | power bicycle | 1M50.20 | Attach a 2" dia. axle to the rear of a bike and use it to lift a weight via a pulley on the ceiling. |
| ref. | ref. hand crank generator | 1M50.30 | see 5K40.80. |
| Mei, 9-3.7 | rocket wheel | 1M50.50 | Two rockets are mounted on the rim of a bike wheel. The second is fired after effect of the first has been measured showing the power developed by a rocket is a function of its velocity |
| | **LINEAR MOMENTUM AND COLLISIONS** | **1N00.00** | |
| | **Impulse and Thrust** | **1N10.00** | |
| PIRA 1000 | collision time pendula | 1N10.10 | |
| UMN, 1N10.10 | collision time pendula | 1N10.10 | An electronic timer measures the impact time as two pendula collide. |
| F&A, Mw-4 | collision time pendula | 1N10.10 | Two metal wire bifilar pendula are suspended as part of a circuit to measure contact time on a counter. |
| Mei, 9-4.3 | time of contact | 1N10.11 | A steel ball suspended from a conducting wire hits a vertical steel plate and the electrical signal gives time of contact. |
| AJP 43(8),733 | fleeting event timer | 1N10.12 | Hitting two hammers together gates a fast oscillator to a counter. |
| Mei, 9-4.4 | contact time by oscillator | 1N10.12 | A ball swings against a plate completing a circuit allowing an oscillator to feed a counter to measure collision time. |
| Mei, 9-4.1 | measuring impulse | 1N10.13 | A pendulum strikes a piezoelectric crystal and generates a voltage spike which is viewed on an oscilloscope. |
| Mei, 9-4.2 | measuring impulse by induction | 1N10.14 | A pendulum strikes a magnet moving it in a coil inducing a current that deflects a galvanometer. |
| PIRA 500 | silicone ball on blackboard | 1N10.15 | |
| UMN, 1N10.15 | silicone ball on blackboard | 1N10.15 | Throw a silicone ball at a dirty blackboard, measure the diameter of the mark, and place weights on the silicone ball until it is squashed to the same diameter. |
| AJP 51(5),474 | ball on the blackboard | 1N10.15 | Compare the imprint of a sponge ball thrown against a dirty blackboard with the force required to get an equal size deformation and calculate the interaction time. |
| Sut, M-107 | deform clay | 1N10.16 | Drop a 50 g mass on some softened clay, then add masses slowly to another blob of clay until the depression is equal. |
| PIRA 200 | egg in a sheet | 1N10.20 | Throw an egg into a sheet held by two students. |
| UMN, 1N10.20 | egg in a sheet | 1N10.20 | Throw an egg into a sheet held by two students. |
| D&R, M-516 | egg in a sheet | 1N10.20 | Throw an egg into a sheet held by two students. |
| Bil&Mai, p 100 | egg in a sheet | 1N10.20 | Throw an egg into a sheet held by two student. Make sure the bottom of the sheet Is pulled upward to form a pocket. |
| Disc 05-09 | egg in a sheet | 1N10.20 | Throw an egg at a sheet held by two people. |
| PIRA 500 | drop egg in water | 1N10.25 | |
| UMN, 1N10.25 | drop an egg in water | 1N10.25 | |
| D&R, M-520 | drop an egg on foam | 1N10.25 | Drop an egg from a height of 1 meter onto the floor and then onto a thick piece of foam. |
| PIRA 500 | pile driver with foam rubber | 1N10.30 | |
| UMN, 1N10.30 | pile driver with foam rubber | 1N10.30 | Break a bar of Plexiglas supported on two blocks with a pile driver. Add foam to a second bar and it doesn't break. |
| Disc 05-10 | piledriver with foam rubber | 1N10.30 | A pile driver breaks a plastic sheet supported at the sides. Add a piece of foam rubber and the plastic does not break. |
| PIRA 1000 | car crashes | 1N10.35 | |
| UMN, 1N10.35 | car crashes | 1N10.35 | Roll a car down an incline to smash beer cans. Vary the bumpers to change the impulse. |
| TPT 13(3),173 | car crashes | 1N10.35 | A cart rolls down an incline and smashes a beer can against a brick wall. Four interchangeable bumpers are used to vary the impulse. |
| AJP 41(11),1294 | car saftey on the air track | 1N10.36 | Models of a person with a head, seat belt and a head rest are placed on an air track cart. |
| PIRA 1000 | auto collision videodisc | 1N10.40 | |
| UMN, 1N10.40 | auto collision videodisc | 1N10.40 | Show segments of the video disc. |
| AJP 36(7),637 | impulse on the air track | 1N10.50 | A rubber band launcher provides an impulse to an air cart. Analysis given is for a lab. |
| Mei, 9-4.14 | impulse acceleration track | 1N10.50 | A mass on a right angle lever imparts a known variable impulse to a cart on a track and the final velocity is measured. |
| AJP 51(9),783 | karate blows | 1N10.55 | Not many physics instructors will be able to perform these demonstrations. |
| AJP 43(10),845 | karate strikes | 1N10.55 | Analysis of karate strikes and description of breaking demonstrations. |

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| Mei, 9-4.11 | water stream impulse | 1N10.56 | The force created by a momentum change in a fine water stream is calculated using measurements obtained with a large scale impulse balance. Construction details. |
| TPT 9(7),413 | jet velocity by impulse | 1N10.57 | The impulse supplied by the counterweight equals the loss of horizontal momentum of a jet of water. The exit velocity of the water jet is then calculated and checked by measuring range. |
| Mei, 9-4.6 | thrust with air carts | 1N10.63 | Two carts, one with an air nozzle, the other with a reversible hemispherical deflector can be connected by a spring to show forces internal and external to a system and the effects on thrust resistance and thrust reversal. |
| AJP 33(10),784 | water jet thrust | 1N10.64 | Measure the vertical height of a water jet, collect water to determine the flow, and match the deflection of the nozzle by hanging weights with the flow turned off. |
| PIRA 1000 | model rocket impulse | 1N10.70 | |
| TPT 13(7),435 | model rocket impulse | 1N10.70 | Using solid fuel model rocket engines as an impulse generator, demonstrate the impulse-momentum theorem by measuring the final velocity. |
| TPT 18(4),315 | model rocket thrust | 1N10.71 | A device provides a method of measuring the thrust of a model rocket engine and recording it on graph paper. Impulse is calculated. Clever. |
| Mei, 9-3.1 | model rocket thrust | 1N10.72 | Modify a toy rockets to maintain continuous discharge. Attach to a platform scale. |
| Mei, 9-3.5 | model rocket thrust | 1N10.74 | An apparatus designed to measure the thrust of a rocket is used to check the manufacturer's specifications. |
| Mei, 9-3.8 | Dyna-Jet thrust | 1N10.75 | Thrust measurements are made on a pulse jet engine (Dyna-Jet). |
| PIRA 1000 | fire extinguisher thrust | 1N10.80 | |
| TPT 12(8),488 | fire extinguisher thrust | 1N10.80 | Measure the thrust of a fire extinguisher. |
| TPT 14(2),112 | measuring impulse | 1N10.81 | Complete treatment of the fire extinguisher cart to get exhaust velocity and average thrust for a variable mass system. |
| Mei, 11-1.15 | air cart rocket thrust | 1N10.85 | A device (diagram) measures thrust of a gas propelled air cart. Speed and acceleration are determined by strobe photography. |
| Mei, 9-3.4 | thrust independent of medium | 1N10.90 | A rocket pendulum maintains the same angle of recoil in air or water showing thrust is independent of medium. |
| | **Conservation of Linear Momentum** | **1N20.00** | |
| PIRA 500 | see-saw center of mass | 1N20.10 | |
| UMN, 1N20.10 | see-saw center of mass | 1N20.10 | Two carts magnetically repel each other on a teeter-totter. Mass of cars can be varied. |
| AJP 33(1),xxv | see-saw center of mass | 1N20.10 | Magnet carts on a balanced board repel when a constraining string is burned. Also load carts unequally. |
| F&A, Md-3 | magnetic reaction carts | 1N20.10 | Two carts with opposing permanent magnets are held together by a string which is burned. |
| F&A, Mp-16 | see-saw center of mass | 1N20.10 | Magnet cars on a balanced board repel each other when a constraining string is burned. Carts may be loaded unequally. |
| Mei, 9-2.4 | see-saw center of mass | 1N20.10 | A string holding two carts with opposing horseshoe magnets is burned and they remain balanced on a board as they repel. |
| Hil, M-15c | see-saw center of mass | 1N20.10 | Two spring loaded carts repel each other on a balanced board. |
| Bil&Mai, p 156 | see-saw center of mass | 1N20.10 | Two spring loaded carts repel each other on a balanced dynamics track. |
| Disc 02-26 | see-saw reaction carts | 1N20.10 | Two spring loaded carts repel each other on a balanced board. |
| TPT 10(9),531 | rolling ball on air cart | 1N20.12 | A ball rolls down a small inclined plane mounted on an air track. Watch the glider start and stop. |
| PIRA 1000 | car on a rolling board | 1N20.15 | |
| UMN, 1N20.15 | car on a rolling board | 1N20.15 | Start and stop a radio controlled car on a board on rollers. |
| Sut, M-123 | car on a rolling board | 1N20.15 | A straight train track is mounted on a movable board. Changing the weighting of the train will change the relative velocities of the train and track. Use a circular track for conservation of angular momentum. |
| Disc 02-20 | car on rolling board | 1N20.15 | Use a radio-controlled car on the board on a series of rollers. |
| Mei, 6-4.9 | car on the road | 1N20.16 | A drawing board rides on perpendicular sets of steel rods to give 2D freedom of motion. Set a toy wind up car on it. |
| AJP 33(10),857 | train on an air track | 1N20.17 | An HO gauge train and 36" track mounted on a air cart. |
| PIRA 200 | sprring apart air track gliders | 1N20.20 | Burn a string holding a compressed spring between two air gliders. |
| UMN, 1N20.20 | spring apart air track glider | 1N20.20 | Two spring loaded carts on the air track initially held together by a electromagnet repel and are timed photoelectrically. |
| F&A, Md-4 | spring apart air track glider | 1N20.20 | Air track carts equipped with iron cores and a spring are held together by an electromagnet. |
| Mei, 11-1.10 | spring apart air track glider | 1N20.20 | Compress spring and burn thread to release, or use a toy pistol cap and hand held tesla coil. |

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| Bil&Mai, p 110 | spring apart dynamics carts | 1N20.20 | A spring between two dynamics carts is triggered. Use carts of equal mass and then double the mass of one cart. |
| Disc 02-19 | reaction gliders momentum conservation | 1N20.20 | Burn a string holding a compressed spring between two unequal mass air gliders. |
| F&A, Md-1 | old reaction carts | 1N20.21 | Two spring loaded carts on a track with light bulbs at the ends of the track to indicate simultaneous arrival. |
| Mei, 7-1.5.5 | old reaction cars | 1N20.21 | Two spring loaded cars on a track fly apart. If they reach the ends at the same time, lights flash. |
| Mei, 9-5.16 | repelling carts | 1N20.22 | Two carts on a track start at rest and are exploded and timed. |
| D&R, M-554 | repelling carts | 1N20.22 | Two carts, one spring loaded, start at rest, are exploded and timed. |
| AJP 41(1),136 | magnetic release | 1N20.23 | The magnetic release for the spring apart air track carts. |
| TPT 28(2),112 | recoiling magnets | 1N20.24 | Hold two small horseshoe magnets together on an overhead projector and observe the recoil. |
| PIRA 1000 | elastic band reaction carts | 1N20.25 | |
| UMN, 1N20.25 | elastic band reaction carts | 1N20.25 | Pull apart two carts of unequal mass attached with an elastic band. |
| Sut, M-121 | elastic band reaction cars | 1N20.25 | A stretched rubber band pulls two carts together with accelerations inversely proportional to their masses. |
| Mei, 9-4.16 | exploding pendula | 1N20.30 | Two large pendula of unequal mass are held together compressing a spring. When the spring is released, two students mark the maxima. |
| Sut, M-120 | reaction swings | 1N20.31 | Planks with bifilar supports may be used in place of reaction carts. |
| AJP 41(7),922 | exploding basketballs | 1N20.32 | Explode a firecracker between a light and heavy basketball that are suspended near the ceiling. Details of the basketball holder are given. |
| Mei, 9-4.19 | big bertha | 1N20.32 | A dry ice cannon is mounted on model railroad tracks. Average velocity of the recoiling cannon and projectile are timed. |
| D&R, M-550 | big bertha | 1N20.32 | A test tube cannon is hung by bifilar supports. Add a small amount of water, stopper, and heat with a Bunsen burner. Average velocities of the recoiling test tube and stopper projectile or compared. |
| AJP 34(8),707 | explosion | 1N20.35 | Explode a firecracker in an iron block 4x4x2" pieced together from three sections. |
| AJP 35(4),359 | explosion - comment about friction | 1N20.35 | The center of mass will move due to friction. |
| AJP 57(2),182 | air track c of m collision | 1N20.60 | An inelastic air track collision with a cart and a spring coupled cart system. |
| | **Mass and Momentum Transfer** | **1N21.00** | |
| PIRA 200 | floor carts and medicine ball | 1N21.10 | |
| PIRA 500 - Old | floor carts and medicine ball | 1N21.10 | |
| UMN, 1N21.10 | floor carts and medicine ball | 1N21.10 | Two people on roller carts throw a medicine ball to each other. |
| Sut, M-119 | floor carts and medicine ball | 1N21.10 | Throw a medicine ball or baseball back and forth, throw several baseballs against the wall. |
| PIRA 1000 | catapult from cart to cart | 1N21.20 | |
| UMN, 1N21.20 | catapult from cart to cart | 1N21.20 | Catapult a ball of equal mass as the cart into a catcher in the second cart. |
| Mei, 7-1.5.4 | catapult from cart to cart | 1N21.20 | Two carts at rest on a track, one catapults a steel ball into the other, each is photoelectrically timed. |
| Mei, 9-4.5 | thrust cars | 1N21.25 | Conservation of momentum of a thrust producing stream on water is shown by two carts on a track: one has a nozzle, the other a bucket to catch the water. |
| Mei, 9-4.7 | thrust cars | 1N21.26 | How to pull the plug on a container of water on a cart to show conservation of momentum by reaction to discharging water stream. |
| PIRA 1000 | ballistic air glider | 1N21.30 | |
| UMN, 1N21.30 | ballistic air glider | 1N21.30 | Shoot a .22 into a wood block mounted on an air glider. Use a timer to determine the velocity. |
| AJP 34(3),xxx | ballistic air glider | 1N21.30 | Shoot a .22 into a block of wood on an air cart. |
| F&A, Mi-4 | ballistic air glider | 1N21.30 | A .22 is fired into a block of wood mounted on an air cart. |
| Mei, 7-1.5.6 | ballistic air glider | 1N21.30 | A rifle is shot into a car on a track. |
| Mei, 11-1.11 | ballistic air glider | 1N21.30 | Shoot a .22 into a block on an air cart. |
| PIRA 1000 | drop sandbag on cart | 1N21.40 | |
| UMN, 1N21.40 | drop sandbag on cart | 1N21.40 | A cart passes by a device that drops a sandbag of equal mass as the cart. Timers measure the velocity before and after the transfer. |
| TPT 19(5),326 | drop weight on moving cart | 1N21.40 | Drop a weight on a moving cart, two people on roller carts push against each other. |
| Mei, 9-4.18 | drop shot on cart | 1N21.41 | Lead shot is dropped from a hopper into a box on a moving cart. The initial velocity is reproducible and the final velocity is measured with a photogate. |
| PIRA 1000 | vertical catapult from moving cart | 1N21.45 | |

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| UMN, 1N21.45 | vertical catapult from moving cart | 1N21.45 | Shoot a ball of equal mass from a moving cart into a catcher. Time to determine the velocity before and after the transfer. |
| F&A, Mg-5a | jump on the cart | 1N21.50 | Run at constant velocity and jump on a roller cart. |
| AJP 57(10),858 | air track ball catcher | 1N21.55 | Shoot a stream of balls at a moving air cart until the cart stops. |
| | **Rockets** | **1N22.00** | |
| TPT 20(2),107 | historical note | 1N22.01 | An article claims rockets will not work in space because there is nothing to push against. |
| PIRA 200 | fire extinguisher wagon | 1N22.10 | Mount a fire extinguisher on a cart and take a ride. |
| UMN, 1N22.10 | fire extinguisher rocket | 1N22.10 | Mount a fire extinguisher on a cart and take a ride. |
| D&R, M-566 | fire extinguisher wagon | 1N22.10 | Mount a large fire extinguisher on a cart and take a ride. Directions for orifice modification of fire extinguisher. |
| Sprott, 1.13 | fire extinguisher wagon | 1N22.10 | Mount the fire extinguisher to a cart or tricycle. |
| Disc 02-24 | fire extinguisher wagon | 1N22.10 | Mount a fire extinguisher on a wagon with the hose attached to a half inch plumbing fitting directed to the rear. |
| PIRA 1000 | rocket lift-off video | 1N22.15 | |
| UMN, 1N22.15 | rocket video | 1N22.15 | Show video of a rocket or shuttle launch. |
| PIRA 200 | water rocket | 1N22.20 | Pump a toy water rocket the same number of times, first with only air, and then with water. |
| UMN, 1N22.20 | water rocket | 1N22.20 | Pump a toy water rocket the same number of times, first with only air, and then with water. |
| AJP 69(3), 223 | water rocket | 1N22.20 | Analysis of a water rocket to determine the optimum amount of water to use to achieve maximum height. |
| AJP, 78 (3), 236 | water rocket | 1N22.20 | A through analysis of the water rocket taking into account water vapor condensation, downward acceleration of water within the rocket, and transient water flow. |
| F&A, Mh-3 | water rocket | 1N22.20 | A commercial water rocket is charged with air and then water. |
| D&R, M-558 | water rocket | 1N22.20 | A conventional water rocket adapted to run on a wire angled upward to the ceiling. |
| Bil&Mai, p 114 | water rocket | 1N22.20 | Pump a toy water rocket the same number of times, first with only air, and then with water. |
| Disc 02-23 | water rocket | 1N22.20 | Use a water rocket first with air only, and then with air and water. |
| Bil&Mai, p 2 | altitude finder | 1N22.21 | Construction of a simple altitude finder / sextant from a protractor, straw, string, and weight. |
| Mei, 11-1.14 | air track rocket | 1N22.23 | Air from a rubber balloon propels an air cart. |
| PIRA 1000 | balloon rocket | 1N22.25 | |
| UMN, 1N22.25 | balloon rocket | 1N22.25 | "Balloon rockets" are available at toy stores. Normal balloons follow more random paths. |
| Bil&Mai, p 65 | balloon rocket | 1N22.25 | Blow up an oblong balloon. Keeping the balloon sealed by pinching the nozzle, tape the balloon parallel to a straw. Put a string through the straw and attach the ends of the string to opposite walls of the classroom. When released the balloon should travel across the room on the string. |
| PIRA 1000 | CO2 cartridge rocket | 1N22.30 | |
| F&A, Mh-1 | rocket car | 1N22.30 | A CO2 powered car accelerates across the lecture bench. |
| Mei, 9-3.2 | rocket car - CO2 cartridge | 1N22.30 | Cartridges of CO2 are used to propel small automobiles or projectiles. |
| TPT 12(1),50 | rocket to the Moon | 1N22.32 | A nice setup of the CO2 rocket on a wire. |
| F&A, Mh-2 | rocket to the Moon | 1N22.32 | A small CO2 powered rocket rides a wire across the classroom. |
| PIRA 1000 | rocket around the Moon | 1N22.33 | |
| UMN, 1N22.33 | rocket around the Moon | 1N22.33 | A CO2 cartridge in the back of a model plane propels it around in circles. |
| Disc 02-22 | CO2 rocket | 1N22.33 | A small CO2 cartridge rotates a counterbalanced bar. |
| D&R, M-426 | alcohol vapor rocket | 1N22.35 | Pour 12 ml of alcohol into a plastic 5 gallon water jug or 20 L carboy. Rotate the jug to distribute the alcohol evenly onto the jug walls. Drop a lighted match into the jug. The jug will bounce up and down on the table. |
| Bil&Mai, p 112 | alcohol vapor rocket | 1N22.35 | Pour 5 mL of alcohol into a 2 L plastic soda bottle. Swirl the alcohol around to vaporize the liquid and then pour out the excess alcohol. Use duct tape to secure the bottle to a straw mounted on a guideline stretched across the room. Securely insert a cork and then ignite the alcohol vapor with a piezo electric igniter. |
| Sprott, 1.13 | methanol rocket | 1N22.35 | Methanol powered rocket using 5 gal plastic water bottle. |
| PIRA 1000 | ball bearing rocket cart | 1N22.40 | |
| UMN, 1N22.40 | ball bearing rocket cart | 1N22.40 | A cart is propelled down a track by 2 1/2" ball bearings rolling down a chute attached to the cart. |
| F&A, Mh-4 | ball bearing rocket cart | 1N22.40 | A cart is propelled down a track by 1" ball bearings rolling down a chute. |
| Mei, 9-3.6 | ball bearing rocket cart | 1N22.40 | Fifteen large steel ball bearings fall through a chute to propel a cart. The last ball moves in the same direction as the cart. |
| F&A, Mh-5 | reaction to a stream of water | 1N22.51 | A nozzle reacts against a water jet. |

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| Mei, 9-4.8 | reaction to a stream of water | 1N22.51 | Several techniques on making the deflection due to the reaction to a stream of water more graphic. |
| Mei, 9-4.9 | reaction to a stream of water or air | 1N22.51 | With string, tie one end of a 3' rubber hose to a spring and turn on the air, then cut the string between the spring and the hose. |
| Sprott, 2.25 | reaction to a stream of water or air - fire hose instability | 1N22.51 | A rubber hose connected to a source of compressed air dangles from a support and flails about. |
| AJP 57(10),943 | computer plots of rocket motion | 1N22.90 | Data from a Smart-pulley Atwoods machine with a funnel on one side is used to generate speed, position, and acceleration graphs. |
| AJP, 75 (5), 472 | altitude measurements for model rocketry | 1N22.90 | A look at the ballistic time of flight equation for maximum altitude of vertically launched rockets and why neglecting atmospheric drag makes almost no difference. |
| | **Collisions in One Dimension** | **1N30.00** | |
| ref. | ref. coef. of restitution | 1N30.01 | see 1R40.xx. |
| PIRA 200 | collision balls | 1N30.10 | Two balls or many balls on bifilar suspension. |
| UMN, 1N30.10 | collision balls | 1N30.10 | Six billiard balls are mounted on bifilar supports. |
| AJP 30(10),767 | collision balls - croquet | 1N30.10 | Weigh the balls at the store to get nearly equal masses. |
| Mei, 9-5.3 | collision balls | 1N30.10 | Eleven billiard balls on bifilar suspension. |
| Hil, M-15a.1 | collision balls | 1N30.10 | Two balls, five balls, six balls on bifilar suspension. |
| D&R, M-586 | collision balls | 1N30.10 | 5 ball on bifilar suspensions. |
| Sprott, 1.12 | collision balls | 1N30.10 | 5 stainless steel balls on bifilar suspensions demonstrate the conservation of momentum and energy. |
| Disc 05-01 | colliding balls | 1N30.10 | Two balls of equal mass collide, then balls of various mass ratios are used. Collisions with a string of equal balls are also demonstrated. |
| AJP, 50 (11), 977 | collision balls | 1N30.10 | How the collision ball experiment can be described by a series of spatially separated mass points and springs of a special type. |
| PIRA 1000 | bowling ball collision balls | 1N30.11 | |
| UMN, 1N30.11 | bowling ball collision balls | 1N30.11 | A large frame holds seven bowling balls on quadfilar supports. |
| Sut, M-68 | collision balls | 1N30.12 | Two balls on bifilar suspension. |
| Mei, 9-5.2 | collision balls | 1N30.13 | A two ball collision ball apparatus for the overhead projector. |
| AJP 49(8),761 | collision balls theory | 1N30.14 | In addition to conservation of momentum and energy, the system must be capable of dispersion-free propagation. |
| AJP 50(11),977 | collision balls theory | 1N30.14 | The collision balls are described as a series of spatially separated masspoints and springs with a force law exponent of 1.5. |
| AJP 72(12), 1508 | collision balls theory | 1N30.14 | A look at the complicated movement of the balls at the first collision and beyond. |
| TPT 35(7), 411 | collision balls theory | 1N30.14 | How to teach about Newton's cradle using scientific explanation. |
| AJP 36(1),56 | pitfalls in rolling ball collisions | 1N30.15 | Friction and other factors that affect rolling collisions. |
| F&A, Mg-2 | billiard balls | 1N30.15 | Do collision balls with billiard balls in a "v" track. |
| Mei, 9-5.7 | billiard balls | 1N30.15 | A set of grooved billiard balls run on steel edges. |
| Hil, M-15a.2 | billiard balls | 1N30.15 | Roll a ball down an incline into a trough with five other balls. |
| Hil, M-15b | billiard balls | 1N30.15 | Looks like a rolling bowling ball hits another. |
| D&R, M-582 | marbles | 1N30.15 | Do collision balls with marbles in a "V" track. |
| Bil&Mai, p 105 | steel balls | 1N30.15 | Do collision balls with 5 steel balls in a curved "V" track. |
| Mei, 9-5.8 | billiard balls | 1N30.16 | Duckpin balls slide on two taut parallel steel wires. Construction details in the appendix, p.566. |
| PIRA 1000 | 3:1 collision balls | 1N30.20 | |
| UMN, 1N30.20 | collision balls - 3:1 | 1N30.20 | |
| F&A, Mg-1 | collision balls, 3:1 | 1N30.20 | A set of identical steel balls on bifilar suspensions. Also one ball can be three times the mass, insert wax for inelasticity. |
| Mei, 9-5.13 | 3:1 collision balls | 1N30.20 | Many collisions in a 3:1:1 system - elastic and inelastic. |
| D&R, M-586, S-320 | 3:1 collision balls | 1N30.20 | Two ball collisions of pendula with 3:1 mass ratio on bifilar suspensions. |
| Sut, M-127 | collision balls, 3:1 | 1N30.21 | Two ball collisions of pendula on bifilar supports. Elastic, inelastic, and 3:1 mass ratio. ref.APT,3,36,1935. |
| TPT 33(3), 169 | collision balls, 3:1 | 1N30.21 | The strange case of collisions between balls with masses in the ratio of 1 to 3. |
| AJP 41(4),574 | time reversal invariance | 1N30.23 | The collisions of equal length pendula of different mass are used to demonstrate time reversal invariance. Also works with three balls. |
| PIRA 500 | impedance match collision balls | 1N30.25 | |
| UMN, 1N30.25 | impedance match collision balls | 1N30.25 | A big ball hits a smaller ball in one frame, and a second frame holds an series of balls between the big and small balls. |
| AJP 36(1),46 | impedance match collision balls | 1N30.25 | Big ball hits a small ball with and without an intermediate series of impedance matching balls. |
| Mei, 9-5.12 | impedance match collision balls | 1N30.25 | First a large ball hits a small ball, then other various sized balls are interposed to maximize energy transfer. |

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| AJP 54(7),660 | collision balls analysis | 1N30.29 | A simplified model of the collision balls that goes beyond conservation of energy and momentum but is still within the scope of an introductory course. |
| PIRA 1000 | air track collision gliders | 1N30.30 | |
| UMN, 1N30.30 | air track collision gliders | 1N30.30 | Two sets of air track carts, one with springs and the other with velcro, give elastic and inelastic collision. |
| AJP 33(10),784 | air trough collisions | 1N30.30 | Elastic and inelastic collisions on the air trough. A circuit is given for a light beam gated oscillator for use with a scaler. |
| Disc 05-03 | elastic and inelastic collisions | 1N30.30 | Air gliders have springs on one end and the post/clay on the other. |
| AJP 42(8),707 | air track collision tricks | 1N30.31 | Place a meter stick on two carts and lift it up before one hits an end bumper, a simple spring release device momentarily held with beeswax. |
| F&A, Mg-4 | air track collision gliders | 1N30.31 | Use a meter stick resting on top of two airtrack carts to give equal velocities. After one hits the end bumper, you have equal and opposite velocities. |
| Mei, 7-1.5.3 | air track collision gliders | 1N30.32 | A moving car runs into a stationary one and sticks. Photogate timing before and after. |
| PIRA 1000 | equal and unequal mass air track collisions | 1N30.33 | |
| F&A, Mg-3 | air track collision gliders | 1N30.33 | Air track carts with bumper springs. |
| Mei, 11-1.1 | air track collision gliders | 1N30.33 | A small cart hits a big one elastically. The big one is placed so that after the collision both carts hit the ends simultaneously. The carts will again collide at the original place. |
| Disc 05-02 | equal and unequal mass collisions | 1N30.33 | Equal and unequal mass air gliders. |
| AJP 33(10),784 | air track collision gliders | 1N30.34 | Elastic and inelastic collisions on the air trough. A circuit is given for a light beam gated oscillator for use with a scaler. |
| TPT 10(7),416 | hot wheels collisions | 1N30.36 | Uses Hot Wheels. |
| TPT 11(1),51 | inelastic collisions | 1N30.41 | A simple student experiment for elastic and inelastic collisions using PSSC collision carts. |
| TPT 9(6),346 | inelastic collisions | 1N30.41 | A simple student experiment for inelastic collisions using PSSC collision carts. |
| AJP 33(6),vi | inelastic collisions air cart clamp | 1N30.43 | Design of a simple rubber clamp for stopping Ealing air carts. |
| AJP 37(9),941 | inelastic collisions with clay | 1N30.43 | Mount a plunger on one air track and a cylinder packed with modeling clay on the other. |
| AJP 36(9),851 | inelastic collisons with velcro | 1N30.43 | Mount velcro on air carts with Swingline paper binders. |
| TPT 10(8),478 | inelastic collisions with velcro | 1N30.43 | Use velcro instead of wax. |
| Mei, 9-5.6 | inelastic collisions | 1N30.43 | Two latching carts that can be loaded come together with equal force. Construction details in appendix, p. 565. |
| F&A, Mi-1 | velocity of a softball | 1N30.45 | A softball is thrown into a box (inelastic collision) and the velocity of the box is obtained from the recoil distance. |
| Bil&Mai, p 120 | velocity of a softball | 1N30.45 | A softball is thrown into a box (inelastic collision) and the velocity of the box is obtained from the recoil distance. Calculate the initial speed of the softball. |
| AJP 54(7),658 | slow inelastic collision | 1N30.46 | An unrolling thread slowly transfers momentum between air track gliders. |
| PIRA 500 | bouncing dart | 1N30.50 | |
| UMN, 1N30.50 | the bouncing dart | 1N30.50 | Same as TPT 22(5),302. |
| TPT 22(5),302 | the bouncing dart | 1N30.50 | A dart hits a block of wood with a thud (inelastic) but with the pointer removed (elastic) knocks the block over showing greater impulse associated with elastic collisions. |
| Bil&Mai, p 101 | rebounding pendula balls | 1N30.50 | Two pendula, one made with a "happy ball", the other with an "unhappy" ball. The elastic pendulum will knock over a 2X4 block while the inelastic pendulum will not. Hint: use a bifilar arrangement. |
| D&R, M-600 | rebounding pendula balls | 1N30.50 | Two pendula, one made with a "Happy" ball, the other with an "Unhappy" ball. The elastic pendulum will knock over a 2X4 block while the inelastic pendulum will not. HINT: use a bifilar arrangement. |
| Mei, 9-5.10 | ball - pendulum collisions | 1N30.51 | A small ball rolls down an incline and strikes a larger pendulum bob on either a putty covered side or a plain steel side. |
| TPT 5(5),124 | pendulum - cart collisions | 1N30.52 | Two pendulums of equal height are released simultaneously from the same height so as to strike low friction carts. The pendulum bobs are of equal mass, one of steel and the other of clay. Greater momentum transfer during the elastic collision is observed. |
| PIRA 1000 | elastic and inelastic model | 1N30.55 | |
| UMN, 1N30.55 | elastic and inelastic model | 1N30.55 | Two carts collide with a wall. One cart stops dead due to suspended masses on the inside oscillating with different frequencies. The cart with the masses oscillating at the same frequency will rebound. |
| PIRA 500 | double ball drop | 1N30.60 | |

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| UMN, 1N30.60 | double ball drop | 1N30.60 | Drop a softball on a basketball. |
| TPT 21(7),466 | dropping superballs | 1N30.60 | Analysis of dropping two stacked superballs. Application to "slingshot effect" of space probes on the grand tour. |
| D&R, M-595 | double ball drop | 1N30.60 | A plastic ball on top of a steel ball are dropped. Acrylic tube can be used as a guide. |
| AJP 75 (11), 1009 | double ball drop | 1N30.60 | The usual tennis ball on a basketball drop shows the tennis ball projected vertically at high speed. However, a mass - spring model of the impact as well as air track data show that the tennis ball should be projected at low speed. Measurements of the forces on each ball and the use of superballs are used to resolve this problem. |
| Bil&Mai, p 103 | double ball drop | 1N30.60 | A tennis ball is placed on top of a basketball and then this system is dropped. |
| Disc 05-05 | high bounce | 1N30.60 | Drop a softball on a basketball (1:3) mass ratio. |
| AJP 55(2),183 | double ball drop | 1N30.61 | Some analysis of the double ball drop. |
| AJP 72(12), 1492 | double ball drop | 1N30.61 | A billiard-theoretic approach to elementary one dimensional elastic collisions |
| AJP 39(6),656 | velocity amplification in collisions | 1N30.62 | The complete treatment: double object, double ball, multiple ball, analog computer circuit, linear and non-linear models. |
| AJP 58(7),696 | modified two ball drop | 1N30.64 | A double mass-spring collision on a guide rod allows more control than the double ball method. |
| PIRA 1000 | double air glider bounce | 1N30.65 | |
| UMN, 1N30.65 | double air glider bounce | 1N30.65 | Let two air gliders accelerate down 30 cm of track and measure the rebound as the mass of the lead glider is increased. |
| AJP 36(9),845 | douple drop history | 1N30.65 | Brief theory of the double ball drop. Suggests trying a double air cart collision on an inclined air track. |
| AJP 42(1),54 | colliding cylinders | 1N30.70 | One cylinder slides down a track and collides with another on a horizontal track. Friction is factored in. |
| AJP 58(6),599 | modified colliding cylinders | 1N30.71 | Modifications to AJP 42(1),54. |
| Mei, 9-1.9 | inelastic collisions photo | 1N30.86 | A strobed photo is made of the collision of two carts on a table. |
| Hil, M-15e.1 | air track collision photo | 1N30.86 | Record air track collisions with strobe photography. |
| AJP 45(7),684 | air track collision timer | 1N30.87 | Plans for an electronic device to be used for velocity readout in air track collision demonstrations. Gives readout before and after collision. |
| | **Collisions in Two Dimensions** | **1N40.00** | |
| PIRA 1000 | shooting pool | 1N40.10 | |
| Mei, 9-5.1 | shooting pool | 1N40.10 | A framework allows a billiard ball pendulum to strike another on an adjustable tee. |
| Mei, 6-4.6 | orthogonal hammers | 1N40.11 | Identical hammers hung at right angles hit a ball. |
| Mei, 9-5.9 | shooting pool | 1N40.12 | An apparatus for recording collisions between ceiling mounted duckpin ball (5" dia.) and bowling ball (8 1/2" dia.). |
| TPT 2(6),278 | shooting pool on the overhead | 1N40.13 | Ink coated balls roll down chutes onto a stage placed on the overhead projector. |
| AJP 31(3),197 | shooting pool | 1N40.14 | A pool shooting box with a soapy glass surface and plans for a ball shooter. |
| AJP 29(9),636 | shadow project collisions | 1N40.16 | Vertically shadow project two dimensional collisions onto the floor. Much Discussion. |
| AJP 30(7),530 | photograph golf ball collisions | 1N40.18 | Suspend two golf balls from a ring that mounts on the camera lens and do a time lapse photo of the collision after one is pulled to the side and released. |
| Mei, 9-5.14 | photograph golf ball collisions | 1N40.18 | The collision of two suspended golf balls is photographed. |
| PIRA 500 | air table collisions - equal mass | 1N40.20 | |
| UMN, 1N40.20 | air table collisions | 1N40.20 | |
| Bil&Mai, p 122 | air puck collisions - Kick Dis | 1N40.20 | Use two Kick Dis self powered toy air pucks on the floor or a large table to do two dimensional collisions. |
| Disc 05-06 | air table collisions (equal mass) | 1N40.20 | Vary the angle of impact between a moving and stationary air puck. Lines are drawn on the screen. |
| PIRA 1000 | air table collisions - unequal mass | 1N40.21 | |
| Hil, M-15d | air table collisions | 1N40.21 | Use dry ice pucks to do two dimensional collisions. |
| Disc 05-07 | air table collisions (unequal mass) | 1N40.21 | Elastic collisions with unequal air pucks. |
| PIRA 1000 | air table collisions - inelastic | 1N40.22 | |
| Disc 05-08 | air table collisions (inelastic) | 1N40.22 | Inelastic collisions between equal and unequal mass air pucks. |
| PIRA 200 | air table collisions | 1N40.24 | |
| TPT 10(6),344 | air table collisions by video | 1N40.24 | Use a video tape of the collision to obtain data. |
| Mei, 10-3.4 | air table collisions | 1N40.24 | Use a spark timer to record collisions on an air table. |

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| Mei, 10-2.3 | air puck collisions | 1N40.24 | The path left by liquid air pucks on a table sprinkled with lycopodium powder show the 90 degree scattering law for particles of equal masses. Also a neutron diffusion demo. Construction details in appendix, p.570. |
| Mei, 10-2.4 | air table collisions | 1N40.24 | Dry ice pucks with spark timer recording. |
| Hil, M-15f.1 | air table collisions photo | 1N40.24 | Use strobe photography to record air table collisions. |
| AJP 56(5),473 | lost momentum | 1N40.25 | The air pucks are modified so the line of force during the collision passes through the center of mass. |
| TPT 22(4),258 | nine-ball on the overhead, etc | 1N40.30 | Collisions with an array of three by three balls on the overhead projector. Also a four-ball two-dimensional coupled pendula suspension. |
| AJP 48(6),496 | focusing collisions | 1N40.40 | Balls are suspended from one string and spaced at a distance of 3r. Depending on the angle the collision is initiated, the collisions will either focus or defocus. |
| AJP 73(1), 28 | super ball bouncing | 1N40.60 | The bounce of balls and superballs in three dimensions. Looks at rebounds with and without sliding, and the grip behavior of superballs. |
| AJP 37(10),1008 | bouncing ball simulation | 1N40.60 | An analog computer (circuit given) shows the path of a bouncing ball on an oscilloscope. |
| AJP 72(7), 875 | super ball bouncing | 1N40.60 | The kinematics of a superball bouncing between two vertical surfaces. |
| AJP 37(1),88 | super ball bouncing | 1N40.60 | Analysis of the trajectory of a super ball from the floor to the underside of a table and back to the hand. |
| AJP 70(5), 482 | super ball bouncing | 1N40.60 | Measuring the horizontal coefficient of restitution for a superball and a tennis ball. |
| AJP, 50 (9), 856 | super ball bouncing | 1N40.60 | More experiments on the bouncing of a super ball. |
| AJP 52(7),619 | computer collisions | 1N40.90 | A FORTRAN program for collisions on a Tektronix 4012 graphics terminal and Honeywell DPS8 computer. |
| | **ROTATIONAL DYNAMICS** | **1Q00.00** | |
| | **Moments of Inertia** | **1Q10.00** | |
| PIRA 200 | inertia wands and two students | 1Q10.10 | Students twirl equal mass wands, one with the mass at the ends and the other with the mass at the middle. |
| UMN, 1Q10.10 | inertia wands and two students | 1Q10.10 | Give students equal mass wands to twirl, one with the mass at the ends and the other with the mass at the middle. |
| Mei, 12-3.3 | inertia wands and two students | 1Q10.10 | Two apparently identical tubes, one with a mass concentration in the center, the other with a mass concentration at the ends. |
| Bil&Mai, p 162 | inertia wand and two students | 1Q10.10 | Two students twirl equal mass wands made from 1 inch PVC pipe, one with the mass at the ends of the wand and the other with the mass in the middle of the wand. |
| TPT 15(9),546 | inertia wands | 1Q10.11 | Weights taped to meter sticks are used as low cost and visually obvious alternates to commercial apparatus. |
| AJP 43(6),563 | inertia rotator and two students | 1Q10.12 | Students rotate a "T" from a disc mounted on the bottom while holding the device by a sleeve. Weights are mounted at different distances on the cross bar. |
| PIRA 1000 | torsion pendulum inertia | 1Q10.20 | |
| TPT 21(7),456 | torsion pendulum inertia | 1Q10.20 | The period of a torsion pendulum is used to determine moment of inertia. Tinker toys allow one to easily construct objects with the same mass but different moments of inertia. Many variations are presented. |
| Mei, 12-3.10 | torsion pendulum inertia | 1Q10.20 | Objects are placed on a trifilar supported torsional pendulum. |
| Mei, 12-3.9 | torsion pendulum inertia | 1Q10.20 | Objects are added symmetrically about the torsional pendulum axis. |
| Sut, M-167 | torsion pendulum inertia | 1Q10.20 | Use the torsion pendulum to determine the moment of inertia. |
| Mei, 11-2.3c | air bearing inertia | 1Q10.25 | Determine the ellipsoids of inertia of a rectangular steel bar with the air bearing supported rotating disc. |
| Mei, 11-2.3g | air bearing inertia | 1Q10.25 | A steel triangle is dropped on an air bearing supported rotating disc. |
| Mei, 11-2.3b | air bearing inertia | 1Q10.25 | Various objects are placed on an air bearing supported rotating disc. |
| PIRA 200 | ring, disc, and sphere | 1Q10.30 | A ring, disc, and sphere of the same diameter are rolled down an incline. |
| UMN, 1Q10.30 | ring, disc, and sphere | 1Q10.30 | A ring, disc, and sphere of the same diameter are rolled down an incline. |
| F&A, Ms-3 | ring, disc, and sphere | 1Q10.30 | Rings, discs, and spheres are rolled down an incline. |
| D&R, M-678 | ring, disc, and sphere | 1Q10.30 | Rings, discs, and spheres are rolled down an incline. |
| Sprott, 1.9 | ring, disc, and sphere | 1Q10.30 | Roll cylinders, hollow spheres, balls, hoops, full cans of soda, etc. down an inclined plane. |
| Bil&Mai, p 164 | ring, disc, and sphere | 1Q10.30 | A ring, disc, and sphere of the same diameter are rolled down an incline. |
| PIRA 1000 | rolling bodies on incline | 1Q10.31 | |
| Disc 06-04 | rolling bodies on incline | 1Q10.31 | Rings, discs, spheres, and weighted discs are rolled down an incline. |
| Hil, M-19c | ring, disc | 1Q10.32 | Disc and ring on the incline plane. |
| PIRA 500 | all discs roll the same | 1Q10.35 | |
| UMN, 1Q10.35 | all discs roll the same | 1Q10.35 | A set of discs of different diameters are rolled down an incline. Also use hoops and spheres. |

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| AJP 73(10), 909 | rolling can lab | 1Q10.37 | How a non-axisymmetric distribution of mass may give a faster rolling can. |
| TPT 18(8),600 | coffee can lab | 1Q10.37 | Rolling an empty coffee can down an incline. A student lab with many tasks. |
| PIRA 500 | racing discs | 1Q10.40 | |
| UMN, 1Q10.40 | racing discs | 1Q10.40 | Two discs of identical mass, one weighted in the center and the other weighted at the rim, are rolled down an incline. |
| F&A, Ms-1 | racing discs | 1Q10.40 | Two wooden discs of the same mass and diameter are loaded with lead to give different moments of inertia. Roll on an incline. |
| Sut, M-161 | racing discs | 1Q10.40 | Two equal mass discs are made to race down an incline, one with a lead core and the other with a lead rim. Both are made to roll up a second incline to show they had the same kinetic energy at the bottom. |
| F&A, Ms-4 | moment of inertia spools | 1Q10.41 | Aluminum wheels are joined by two brass cylinders that can be placed at different radii to change the moment of inertia. |
| PIRA 500 | racing soups | 1Q10.50 | |
| TPT 16(8),553 | racing soups | 1Q10.50 | Racing two soups first down an incline and then down and across the floor. Betting is used to make the demonstration more exciting. |
| D&R, M-682 | racing soups | 1Q10.50 | Two soup cans race down an incline. One is filled with mainly liquid and the other with mainly solid food. |
| Sut, M-162 | winning ball | 1Q10.51 | Use mercury filled rollers for sure winners. |
| PIRA 1000 | weary roller | 1Q10.55 | |
| Sut, M-163 | weary roller | 1Q10.55 | Load a roller with fine dry sand or powdered tungsten. |
| Sut, M-60 | viscosity | 1Q10.56 | A raw egg in a torsion pendulum damps more quickly than a boiled egg due to internal friction. Also spinning eggs - angular momentum. |
| AJP 34(2),xv | moment of inertia of a ball | 1Q10.65 | An air spinner for a 2" bronze ball and a method of mapping out the three axes of moment of inertia. |
| TPT 20(1),50 | errant pool balls | 1Q10.66 | Directions for making several different types of weird acting pool balls. |
| PIRA 1000 | rigid and non-rigid rollers | 1Q10.70 | |
| F&A, Mz-3 | rigid and non-rigid rotations | 1Q10.70 | Lead rings, the masses of a torsion pendulum, can be either locked or freed to show terms in Steiner's equation. |
| Mei, 12-3.6 | rigid and non-rigid rotators | 1Q10.70 | Two lead rings are mounted as a torsion pendulum with rotational axes parallel to the pendulum. The period is measured with the rings freed and locked. |
| Mei, 12-3.5 | rigid and non-rigid rotations | 1Q10.70 | Two masses on a horizontal bar fixed to a vertical shaft are spun by a falling weight. The masses can be locked or freed to rotate in the same plane as the vertical shaft. |
| Mei, 12-3.7 | Steiner's theorem | 1Q10.71 | An adjustable double dumbbell on a rotating bar arrangement. |
| Mei, 12-3.11 | parallel axis wheels | 1Q10.75 | The period of a bicycle wheel suspended as a pendulum is measured with the wheel spinning and locked. |
| | **Rotational Energy** | **1Q20.00** | |
| PIRA 200 | whirlybird (adjustable angular momentum) | 1Q20.10 | A weight on a string wrapped around a wheel drives a radial rod with adjustable weights. |
| UMN, 1Q20.10 | adjustable angular momentum | 1Q20.10 | A weight on a string wrapped around a wheel drives a radial rod with adjustable weights. |
| F&A, Mr-5 | adjustable angular momentum | 1Q20.10 | A weight wrapped around a wheel drives a radial bar with adjustable weights. |
| Mei, 12-4.5 | adjustable angular momentum | 1Q20.10 | Hanging weights from three coaxial pulleys provides different applied torques to a radial bar with movable weights to provide adjustable moment of inertia. |
| Sut, M-166 | adjustable amgular momentum | 1Q20.10 | Two equal masses are mounted on a radial bar fixed to a horizontal axle with a pulley. |
| D&R, M-650 | adjustable angular momentum | 1Q20.10 | A weight on a string wrapped around a one of two pulleys drives radial bars with movable weights. |
| Disc 06-01 | angular acceleration machine | 1Q20.10 | A weight over a pulley turns a bar with adjustable weights. On screen timer and protractor helps measurements. |
| Mei, 13-2.1 | adjustable angular momentum | 1Q20.12 | Hang various weights from the axle of a large wheel and time the fall. |
| AJP 33(10),848 | adjustable angular momemtum | 1Q20.13 | A horizontal bar mounted at its midpoint on a turntable has pegs for mounting weights at various distances, and is accelerated by a string to falling mass. |
| Mei, 11-2.3e | adjustable angular momentum | 1Q20.14 | Spin the air bearing supported rotatable disc with a mass hanging on a string. |
| PIRA 1000 | flywheel and drum with weight | 1Q20.15 | |
| Mei, 12-4.7 | adjustable angular momentum | 1Q20.17 | A falling weight on a string wrapped around a spindle spins a variety of objects to show Newton's second law for angular motion. |
| PIRA 1000 | angular acceleration wheel | 1Q20.20 | |

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| UMN, 1Q20.20 | angular acceleration wheel | 1Q20.20 | Measure the acceleration of a bike wheel with a mass on a string wrapped around the axle. |
| Mei, 12-4.6 | bike wheel angular acceleration | 1Q20.20 | Measure the angular acceleration of a bike wheel due to the applied torque of a mass on a string wrapped around the axle. |
| Disc 06-02 | bike wheel angular acceleration | 1Q20.20 | Use a spring scale to apply a constant torque to a bike wheel and measure the angular acceleration. |
| PIRA 1000 | accelerate light and heavy pulleys | 1Q20.25 | |
| UMN, 1Q20.25 | accelerate light and heavy pulleys | 1Q20.25 | |
| Hil, M-15f.2 | angular acceleration | 1Q20.26 | Use strobe photography to record the motion of a large disc accelerated by a mass on a string over a pulley. |
| Mei, 10-2.6 | rotating dry ice puck | 1Q20.27 | A dropping mass on a string wrapped around a massive dry ice puck gives both linear and angular acceleration. |
| Mei, 10-2.7 | rotational dynamics | 1Q20.28 | A dry ice puck with strings wrapped around two different radii going to equal masses hanging on opposite end of the table is stationary while a piece of masking tape is placed over one winding. Remove the tape and the puck spins and translates. |
| PIRA 500 | rolling spool | 1Q20.30 | |
| UMN, 1Q20.30 | rolling spool | 1Q20.30 | A spool rolled down an incline on its axle and takes off when it reaches the bottom and rolls on its rim. |
| TPT 10(4),210 | rolling spool | 1Q20.30 | A large version of the rolling spool (16" dia.) is used as a lab. Construction hints and complete analysis. |
| F&A, Mr-4 | rolling spool | 1Q20.30 | A large spool is rolled down an incline on its small axle. When the outer discs reach the table, the thing takes off. |
| Sut, M-165 | rolling spool | 1Q20.30 | A spools rolls down a narrow incline on its axle. When it reaches the bottom, it rolls on the diameter of the outer discs. |
| Disc 06-05 | spool on incline | 1Q20.30 | A spool rolls down an incline on its central radius. |
| Mei, 9-4.15 | rolling spool | 1Q20.31 | Place the rolling spool demonstration on a low friction sheet to show conservation of linear momentum as the sheet moves backward when the roller hits bottom. |
| PIRA 1000 | bike wheel on incline | 1Q20.35 | |
| UMN, 1Q20.35 | bike wheel on incline | 1Q20.35 | A bike wheel rolls down an incline on its axle with the axle pinned to the wheel or free. |
| Disc 06-06 | bike wheel on incline | 1Q20.35 | A bike wheel rolls down an incline on its axle. The wheel can be pinned to the axle. |
| Mei, 12-5.6 | rolling up an incline | 1Q20.41 | A roller is timed as it rolls up an incline under the constant torque produced by a cord wrapped around over a pulley to a hanging mass. |
| Mei, 17-3.2 | start a wheel | 1Q20.42 | Use a large DC motor and a large wheel to show the angular acceleration of a rotating body with a constant driving torque. Picture. Diagram. |
| AJP 47(4),367 | rolling pendulum | 1Q20.44 | A spherical bob can roll on a track of the same arc as its swing when suspended by a cord. Comparison of the motion in the two cases shows the effect of the rotational motion in rolling. |
| AJP 46(3),300 | radius of gyration (Here?) | 1Q20.46 | Slide an air cart down an inclined instrumented air track, then add a wood track and roll a ball down the same incline. |
| D&R, M-684 | rotational translation | 1Q20.46 | Two identical rolls of toilet paper. Drop one so it does not unroll simultaneously with dropping the other while continuing to hold onto the end so that it unrolls as it falls. One is the motion of a rigid body in free fall the other is rotation about the center of mass while falling. |
| AJP 28(4),405 | spin a swing | 1Q20.47 | Wind up two balls on strings from a common support with a slack connecting string between them. As they unwind, the angular velocity decreases until the connecting string becomes taut, then increases. Ref: AJP 27, 611 (1959) |
| PIRA 500 | faster than "g" | 1Q20.50 | |
| UMN, 1Q20.50 | faster than "g" | 1Q20.50 | A ball jumps from the end of a hinged stick into a cup as the stick rotates. |
| AJP 52(12),1142 | faster then gravity | 1Q20.50 | A ball at the end of a falling stick jumps into a cup. |
| AJP 74(1), 82 | falling chimney | 1Q20.50 | Comments on AJP 71(10), 1025. |
| AJP 71(10), 1025 | falling chimney | 1Q20.50 | Small scale toy models are used to reproduce the dynamics of the falling chimney. |
| F&A, My-6 | falling chimney | 1Q20.50 | A hinged incline with a ball on the end jumps into a cup a few inches down the board as the incline drops. |
| Sut, M-206 | falling chimney | 1Q20.50 | Diagram. Ball on the end of a falling stick jumps into a cup attached near the end of the stick. |
| Hil, M-19k | falling chimney | 1Q20.50 | A ball on the end of a pivoting stick jumps into a cup. Includes TPT 3(7),323. |
| D&R, M-104 | falling chimney | 1Q20.50 | A ball at the end of a hinged stick falls into a cup mounted on the stick. |

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| Bil&Mai, p 157 | falling chimney | 1Q20.50 | A ball on the end of a pivoting stick jumps into a cup mounted on the stick. |
| Disc 06-11 | hinged stick and ball | 1Q20.50 | A ball at the end of a hinged stick falls into a cup mounted on the stick. |
| PIRA 1000 | bowling ball faster than "g" | 1Q20.51 | |
| UMN, 1Q20.51 | bowling ball faster than "g" | 1Q20.51 | A bowling ball at the end of ten foot ladder jumps into a five gallon pail. |
| AJP 41(8),1013 | faster than "g" - add mass | 1Q20.52 | Analysis of adding mass to the plank. |
| TPT 20(2),100 | falling chimney | 1Q20.52 | Use of a triangular board to increase R/I for the board. Analysis included. |
| TPT 13(7),435 | falling chimmey | 1Q20.52 | A mass can be added to the end of the bar to slow it down causing the ball to miss the cup. |
| Mei, 9-2.5 | falling chimney | 1Q20.53 | Hinged beam falls with paint brushes at and off the center of mass record the motion of the two points. |
| AJP 56(8),736 | "faster than g" revisited | 1Q20.54 | An analysis three cases, one in which the particle catches up with the rod. |
| TPT 3(7),323 | free fall paradox | 1Q20.54 | Short derivation of the "faster than g" demonstration. |
| PIRA 1000 | pennies on a meter stick | 1Q20.55 | |
| UMN, 1Q20.55 | pennies on a meter stick | 1Q20.55 | Line a meter stick with pennies and drop one end with the other hinged. Happens to fast to see well. Use with the video. |
| F&A, Mw-2 | pennies on a meter stick | 1Q20.55 | A meter stick is loaded with pennies and held horizontally, then released at one end. Pennies on the first 2/3 stay with the stick. |
| Disc 06-10 | penny drop stick | 1Q20.55 | A horizontal meter stick, hinged at one end, is loaded with pennies and released. |
| PIRA 1000 | falling meter sticks - scaling | 1Q20.60 | |
| UMN, 1Q20.60 | falling meter sticks - scaling | 1Q20.60 | Compare the rate of fall of one meter and two meter sticks. |
| | **Transfer of Angular Momentum** | **1Q30.00** | |
| PIRA 200 | passing the wheel | 1Q30.10 | Pass a bicycle wheel back and forth to a person on a rotating stool. |
| UMN, 1Q30.10 | passing the wheel | 1Q30.10 | A bicycle wheel is passed back and forth to a person on a rotating stool. |
| Sut, M-179 | passing the wheel | 1Q30.10 | The lecturer on a rotating stool passes a spinning bike wheel back and forth to an assistant while turning it over. |
| PIRA 1000 | pass bags o' rice | 1Q30.15 | |
| UMN, 1Q30.15 | pass bags o' rice | 1Q30.15 | |
| PIRA 500 | drop bags o' rice | 1Q30.20 | |
| UMN, 1Q30.20 | bags o' rice | 1Q30.20 | A person on a rotating stool holds out 10 lb bags of rice and drops them. |
| PIRA 1000 | satellite de rotator | 1Q30.25 | |
| UMN, 1Q30.25 | satellite derotator | 1Q30.25 | Same a disc 07-09. |
| Mei, 13-7.1 | de-spin device | 1Q30.25 | Two heavy weights on cables are released from a vertically spinning disc to slow the system by conservation of angular momentum. |
| Mei, 13-7.2 | de-spin device | 1Q30.25 | A mass flies out on a string satellite de-spin device with derivation of proper dimensions and weights. |
| Disc 07-09 | satellite derotator | 1Q30.25 | Heavy weights fly off a rotating disc carrying away angular momentum. |
| PIRA 1000 | catch the bag on the stool | 1Q30.30 | |
| UMN, 1Q30.30 | catch the bag on the stool | 1Q30.30 | Sit on the rotating stool and catch a heavy ball at arms length. |
| F&A, Mt-7 | catch the bag on the stool | 1Q30.30 | Throw or catch a bag of lead shot off axis while sitting on a rotating platform. |
| Sut, M-180 | catch the ball on the stool | 1Q30.30 | Baseballs or billiard balls may be thrown or caught at an arm's length by a demonstrator on a rotating stool. |
| Mei, 11-2.3d | catch the ball on the stool | 1Q30.31 | Roll a ball down an incline and catch it off axis on the air bearing supported rotating disc. |
| TPT, 37(3), 169 | demonstrating angular momentum conservation | 1Q30.32 | Using a homemade set-up with smart pulleys, angular momentum conservation is explored quantitatively. |
| AJP 31(2),91 | shoot ball at a shaft | 1Q30.33 | Shoot a steel ball at a catcher on the end of an arm that rotates. |
| AJP 33(8),iii | catch a ball on a rotating bar | 1Q30.34 | Roll a ball down an incline and catch it on the end of a modified Welch Centripetal Force Apparatus (No. 930) Similar to AJP 31,91 (1963). |
| Mei, 11-2.3a | drop disc on rotating disc | 1Q30.40 | A second disc is dropped on an air bearing supported rotating disc. Spark timer recording. |
| TPT 22(6),391 | spinning funnel | 1Q30.50 | A funnel filled with sand spins faster as the sand runs out. |
| TPT 22(9),554 | spinning funnel | 1Q30.50 | A letter about TPT 22(6),391, "Demonstrating conservation of angular momentum". |
| TPT 11(5),303 | stick-propeller device | 1Q30.90 | The stick-propeller device appears to produce angular momentum from nowhere. |
| | **Conservation of Angular Momentum** | **1Q40.00** | |
| PIRA 200 | rotating stool and weights | 1Q40.10 | Spin on a rotating stool with a dumbell in each hand. |
| UMN, 1Q40.10 | rotating stool and dumbells | 1Q40.10 | A person on a rotating stool moves dumbbells out and in. |
| F&A, Mt-2 | rotating stool and dumbells | 1Q40.10 | Instructor stands on a rotating platform with a heavy dumbbell in each hand. |
| Sut, M-176 | rotating stool and dumbells | 1Q40.10 | Extend and retract your arms while rotating on a stool. |

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| Hil, M-19i | rotating stool and dumbells | 1Q40.10 | Spin on a rotating stool with a dumbbell in each hand. |
| D&R, M-764 | rotating stool and dumbbells | 1Q40.10 | A person sits on a rotating stool with dumbbells in outstretched hands, moving them in and then out. |
| Bil&Mai, p 166 | rotating stool and dumbbells | 1Q40.10 | Make a rotating platform with a Lazy Susan and some plywood. A student spins on the rotating platform with a dumbbell in each hand. |
| Disc 07-04 | rotating stool with weights | 1Q40.10 | A person sits on a rotating stool and moves weights in and out. |
| AJP 45(7),636 | big rotating stool and dumbells | 1Q40.11 | A cable pulley system moves large masses from 60 to 180 cm. |
| AJP 30(7),528 | rotating platform and dumbells | 1Q40.12 | Make a rotating platform out of two disks of 3/4" plywood and a large diameter thrust bearing. |
| Mei, 13-7.9 | rotating stool | 1Q40.13 | Rotating platform made out of an auto front wheel bearing. |
| PIRA 500 | rotating stool and long bar | 1Q40.15 | |
| UMN, 1Q40.15 | rotating stool and long bar | 1Q40.15 | Sit on a rotating stool holding a long bar with masses at the ends. Rotate the bar one way and you turn the other way. |
| Disc 07-05 | rotating stool and long bar | 1Q40.15 | Sit on the stool and hold a long bar with weights on the ends. Rotate the bar and you will move in the opposite sense. |
| F&A, Mt-3 | rotating stool and bat | 1Q40.16 | Stand on a rotating platform and swing a bat. |
| Sut, M-172 | rotating stool and bat | 1Q40.16 | Stand on a rotating stool and swing a baseball bat. |
| PIRA 500 | squeezatron | 1Q40.20 | |
| UMN, 1Q40.20 | squeezatron | 1Q40.20 | A flyball governor can be expanded or contracted by squeezing a handle. |
| AJP 33(4),345 | rotating adjustable balls | 1Q40.20 | Plans for a two ball adjustable governor type conservation apparatus. |
| F&A, Mt-1 | squeezatron | 1Q40.20 | A flyball governor can be expanded or contracted by a squeeze handle. |
| Mei, 13-7.13 | squeezatron | 1Q40.20 | Pulling a string decreases the radius of two masses rotating at the ends of a rod. |
| Sut, M-177 | squeezatron | 1Q40.20 | A mechanical device for showing the pirouette effect. |
| Mei, 10-2.9 | dry ice puck rotators | 1Q40.21 | Two dry ice puck rotators: a) steel balls separate, b) they come together. |
| PIRA 200 | rotating Hoberman sphere | 1Q40.22 | Connect a ball bearing fishing swivel to a Hoberman Sphere mobile. Spin the mobile and pull the string. The sphere will spin faster when it collapses. |
| PIRA 1000 | centrifugal governor | 1Q40.23 | |
| F&A, Mm-4c | governors | 1Q40.23 | A small governor is spun on a hand crank rotator. |
| Sut, M-158 | Watt's regulator | 1Q40.23 | Use a model of Watt's regulator. |
| Hil, M-16f | govenors | 1Q40.23 | The Cenco Watt's governor shown with a valve regulating gear. |
| Disc 05-26 | centrifugal governor | 1Q40.23 | A model of a governor. |
| PIRA 1000 | pulling on the whirligig | 1Q40.25 | |
| UMN, 1Q40.25 | pulling on the whirligig | 1Q40.25 | Pull on the bottom ball of the whirligig. |
| F&A, Ms-5 | pulling on the whirligig | 1Q40.25 | Balls are attached to either ends of a string that passes through a hollow tube. Set one ball twirling and pull on the other ball to change the radius. |
| Mei, 13-7.6 | pulling on the whirligig | 1Q40.25 | Shorten the string of a rotating ball on a string. |
| Sut, M-186 | pulling on the whirligig | 1Q40.26 | A ball on a string rolls on the lecture table. In one case the cord wraps itself around a vertical rod. In the other, the cord is pulled through a hole in the table. |
| PIRA 200 | rotating stool and bicycle wheel | 1Q40.30 | Invert a spinning bike wheel while sitting on a rotating stool. |
| UMN, 1Q40.30 | rotating stool and bicycle wheel | 1Q40.30 | A person sits on a rotating stool, spins a bicycle wheel and turns it over and back. |
| F&A, Mu-1 | rotating stool and bicycle wheel | 1Q40.30 | Inverting a spinning bicycle wheel while on a rotating stool, passing it back and forth. |
| Sut, M-178 | rotating stool and bicycle wheel | 1Q40.30 | Spin and turn a bike wheel while on a rotating stool. |
| D&R, M-764 | rotating stool and bicycle wheel | 1Q40.30 | A person sits on a rotating stool, spins a bicycle wheel, and turns it over and back. |
| Sprott, 1.16 | rotating stool and bicycle wheel | 1Q40.30 | A spinning bicycle wheel with handles is inverted while sitting on a rotating platform. |
| Disc 07-06 | rotating stool and bicycle wheel | 1Q40.30 | Invert a spinning bike wheel while sitting on a rotating stool. |
| AJP 35(3),286 | stool, bicycle wheel, and friction | 1Q40.31 | Slow down the bike wheel deliberately to emphasize the role of friction in transfer of momentum. |
| Hil, M-19f | rotating stool and bicycle wheel | 1Q40.32 | Wrap the bicycle wheel with no. 9 iron wire. |
| Sut, M-175 | drop the cat | 1Q40.33 | Turn yourself around on a rotating stool by variation of moment of inertia. Also, make a model of a cat. |
| D&R, M-800 | drop the cat | 1Q40.33 | Analysis of a dropped cat landing on its feet. |
| TPT 11(7),415 | skiing | 1Q40.34 | Go skiing while holding a bike wheel gyro. By conservation of angular momentum, turn yourself with the gyro. |
| Mei, 13-7.7 | skiing | 1Q40.34 | Stand on a rotating turntable with skies on to show the upper part of the body turning opposite the lower. |
| PIRA 1000 | train on a circular track | 1Q40.40 | |
| UMN, 1Q40.40 | train on a circular track | 1Q40.40 | A HO gage train runs on a track mounted on a bike rim. |
| F&A, Mt-4 | angular momentum train | 1Q40.40 | A circular track on a rotating platform and a train have the same mass. The train and track move in opposite directions. |

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| Hil, M-8b | angular momentum train | 1Q40.40 | A train on a rotating platform. |
| Disc 07-02 | train on a circular track | 1Q40.40 | A wind up train rides on a track mounted on the rim of a horizontal bicycle wheel. |
| AJP 41(1),137 | angular momentum train - air table | 1Q40.41 | The circular track is mounted on a large air table puck. |
| Sut, M-185 | frictional transfer of ang. momemtum | 1Q40.42 | Diagram. A balanced framework constrains a spinning wheel. As the wheel slows down, the framework begins to rotate. |
| Sut, M-174 | coupled windmills | 1Q40.43 | Picture. Two angular momentum machines (M-166) are coupled by a spring. The spring is wound and both are released simultaneously to show opposite reactions. |
| AJP 44(1),21 | counter spinning | 1Q40.44 | An induction motor is mounted so both the frame and armature can rotate freely. No torque is required to tilt the direction of axis of rotation unless either the frame or armature is constrained. |
| D&R, M-768 | counter spinning | 1Q40.44 | A motor is placed on a lazy susan with rotation axes aligned. Turn on the motor and observe the motor and lazy susan rotate in opposite directions. Repeat with motor shaft displaced from lazy susan axis. |
| PIRA 1000 | wheel and brake | 1Q40.45 | |
| AJP 57(10),951 | noncoaxial rotating disks | 1Q40.45 | A battery driven turntable rotates noncoaxially on a frictionless turntable. |
| Disc 07-08 | wheel and brake | 1Q40.45 | A horizontal rotating bicycle wheel is braked to a large frame and the combined assembly rotates slower. |
| PIRA 1000 | pocket watch | 1Q40.50 | |
| Mei, 13-7.8 | pocket watch | 1Q40.50 | A small pendulum is suspended from the stem of a pocket watch placed on a small watch glass on a stand. |
| Sut, M-173 | pocket watch | 1Q40.50 | Suspend a pocket watch by its ring from a sharp edge. |
| D&R, M-772 | pocket watch | 1Q40.50 | Movement of a pocket watch balanced on an inverted watch glass is magnified with a laser and small mirror. |
| Disc 07-03 | tail wags dog | 1Q40.50 | Use a laser to magnify the motion of a pocket watch. |
| Mei, 13-7.4 | various demos | 1Q40.52 | You read this one. (If you aren't into Phil Johnson's humor it becomes: A simple mechanical system whose momentum is partly angular and partly linear). |
| Mei, 13-7.3 | various demos - angular momentum conservation | 1Q40.53 | A pie plate or disk suspended by three threads. At its center is attached a screw that allows a weight on ball bearings to descend and touch the plate. If the plate is rotated the proper number of turns before the weight is released, the whole system comes to a stop when the weight meets the plate. |
| Mei, 13-7.5 | various demos | 1Q40.53 | A free system of two discs, one attached to a motor shaft and the other to the motor, is powered through slip rings. Show the discs rotate in opposite directions and come to rest at the same time. |
| AJP 31(1),42 | orbital angular momentum | 1Q40.54 | Apparatus Drawings Project No.33: A dumbbell pivoting on its center of mass, on a counterweighted rod rotated about its center of mass, remains oriented in the original direction until friction prevails. |
| F&A, Mt-5 | buzz button | 1Q40.55 | Pull on a twisted loop of string threaded through a large button to get the thing to oscillate. |
| Sut, M-171 | buzz button | 1Q40.55 | A 6" wooden disc supported by a loop of string passing through two holes drilled 1/2" apart. Directions for showing constancy of axes. |
| Mei, 10-3.3 | colliding air pucks | 1Q40.57 | The linear and angular momentum are recorded with strobed photography. The pucks have an arrow to indicate rotation. |
| Mei, 10-2.11 | colliding spinning orbiting pucks | 1Q40.59 | One massive dry ice puck contains a motorized windlass that winds up a connecting string, the other has the string wound around it. One orbits, the other spins and when the come together they stop dead. |
| PIRA 1000 | sewer pipe pull | 1Q40.60 | |
| UMN, 1Q40.60 | sewer pipe pull | 1Q40.60 | Put "o" rings around a section of large PVC pipe to act as tires. Place on a sheet of paper and pull the paper out from under it. |
| AJP 54(8),741 | sewer pipe pull | 1Q40.60 | A newspaper is pulled out from under a large sewer pipe with O ring tires. When the paper is all the way out, the pipe stops dead. |
| Mei, 13-7.10 | various demos | 1Q40.60 | Pull a strip of paper horizontally from under a rubber ball. As soon as the ball is off the strip, it stops dead. |
| AJP 28(1),76 | off-center flywheel | 1Q40.63 | A flat plate is free to rotate on a block of dry ice. The plate rotates about its center of mass when the flywheel at one end slows down. |
| AJP 53(8),735 | double flywheel rotator | 1Q40.65 | Two flywheels free to rotate about a vertical axis on a bar which is also free to rotate about a vertical axis are coupled in various ways to demonstrate "spin-spin" and "spin-orbit" coupling with and without dissipation. |
| PIRA 1000 | marbles and funnel | 1Q40.70 | |
| Disc 07-01 | marbles and funnel | 1Q40.70 | The angular speed of marbles increases as they approach the bottom of a large funnel. |

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| PIRA 1000 | Hero's engine | 1Q40.80 | |
| UMN, 1Q40.80 | Hero's engine | 1Q40.80 | Similar to disc 15-07. |
| AJP 46(7),773 | Hero's engine | 1Q40.80 | Plans for a machine shop built Hero's engine. |
| F&A, Hn-5 | Hero's engine | 1Q40.80 | A model of Hero's engine. |
| Mei, 13-7.11 | Hero's engine | 1Q40.80 | A simple Hero's engine made of a tin can. |
| Sut, M-183 | Hero's engine | 1Q40.80 | Cylindrical boiler pivots on a vertical axis with tangential pressure relief nozzles. |
| Hil, H-5a.1 | Hero's engine | 1Q40.80 | A suspended round bottom flask with two nozzles. |
| Sprott, 2.5 | Hero's engine | 1Q40.80 | A steam engine that spins when heated. |
| Disc 15-07 | Hero's engine | 1Q40.80 | The flask rotates on a horizontal axis. |
| F&A, Mt-6 | Hero's engine - sprinkler | 1Q40.81 | A lawn sprinkler. |
| Sut, M-184 | Hero's engine - sprinkler | 1Q40.81 | A gravity head of water is used to drive a Hero's engine device (lawn sprinkler). |
| Sprott, 1.13 | Hero's engine - sprinkler | 1Q40.81 | A lawn sprinkler powered by air. |
| PIRA 1000 | air rotator with deflectors | 1Q40.82 | |
| Disc 06-03 | air rotator with deflectors | 1Q40.82 | Run an air sprinkler, then mount deflectors to reverse the jet. |
| AJP 57(7),654 | the Feynman inverse sprinkler | 1Q40.85 | A demonstration showing the inverse sprinkler moves in a direction opposite to that of a normal sprinkler. |
| AJP 59(4),349 | inverse sprinkler - kinematic study | 1Q40.85 | An extension of the AJP 57(7) article. |
| AJP 58(4),352 | the sprinkler problem | 1Q40.85 | A design for the sprinkler/inverse sprinkler and a lot of analysis. |
| Mei, 13-7.12 | Hero's engine | 1Q40.86 | Place an air jet Hero's engine in a bell jar and pump out some air. |
| AJP 56(4),307 | inverse sprinkler demonstration | 1Q40.87 | An inverse sprinkler made of soda straw in a carboy exhibits no motion. |
| AJP 54(9),798 | inverse sprinkler - no rotation | 1Q40.88 | A conservation of angular momentum argument is invoked to show that no rotation will result in an inverse sprinkler. |
| AJP 55(6),488 | inverse sprinkler | 1Q40.88 | A letter full of opinions. |
| AJP 55(6),488 | inverse sprinkler letter reply | 1Q40.88 | The writer of the previous letter has comments "drawn from thin air", not unlike most of these little blurbs. |
| | **Gyros** | **1Q50.00** | |
| AJP 43(4),365 | elementary explanation | 1Q50.01 | Precession explained using only Newton's laws. |
| AJP 47(4),346 | behavior of a real top | 1Q50.01 | Analysis of the behavior of a real top with a round end spinning on a surface with friction. |
| AJP 45(11),1107 | analysis | 1Q50.01 | An elementary discussion of the gyroscope is presented. It is based on conservation of angular momentum and energy and does not require calculus. |
| AJP 29(8),550 | elementary analysis comment | 1Q50.01 | Comment on AJP 28(9),808. |
| AJP 57(5),428 | explaining top nutation | 1Q50.01 | The stability of torque-free rotations and top nutation without sophisticated mathematics. |
| AJP 45(12),1194 | physical explanation | 1Q50.01 | Consider the rotation of two equal masses mounted on a frame of negligible mass. Also note that the mathematical simplification made in the study of rigid-body motion often tend to obscure what is happening. |
| AJP 28(9),808 | elementary analysis | 1Q50.01 | One approach to explaining the gyroscope in language familiar to the student. |
| TPT 20(1),34 | physical explanation | 1Q50.01 | Precession explained qualitatively without recourse to right-hand rules, torques, etc. A train track displacement demo is presented as an analog. |
| TPT 18(3),210 | physical explanation | 1Q50.01 | A simple physical explanation of precession. |
| PIRA 200 - Old | precessing disc | 1Q50.10 | Spin a cardboard disc on a pencil inserted in a hole at the center and touch a finger to the rim. |
| UMN, 1Q50.10 | precessing disc | 1Q50.10 | A phonograph record (or aluminum disc) is spun on a nail at the end of a wood dowel. Have the class predict which way the record will turn when touched with a finger. |
| AJP 28(5),504 | cardboard precession | 1Q50.10 | Spin a cardboard disc on a pencil inserted in a hole in the center and touch a finger to the rim. |
| F&A, Mu-7 | precessing disc | 1Q50.10 | A 6" aluminum disc on a long axial rod is hand spun to show precession due to gravitational torque. |
| Mei, 13-5.14 | phonograph record | 1Q50.10 | A wood bar spinning in a horizontal plane on a pivot is tapped and the plane of rotation tips. |
| Hil, M-19h | phonograph record | 1Q50.10 | Spin a cardboard disc on a nail driven into the center into the end of a stick. Place a finger on the disc to cause it to precess. |
| PIRA 200 - Old | bicycle wheel gyro | 1Q50.20 | Spin a bicycle wheel mounted on a long axle with adjustable counterbalance. |
| UMN, 1Q50.20 | bicycle wheel gyro | 1Q50.20 | A small weighted bicycle wheel is mounted at the end of a long axle pivoted in the middle with an adjustable counterweight. |
| AJP 31(5),393 | bicycle wheel gyro | 1Q50.20 | The counterbalanced bicycle wheel gyro with clip-on vector arrows for the angular momentum and torque vectors. |
| TPT 21(5),332 | bicycle wheel gyro | 1Q50.20 | Spinning bike wheel mounted on an adjustable counterbalanced axle. |

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| F&A, Mu-2 | bicycle wheel gyro | 1Q50.20 | A bicycle wheel is mounted on a long axle with adjustable counterbalance. |
| Mei, 13-5.2 | bicycle gyro | 1Q50.20 | Drawings for making a very nice gyro out of a 24" bike wheel. |
| Mei, 13-5.5 | bicycle wheel gyro | 1Q50.20 | Weigh one end of a bike wheel gyro axle while the gyro is hanging vertically, spinning while supported horizontally, and precessing about the scale. |
| Hil, M-19g | bicycle wheel gyro | 1Q50.20 | A bicycle wheel gyro with a slightly different setup. |
| Disc 07-11 | gyro with adjustable weights | 1Q50.20 | A small gyro is at the end of a pivoting rod with an adjustable counterweight. |
| PIRA 1000 | bike wheel on gimbals | 1Q50.21 | |
| Sut, M-187 | bicycle wheel gyro | 1Q50.21 | A spinning bike wheel with two handles is supported by a loop of string around one of the handles. Counterweights may be applied. |
| Sprott, 1.16 | bicycle wheel gyroscope | 1Q50.21 | A spinning bicycle wheel is attached to a wire and suspended from a support. |
| AJP 30(7),528 | suspended bike wheel | 1Q50.22 | A ball at one end of a bike wheel axle is placed into a socket on a bearing for demonstrating precession and nutation on a large scale. |
| Mei, 13-5.1 | bike wheel turnaround | 1Q50.22 | Posts from a rotating platform support both ends of the axle of a bike wheel. One post is hinged so the wheel can be supported from one end only as the platform rotates. |
| Sut, M-189 | suspended bike wheel | 1Q50.22 | A bicycle wheel with handles is supported by loops of string tied to a crossbar that is hung by a single string. Push the ends of the handles horizontally in opposite directions. |
| D&R, M-706 | suspended bike wheel | 1Q50.22 | A spinning bicycle wheel with handles is supported by a loop of string around one of the handles. |
| Disc 07-12 | bike wheels on gimbals | 1Q50.22 | A bicycle wheel on gimbals has a long axle that can be weighted. |
| PIRA 1000 | bike wheel presession | 1Q50.23 | |
| AJP 34(4),xvii | path of a rim point | 1Q50.23 | Photograph a flashing light attached to the rim of a spinning wheel during forced precession. |
| Disc 07-10 | bike wheel precession | 1Q50.23 | A spinning bicycle wheel is supported by a rope at one end of a long axle. |
| PIRA 1000 | walking the wheel | 1Q50.24 | |
| UMN, 1Q50.24 | walking the wheel | 1Q50.24 | A spinning bicycle on a short axle dangles from a string held in the hand. Try to apply a torque that will bring the axle to a horizontal position. |
| F&A, Mu-14 | walking the wheel | 1Q50.24 | A spinning bike wheel is mounted on one end of an axle and the other end has a loop of string. Try to get the bike wheel in the vertical position by applying a torque to the string. |
| PIRA 500 | double bike wheel gyro | 1Q50.25 | |
| UMN, 1Q50.25 | double bike wheel gyro | 1Q50.25 | Two bike wheel are mounted coaxially. Try the standard demos with the wheels rotating in the same direction and in opposite directions. |
| AJP 41(1),131 | double bike wheel gyro | 1Q50.25 | Do the standard single bike wheel demos with two coaxial bike wheels counter rotating. |
| TPT 22(5),324 | double bike wheel gyro | 1Q50.25 | Two bike wheels are mounted on the same axle. The standard demos are done with the wheels rotating in the same and opposite directions. |
| D&R, M-706 | double bike wheel gyro | 1Q50.25 | Two bike wheels are mounted coaxially. Try the standard demos with the wheels rotating in the same and in opposite directions. |
| Disc 07-13 | double bike wheel | 1Q50.25 | The double bike wheel gyro precesses when both wheels rotate in the same direction. Has a nonstandard mount. |
| AJP 46(11),1190 | inverted bike | 1Q50.26 | Three demos involving bike wheel demos, one of which is a double wheel device. |
| PIRA 1000 | MITAC gyro | 1Q50.30 | |
| UMN, 1Q50.30 | MITAC gyro | 1Q50.30 | A commercial motorized gyro on gimbals. |
| AJP 28(1),78 | MITAC gyro | 1Q50.30 | Evaluation of the MITAC gyro. Paint the gimbals as suggested by AJP 14,116 (1946). |
| F&A, Mu-10 | MITAC gyro | 1Q50.30 | A commercially built motorized gyro on a gimbal includes counterweights. |
| D&R, M-710 | MITAC gyro | 1Q50.30 | A commercial motorized gyro on gimbals. |
| Disc 07-14 | motorized gyroscope | 1Q50.30 | A motorized gyro in gimbals. |
| PIRA 1000 | ride a gyro | 1Q50.31 | |
| UMN, 1Q50.31 | ride a gyro | 1Q50.31 | Same as AJP 56(7),657. |
| AJP 56(7),657 | a large gyro | 1Q50.31 | Make a gyro out of an auto wheel and tire. This is big enough to sit on. |
| PIRA 1000 | gyro in gimbals | 1Q50.35 | |
| UMN, 1Q50.35 | gyro in gimbals | 1Q50.35 | Push a cart with a gyro around the room. |
| Sut, M-170 | gyro on turntable | 1Q50.35 | A gyro set in gimbals is carried around. |
| Disc 07-07 | gyroscopic stability | 1Q50.35 | Move a gyro mounted on gimbals. |
| PIRA 1000 | suitcase gyro | 1Q50.40 | |
| UMN, 1Q50.40 | suitcase gyro | 1Q50.40 | Spin up a flywheel hidden in a suitcase and have a student turn around with it. |

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| AJP 34(12),1201 | suitcase gyro | 1Q50.40 | A battery powered motor runs a flywheel in a suitcase. |
| F&A, Mu-4 | suitcase gyro | 1Q50.40 | A large gyro is mounted in a suitcase. |
| F&A, Mu-8 | feel of a gyro | 1Q50.41 | Hold a heavy gyro outfitted with good handles. |
| Hil, M-19a | various gyros | 1Q50.42 | pictures of various gyros. |
| Hil, M-19b.1 | magnetic gyro | 1Q50.43 | Two magnetic gyros. |
| PIRA 500 | air bearing gyro | 1Q50.45 | |
| UMN, 1Q50.45 | air bearing gyro | 1Q50.45 | A large air support for a bowling ball. |
| AJP 33(4),322 | air bearing gyro | 1Q50.45 | Shop drawings and construction hints for making a air bearing for a 4" diameter ball. |
| AJP 28(2),150 | air bearing gyro | 1Q50.45 | Apparatus Drawings Project No.3: Air suspension gyro for a hardened steel ball bearing. Designed for use lab. |
| AJP 32(9),xiii | air bearing gyros | 1Q50.45 | A bowling ball air gyro spins for a half hour when spun by hand. The uneven weight distribution produces precession. Also shows a 4" steel ball bearing air gyro. |
| TPT 11(6),361 | air bearing gyro | 1Q50.45 | Directions for making an air bearing for a bowling ball. |
| Mei, 11-2.2 | air bearing gyro | 1Q50.45 | The air bearing gyro. Construction details in appendix, p. 587. |
| Mei, 13-5.3 | air-bearing gyro | 1Q50.45 | A large air bearing gyro has a long horizontal shaft with arrow heads for visual emphasis. |
| Mei, 13-5.7 | air bearing gyro | 1Q50.45 | Small mirrors on an air bearing gyro are used to demonstrate instantaneous axis of rotation, angular momentum vector, etc. |
| PIRA 200 | precessing gyro | 1Q50.50 | |
| Sut, M-188 | precession with quality gyro | 1Q50.50 | A high quality gyroscope with a counterweight is used to show the fundamental precession equation with fair precision. |
| Mei, 13-5.12 | precession | 1Q50.51 | A model shows precessing axes. |
| F&A, Mu-6 | instantaneous axis | 1Q50.52 | A bicycle wheel is pivoted at the center of mass and has a disc mounted above the wheel in a parallel plane. The instantaneous axis can be seen as the point of no motion on the upper disc. |
| Mei, 13-5.11 | precession of the equinoxes | 1Q50.53 | A rubber band provides a torque to a gyro framework hanging from a string causing precession. |
| AJP 44(7),702 | precessing Earth model | 1Q50.54 | A fairly complex gyroscope. |
| UMN, 1Q50.55 | wobbly Earth | 1Q50.55 | Add abstract in Handbook.FM |
| Mei, 13-5.15 | precessing ball | 1Q50.56 | A ball placed on a rotating table precesses about the vertical axis with a period 7/2 of the table. |
| Mei, 13-5.8 | Kollergang | 1Q50.57 | A device induces precession and change of weight is noted. |
| Mei, 13-5.13 | nutations | 1Q50.58 | A vertical gimbal mounted shaft has a gyro on the bottom end and a light bulb and lens on the top. Nutations of the gyro are shown by the moving spot of light on the ceiling. |
| AJP 42(8),701 | motorcycle as a gyro | 1Q50.59 | The handlebars are twisted (but not moved) in the direction opposite to the turn to lay the machine over. |
| F&A, Mu-9 | tip a bike wheel | 1Q50.59 | A bike wheel on a front fork is hand spun and tipped to one side. |
| PIRA 1000 | gyrocompass | 1Q50.60 | |
| F&A, Mu-5 | gyro on turntable | 1Q50.60 | A gyro in a gimbal sits on a rotating table. Remove the degree of freedom about the vertical axis and the gyro will flip as the table is reversed. |
| Mei, 13-5.6 | 2 degrees of freedom | 1Q50.60 | Spin flip on turning a restricted gyroscope. |
| Sut, M-192 | gyrocompass | 1Q50.60 | A gyroscope in gimbals is deprived of one degree of freedom. A slight change of direction will cause a spin flip. |
| Mei, 13-6.2 | gyrocompass | 1Q50.61 | Shows the origin of the error of an uncorrected gyrocompass. |
| Sut, M-193 | airplane turn indicator | 1Q50.62 | Diagram. Model of an airplane turn indicator in which the gyro precesses about the axis of the fuselage. |
| Mei, 13-6.1 | gyrocompass | 1Q50.63 | A model of a gyrocompass for any latitude on the spinning Earth. |
| PIRA 1000 | stable gyros | 1Q50.70 | |
| F&A, Mu-11 | stable gyros | 1Q50.70 | A gyro on a ladder will become stable when spinning. |
| F&A, Mu-16 | stable gyro car | 1Q50.71 | A spinning gyro mounted on a two wheel cart rides a stretched wire. |
| Sut, M-198 | stable gyro | 1Q50.71 | A very clever gyro "rider" on a model bike. |
| Sut, M-200 | stable gyro monorail car | 1Q50.71 | A monorail car stabilized by a gyro. |
| PIRA 1000 | ship stabilizer | 1Q50.72 | |
| Sut, M-194 | ship stabilizer | 1Q50.72 | Model of a ship stabilizer. |
| Sut, M-196 | ship stabilizer | 1Q50.72 | A large boat model you can sit in with a motor driven gyroscope. |
| Disc 07-18 | ship stabilizer | 1Q50.72 | A motorized gyro is free to turn on a vertical axis when the ship model is rocked. |
| Sut, M-199 | gyro on stilts | 1Q50.73 | A top-heavy gyro on stilts teeters about its position of unstable equilibrium. |
| F&A, Mu-15 | trapeze gyros | 1Q50.74 | A gyro on a trapeze is stable only when spinning. |
| Mei, 13-5.4 | trapeze gyros | 1Q50.74 | Gyro on a trapeze shows stability when there are two degrees of freedom. |
| Sut, M-197 | trapeze gyros | 1Q50.74 | Gyro on a trapeze. |

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| Mei, 13-5.10 | ganged gyros | 1Q50.75 | Ganged gyros are spun in the same or opposite directions. |
| Sut, M-195 | gyro damped pendulum | 1Q50.76 | Picture. Frictional torque can be applied to the precession axis to damp the motion of the pendulum. |
| Sut, M-201 | gyro pendulum | 1Q50.80 | A gyroscope is hung from one end of its spin axle by a string and is swung as a pendulum. |
| F&A, Mu-13 | Maxwell's gyro | 1Q50.90 | The extended shaft of a gyro supported at its center of mass will trace out complex contours. |
| Sut, M-191 | Maxwell's gyro | 1Q50.90 | The spindle of a heavy spinning wheel pivoted at its center of gravity will follow an irregularly shaped object. |
| Sut, M-190 | walking gyro | 1Q50.90 | An apparatus for walking a gyroscope along a cradle. |
| AJP 30(7),503 | air bearing Maxwell's top | 1Q50.95 | Plans for an air bearing Maxwell's top resting on a 2" dia ball with matching air bearing cup with tangential air jets to provide torque. |
| AJP 30(7),528 | gyroscope accelerator | 1Q50.99 | A six inch wheel from a child's wagon in a 1/4" drill is used to spin up a gyroscope. |
| | **Rotational Stability** | **1Q60.00** | |
| PIRA 200 - Old | bicycle wheel top | 1Q60.10 | Extend the axle of a weighted bike wheel and terminate with a rubber ball. |
| UMN, 1Q60.10 | bike wheel top | 1Q60.10 | Extend the axle of a weighted bike wheel and terminate with a rubber ball. |
| PIRA 1000 | humming top | 1Q60.15 | |
| UMN, 1Q60.15 | humming top | 1Q60.15 | The standard toy top that you pump up. |
| TPT 22(1),36 | yo-yo top | 1Q60.15 | Description of an antique toy demonstrating various aspects of rigid body rotational motion. Several pictures should make it possible to duplicate the thing. |
| F&A, Mu-3 | old fashioned top | 1Q60.16 | An old fashioned top that you throw with a string. |
| Mei, 13-5.9 | gyro gun | 1Q60.18 | A shell is spun by hand before being fired by a gun. |
| AJP 70(10), 1025 | Euler's disk | 1Q60.25 | A look at the motion of a spinning disk on a smooth surface. Does the disk slip during its motion. |
| TPT 45(7), 430 | Euler's disk | 1Q60.25 | Non calculus treatment of a spinning disk on a smooth surface. |
| AJP 40(10), 1543 | spinning coin | 1Q60.25 | Understanding the spinning coin by looking at the standard treatment of top motion. |
| AJP 51(5), 449 | spinning coin | 1Q60.25 | An analysis of "wobbling", exhibited by common objects (coins, bottles, plates, etc) when they are spun on horizontal, flat surfaces. The apparatus maintains "wobbling" motion of a metal cylinder, which can be observed in slow motion by means of stroboscopic illumination. |
| AJP 78(5), 467 | spinning tubes - Wobbler | 1Q60.25 | Press the end of a short tube with your finger and then let it slip out. The tube will "wobble" with a stroboscopic rotation. |
| PIRA 500 | tippe top | 1Q60.30 | |
| UMN, 1Q60.30 | tippe top | 1Q60.30 | The tippe top. |
| AJP 28(4),407 | tippe top | 1Q60.30 | A tippe top was spun on smoked glass. Photos show the path of the stem until flip and the soot marks on the top. |
| AJP 68(9), 821 | tippe top | 1Q60.30 | Aspects of motion for the tippe top and other tops with spherical pegs are examined. |
| AJP 70(8), 815 | tippe top | 1Q60.30 | Geometric theory of rapidly spinning tops, tippe tops, and footballs. |
| TPT 16(5),322 | tippe top | 1Q60.30 | A brief review of the history of the tippe top problem. |
| F&A, Mu-17 | tippe top | 1Q60.30 | The tippe top flips when spun. |
| Mei, 13-3.1 | tippe top | 1Q60.30 | Show that the tippe top spins in the opposite of the expected direction when inverted. |
| D&R, M-788 | tippy top | 1Q60.30 | A tippy top or heavy class ring will undergo a 180 degree change of orientation when spun. |
| Disc 07-17 | tippy top | 1Q60.30 | The tippe top flips. |
| AJP 45(1),12 | tippe top analysis | 1Q60.31 | Physical arguments are presented which support the convention that the influence of sliding friction is the key to the understanding of the top's behavior. A rigorous analysis of the top's mechanics is offered, together with computer-generated solutions of the equations of motion. |
| PIRA 500 | spinning football | 1Q60.35 | |
| UMN, 1Q60.35 | spinning football | 1Q60.35 | Spin a football and it raises up on end. |
| AJP 40(9),1338 | spinning football | 1Q60.35 | Spin a football on its side. |
| F&A, Mu-18 | spinning football | 1Q60.35 | Spin a football and it rises onto its pointed end. |
| F&A, Mu-19 | spinning football | 1Q60.35 | An iron slug cut in the shape of a football is put on a magnetic stirrer. |
| D&R, M-788 | spinning football | 1Q60.35 | Spin a football or a panty hose container and they will rise up and spin on the pointed end. |
| Disc 07-16 | football spin | 1Q60.35 | Spin a football on its side and it will rise up on its end. |
| AJP 72(6), 775 | spinning egg | 1Q60.36 | Examines the behavior of spinning eggs and the question of which end will rise. |
| TPT 15(3),188 | spinning L'Eggs | 1Q60.36 | Instead of hard and soft boiled eggs, fill L'Eggs with water, paraffin, or air. Instructions and a little analysis are included. On a separate subject, a hint to use an egg instead of a ball in the floating ball demo. |

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| TPT 9(5),262 | spinning egg | 1Q60.36 | Try the spinning egg demo with eggs boiled for different lengths of time. |
| Sut, M-202 | spinning eggs, etc. | 1Q60.36 | Positional stability of various shaped objects. |
| D&R, M-646 | spinning eggs or L'Eggs | 1Q60.36 | Spin raw and hard boiled eggs. L'Eggs containers may be filled with different substances or water for a more permanent alternative. |
| PIRA 1000 | billiard ball ellipsoid | 1Q60.37 | |
| UMN, 1Q60.37 | billiard ball ellipsoid | 1Q60.37 | Same as AJP 44(11),1080. |
| AJP 44(11),1080 | billiard ball elipsoid | 1Q60.37 | A billiard ball on an air bearing shows the spectacular motion of free rotating rigid and semirigid bodies moving near their inertial singularities. Or, the billiard ball on an air bearing acts goofy when you spin it in certain ways. |
| F&A, Mu-12 | billiard ball ellipsiod | 1Q60.37 | A billiard ball weighted with brass rods along orthogonal axes will show spin flip. |
| PIRA 1000 | tossing the book | 1Q60.40 | |
| UMN, 1Q60.40 | tossing the book | 1Q60.40 | Throw a book or board up in the air spinning it about its three principle axes. |
| AJP 46(5),575 | tossing the book | 1Q60.40 | Directions of constructing blocks of inhomogeneous mass distribution for use in demonstrating the intermediate-axis theorem. |
| TPT 17(9),599 | tossing the book, etc | 1Q60.40 | A simple method of measuring the moments of inertia about the three axes before tossing the book. Also has a simple straw and paperclip inertia wand. |
| F&A, Mu-20 | tossing the book | 1Q60.40 | A board of unequal dimensions is tossed and spins about various axes. |
| Mei, 12-3.2 | tossing the book | 1Q60.40 | Toss a 8x4x1 block into the air. |
| Disc 07-20 | stable and unstable axes of rotation | 1Q60.40 | Toss a rectangular board into the air. |
| PIRA 1000 | tossing the hammer | 1Q60.45 | |
| UMN, 1Q60.45 | tossing the hammer | 1Q60.45 | |
| TPT 28(8),556 | the hammer flip simplified | 1Q60.46 | An explanation of the hammer flip using only the concept of centrifugal force in a rotating reference frame. |
| PIRA 1000 | spinning lariat, hoop, and disc | 1Q60.50 | |
| F&A, Mu-21 | spinning lariat, etc. | 1Q60.50 | A rod, hoop, and flexible chain are attached to a hand drill. |
| Sut, M-168 | spinning lariat | 1Q60.50 | A hand drill held vertically is used to rotate loops of rope or chain. |
| Hil, M-16b.1 | spinning lariat | 1Q60.50 | A loop of flexible chain is attached to a hand drill. |
| PIRA 1000 | spinning rod and hoop | 1Q60.51 | |
| UMN, 1Q60.51 | spinning lariat, hoop, and disc | 1Q60.51 | A hoop and disc suspended from the edge are spun with a hand drill until they each stability. |
| Disc 07-19 | spinning rod and hoop of wire | 1Q60.51 | Spin a hoop and long rod with a drill. |
| Mei, 12-3.4 | spinning lariat, bar | 1Q60.52 | A bar is hung from one end by a string on a hand drill. When spun, the bar will rise. Also spin a loop of chain. |
| Mei, 12-3.1 | spinning box | 1Q60.53 | A rectangular box rotated from a chain around any of the three principle axes will rotate about the axis of maximum rotational inertia. |
| AJP 48(1),54 | rotating vertical chain | 1Q60.54 | The five stable patterns observed in a vertical rotating chain are used to introduce Bessel's function. |
| F&A, Mz-8 | spinning bifilar pendula | 1Q60.56 | A variable speed motor drives a horizontal rod in a horizontal plane with bifilar pendula of different lengths attached. |
| AJP 30(8),561 | orbital stability | 1Q60.70 | Identical masses slide out on a horizontally rotating crossarm both attached to the same central hanging mass. |
| Mei, 8-7.1 | quadratic restoring force | 1Q60.71 | A leaf spring provides a quadratic restoring force to dumbbells rotating on a crossarm. Each angular velocity corresponds to only one stable orbit. |
| AJP 58(1),80 | rotational instability | 1Q60.72 | Different springs will result in conservation of angular momentum or instability in a spring loaded dumbbell. |
| Mei, 8-6.1 | linear restoring force | 1Q60.73 | Two dumbbells slide out as a crossarm rotates with a spring providing the restoring force. At the critical angular velocity the orbits are stable at any radius. |
| PIRA 1000 | static/dynamic balance | 1Q60.80 | |
| UMN, 1Q60.80 | static/dynamic balance | 1Q60.80 | Same as disc 07-15. |
| Disc 07-15 | static/dynamic balance | 1Q60.80 | A rotating system suspended by springs shows both the difference between static and dynamic balance. |
| AJP 40(1),199 | dynamic tire balancing | 1Q60.81 | Analysis of dynamically balanced wheels shows they must also be statically balanced. |
| D&R, M-720 | dynamic tire balancing | 1Q60.81 | Using masses on a bicycle wheel to analyze tire balancing and mass placement. |
| AJP 42(2),100 | Marion's dumbell | 1Q60.90 | A simple apparatus to demonstrate the non-colinearity of the angular velocity vector and the angular momentum vector. Helps students increase their understanding of angular velocity, angular momentum, and the inertial tensor. Theory and construction details. |

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| | **PROPERTIES OF MATTER** | **1R00.00** | |
| | **Hooke's Law** | **1R10.00** | |
| PIRA 200 | stretching a spring | 1R10.10 | Add masses to a pan balance and measure the deflection with a cathetometer. |
| UMN, 1R10.10 | stretching a spring | 1R10.10 | Add masses to a pan balance and measure the deflection with a cathetometer. |
| TPT 18(8),601 | stretching a spring | 1R10.10 | Examining the force-displacement curve at small extensions. |
| D&R, M-438 | stretching a spring | 1R10.10 | Add masses to a spring and measure displacement. Do the same for a rubber band or Bungee cord. |
| Disc 08-01 | Hooke's law | 1R10.10 | Add 10, 20, and 30 newtons to a large spring. |
| PIRA 1000 | strain gauge | 1R10.20 | |
| UMN, 1R10.20 | strain gauge | 1R10.20 | A spring attached to a Pasco dynamic force transducer is pulled to various lengths. Display the resulting force on a voltmeter. |
| PIRA 1000 | pull on a horizontal spring | 1R10.25 | |
| UMN, 1R10.25 | pull on a horizontal spring | 1R10.25 | Pull on a horizontal spring with a spring scale. |
| PIRA 1000 | springs in series and parallel | 1R10.30 | Pull on a spring, springs in series, and springs in parallel with a spring scale. Compare the force required to stretch each case 60 cm. |
| UMN, 1R10.30 | springs in series and parallel | 1R10.30 | Add abstract in Handbook.FM |
| | **Tensile and Compressive Stress** | **1R20.00** | |
| PIRA 200 - Old | breaking wire | 1R20.10 | Add weights to baling wire attached to the ceiling until the wire breaks. |
| UMN, 1R20.10 | breaking wire | 1R20.10 | Add heavy masses to a thin copper wire until the wire breaks. |
| F&A, MA-10 | breaking wire | 1R20.10 | Add weights to baling wire attached to the ceiling until the wire breaks. |
| Sut, M-63 | breaking wire | 1R20.10 | Contains several hints about stretching wires. |
| PIRA 1000 | elastic limits | 1R20.11 | |
| Disc 08-04 | elastic limits | 1R20.11 | Stretch springs of copper and brass. The copper spring remains extended. |
| AJP 28(4),404 | breaking wire support | 1R20.12 | Drill a hole axially up a 1/4" eye hook and solder the wire in. |
| PIRA 1000 | Young's modulus | 1R20.15 | |
| Disc 08-05 | Young's modulus | 1R20.15 | Hang weights from a wire. Use a laser and mirror optical lever to display the deflection. |
| F&A, MA-11 | Poisson's ratio | 1R20.18 | A rubber hose is stretched to show lateral contraction with increasing length. |
| PIRA 1000 | bending beam | 1R20.20 | |
| UMN, 1R20.20 | bending beam | 1R20.20 | Ten lbs. is hung from the center of a meter stick supported at the ends. Orient the meter stick on edge and then on the flat. |
| Mei, 18-1.5 | rectangular bar under stress | 1R20.20 | A rectangular cross section bar is loaded in the middle while resting on narrow and broad faces. |
| Sut, M-66 | bending the meter stick | 1R20.20 | Some techniques for making the amount of bending visible to the class. |
| Disc 08-06 | bending beams | 1R20.20 | Hang weights at the ends of extended beams. Use beams of different lengths and cross sections. |
| PIRA 1000 | sagging board | 1R20.25 | |
| UMN, 1R20.25 | sagging board | 1R20.25 | Place the ends of a thin board on blocks, then add mass to the center. |
| TPT 28(6),416 | aluminum/steel elasticity paradox | 1R20.27 | Copper and brass rods sag different amounts under their own weight but steel and aluminum do not. |
| Mei, 18-1.3 | stretch a hole | 1R20.31 | Holes arranged in a circle in a rubber sheet deform into an ellipse when stretched. |
| Sut, M-67 | deformation under stress | 1R20.32 | A pattern is painted on a sheet of rubber and deformed by pulling on opposite sides. |
| Mei, 18-1.7 | stress on a brass ring | 1R20.38 | A strain gauge bridge is used to measure the forces required to deform a brass ring. Diagram. Construction details. |
| ref. 2B20.53 | squeeze the flask | 1R20.39 | See 2B20.53 for a demo of stress and elasticity of a glass flask or bottle. |
| PIRA 1000 | buckling tubes | 1R20.40 | |
| PIRA 1000 | Bologna bottles | 1R20.60 | |
| Hil, M-19j.2 | bologna bottles | 1R20.60 | Carborundum and bologna bottles. |
| Disc 08-08 | bologna bottle | 1R20.60 | Pound a nail with a Bologna bottle, then add a carborundum crystal to shatter the bottle. |
| PIRA 1000 | Prince Rupert's drops | 1R20.70 | |
| F&A, MA-6 | Prince Rupert's drops | 1R20.70 | Prince Rupert's drops. |
| Sut, H-26 | Prince Rupert's drops | 1R20.70 | Drops of glass cooled quickly can be hit with a hammer but shatter when the tip is broken off. |
| Hil, M-19j.3 | Prince Rupert's drops | 1R20.70 | Prince Rupert's drops. |
| | **Shear Stress** | **1R30.00** | |
| PIRA 1000 | shear book | 1R30.10 | |
| UMN, 1R30.10 | shear book | 1R30.10 | Use a thick book to show shear. |

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| F&A, MA-8 | shear book | 1R30.10 | Use a very thick book to demonstrate shear. |
| Sut, M-65 | shear block | 1R30.10 | Stacks of cards or a big book. |
| PIRA 500 | foam block | 1R30.20 | |
| UMN, 1R30.20 | foam block | 1R30.20 | Push on the top of a large foam block to show shear. |
| TPT 14(6),373 | foam block | 1R30.20 | Nice pictures of a foam block for sheer demonstrations. |
| F&A, MA-9 | foam block | 1R30.20 | A large sponge is used to show shear. |
| Sut, M-64 | foam block | 1R30.20 | Use a rectangular block of rubber. |
| Bil&Mai, p 176 | foam block | 1R30.20 | A large foam block with squares drawn on the side with a marker is used to model a beam that is loaded in the middle. The top of the block shows compression while the bottom shows it is being stretched. |
| PIRA 500 | spring cube | 1R30.30 | |
| UMN, 1R30.30 | spring cube | 1R30.30 | A 3x3x3 cube of cork balls is held together with springs. |
| F&A, MA-1 | spring cube | 1R30.30 | A cube of 27 cork balls fastened together with springs. |
| Mei, 18-1.5 | plywood sheets | 1R30.31 | A stack of plywood sheets with springs at the corners is used to show shear, torsion, bending, etc. Diagram. |
| AJP 45(1),45 | shear and stress modulus | 1R30.35 | Unsophisticated apparatus for measuring elastic constants of a thin flexible strip and rod. |
| PIRA 1000 | torsion rod | 1R30.40 | |
| UMN, 1R30.40 | torsion rod | 1R30.40 | |
| F&A, MA-12 | modulus of rigidity | 1R30.40 | A rod is twisted by a mass hanging off the edge of a wheel. |
| F&A, MA-13 | bending and twisting | 1R30.40 | Wind a copper strip around a rod and then remove the rod and pull the strip straight to show twisting. |
| Disc 08-03 | torsion rod | 1R30.40 | Rods of various materials and diameters are twisted in a torsion lathe. |
| AJP 31(5),391 | shear and twist in screw dislocation | 1R30.45 | Rule a thick walled vacuum tube with a grid, slit lengthwise, and dislocate one unit. |
| | **Coefficient of Restitution** | **1R40.00** | |
| PIRA 500 | bouncing balls | 1R40.10 | |
| UMN, 1R40.10 | bouncing balls | 1R40.10 | Drop balls of different material on a tool steel plate. |
| AJP 68(11), 1025 | dead and live balls | 1R40.10 | The coefficient of restitution for collisions of happy ball, unhappy balls, and tennis balls is examined and modeled. |
| F&A, Mw-3 | bouncing balls | 1R40.10 | Balls of various materials are bounced off plates of various materials. |
| Mei, 9-1.5 | bouncing ball | 1R40.10 | Loss of mechanical energy in the coefficient of restitution. |
| Sut, M-69 | bouncing balls | 1R40.10 | Drop balls on a glass plate. |
| D&R, M-595 | bouncing balls | 1R40.10 | Balls of different materials are bounced off plates of different materials and even flexible diaphragms. |
| Disc 05-04 | coefficient of restitution | 1R40.10 | Drop glass, steel, rubber, brass, and lead balls onto a steel plate. |
| TPT 15(7),420 | bouncing balls | 1R40.11 | An eight inch or larger reflecting telescope mirror blank provides a concave surface for bouncing balls. |
| Mei, 9-5.5 | coefficient of restitution | 1R40.11 | Drop a small ball bearing on a concave lens. |

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| Hil, M-19j.1 | coefficient of restitution | 1R40.12 | Rubber balls of differing elasticity and silly putty are dropped in a tube onto a steel surface. |
| AJP 58(2),151 | coef. of restitution in baseballs | 1R40.13 | Analysis leading to a prediction of up to 15 foot difference in long fly balls due to variation in coefficient of restitution. |
| PIRA 200 | dead and live balls | 1R40.30 | Drop bounce and no-bounce balls. |
| UMN, 1R40.30 | dead and live balls | 1R40.30 | Drop bounce and no-bounce balls. |
| AJP 37(3),333 | dead and live balls | 1R40.30 | Drop a black super ball and a ball rolled from apiezon wax. |
| Mei, 9-5.4 | dead ball | 1R40.31 | A non-bounce ball: fill a hollow sphere with iron filings or tungsten powder. |
| | **Crystal Structure** | **1R50.00** | |
| F&A, MA-3 | solid shapes | 1R50.10 | How to make solid tetrahedrons and octahedrons. |
| Hil, A-1e | solid models | 1R50.15 | Styrofoam balls and steel ball bearings are used to make crystal models. |
| Mei, 40-1.17 | sphere packing | 1R50.16 | Balls are stacked on vertical rods mounted on a board to build various crystal structures. Diagram. |
| AJP 31(3),190 | Moduledra crystal models | 1R50.17 | Tetrahedral and octahedral building blocks are used to construct a large variety of crystal shapes. Many pictures. |
| AJP 39(5),545 | elastic crystal models | 1R50.18 | Crystal models are built with a combination of compression and tension springs. |
| PIRA 1000 | crystal models | 1R50.20 | |
| UMN, 1R50.20 | crystal models | 1R50.20 | |
| AJP 68(10), 950 | crystal models | 1R50.20 | An argument for a 15th Bravais lattice. |
| AJP 70(2), 187 | crystal models | 1R50.20 | Comments on AJP 68(10), 950 and why there is no need to invoke a 15th lattice type. |
| Hil, A-1d | crystal lattice models | 1R50.20 | Have many crystal lattice models available. |
| Disc 16-15 | crystal models | 1R50.20 | Show lattice models of sodium chloride, calcium carbonate, graphite, and diamond. |
| F&A, MA-4 | ice model | 1R50.21 | How to make ball and stick water molecules that can be stuck together to make ice. |
| F&A, MA-2 | tennis ball crystals | 1R50.22 | Old tennis balls glued together to give two close packed crystals. |
| D&R, S-200 | tennis ball crystals | 1R50.22 | Various crystal models constructed from layers of tennis balls. |
| TPT 5(7), 311 | crystals - mirror images | 1R50.24 | Mirror images and symmetry in crystals and physics. |
| Mei, 18-1.7 | Poisson contraction model | 1R50.25 | A two dimensional spring model to show Poisson contraction in crystals. |
| Mei, 40-1.18 | crystal overlays | 1R50.29 | Colored overlays of crystal structure for use on the overhead projector. Picture. |
| Sut, H-43 | crystal structure | 1R50.30 | Show natural crystals of salt, quartz, and other minerals, and lantern slides of snow crystals. |
| D&R, S-195 | crystal structure in atomic planes | 1R50.30 | Periodicity of crystal structure of atomic planes illustrated by "egg crate foam". |
| AJP 41(5),744 | crystal growth from melt | 1R50.31 | Several organic compounds produce good crystals from melts on microscope slides. |
| F&A, Om-13 | crystal growth in a film | 1R50.31 | Crystal growth on a freezing soap film is observed through crossed Polaroids |
| F&A, Hl-11 | ice nuclei | 1R50.31 | Large ice crystals form on the surface of a supercooled saturated sugar solution. |
| AJP 34(2),167 | make tin crystal | 1R50.32 | Pour pure tin into a Pyrex mold, other steps. |
| PIRA 1000 | crystal fault model | 1R50.40 | |
| AJP 37(8),789 | array of spheres | 1R50.40 | Prepare a slide with a monolayer of 2.68 micron diameter polymer spheres that exhibits grain boundaries, extended dislocations, etc. |
| AJP 34(11),1064 | stacking fault model | 1R50.40 | A closest packing spheres model that demonstrates a fault going from fcc to hcp. |
| F&A, MA-5 | crystal faults | 1R50.40 | One layer of small ball bearings between two Lucite sides. |
| D&R, S-200 | faults in a crystal | 1R50.40 | A single layer of small ball bearings in an acrylic enclosure on the overhead display vacancies and dislocations. |
| Disc 16-16 | faults in crystal | 1R50.40 | Show natural faults in a calcite crystal, then the single layer of small spheres model. |
| AJP 40(4),618 | deformation front model | 1R50.42 | A water film evaporating from an array of mesas shows the film edge pinned at several locations. |
| PIRA 1000 | crushing salt | 1R50.45 | |
| UMN, 1R50.45 | crushing salt | 1R50.45 | Crush a large salt crystal in a big clamp. |
| F&A, MA-7 | crushing salt | 1R50.45 | A large salt crystal is crushed in a "c" clamp. |

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| | **SURFACE TENSION** | **2A00.00** | |
| | **Force of Surface Tension** | **2A10.00** | |
| PIRA 500 | sliding wire | 2A10.10 | |
| UMN, 2A10.10 | sliding wire | 2A10.10 | A soap film provides the force to slide a light wire on a frame. |
| F&A, Fi-7 | force on a film | 2A10.10 | A soap film pulls a wire up a frame. |
| Sut, M-233 | sliding wire | 2A10.10 | A soap film pulls a sliding wire up a U shaped frame. |
| Disc 13-21 | soap film pullup | 2A10.10 | A soap film pulls a sliding wire up a "U" shaped frame. |
| Mei, 16-5.1 | sliding wire | 2A10.11 | A sliding wire frame film with a spring on one end and a string pull on the other shows that tension does not increase with length. |
| Hil, M-21a | sliding wire, etc. | 2A10.12 | The sliding wire, wire cubes, and other soap film stuff is pictured. |
| PIRA 1000 | submerged float | 2A10.15 | |
| UMN, 2A10.15 | submerged float | 2A10.15 | When submerged, a wire hoop keeps a float beneath the surface of water due to surface tension. |
| F&A, Fi-1 | submerged float | 2A10.15 | Surface tension holds a brass ring on a float beneath the water. |
| Sut, M-213 | submerged float | 2A10.15 | A cork and lead device floats with a wire ring above the surface. Push the ring below the surface and it remains until soap is added to reduce the surface tension. |
| PIRA 200 | floating metals | 2A10.20 | Float needles, paperclips, rings of wire, etc. on water. |
| Sut, M-213 | floating metals | 2A10.20 | Float needles, paper clips, rings of wire, etc. on water. |
| D&R, F-330 | floating metals | 2A10.20 | Float a needle in a petrie dish of water. |
| PIRA 1000 | floating metal sheet | 2A10.21 | |
| Mei, 16-5.5 | floating aluminum sheet | 2A10.21 | A sheet of aluminum will float on the surface of clean water. |
| Disc 13-20 | floating metal sheet | 2A10.21 | Float a sheet of metal on the surface of distilled water and add weights until the metal sinks. |
| PIRA 1000 | leaky boats | 2A10.25 | |
| UMN, 2A10.25 | leaky boats | 2A10.25 | Try to float several large (one foot long) flat bottomed boats made of different screen material or aluminum with different size holes. |
| F&A, Fi-16 | leaky boats | 2A10.25 | A screen boat, razor blade, or small metal boat with a large hole all float on water. |
| Sut, M-218 | watertight sieves | 2A10.25 | A mesh boat floats until a drop of water is placed inside it. Dry cheesecloth holds water in an inverted beaker. |
| D&R, F-330 | watertight sieves | 2A10.25 | A fine sieve will hold water if it is added carefully, but will leak if the underside is touched with a finger. |
| Bil&Mai, p 182 | leaky boats | 2A10.25 | A mesh basket floats until a drop of soap is added to the water. |
| Mei, 16-5.6 | waterproof fabric model | 2A10.28 | Paraffin coated pegs serve as large model fibers. Pictures. |
| PIRA 1000 | surface tension balance | 2A10.30 | |
| AJP 58(8),791 | surface tension balance | 2A10.30 | An improved method for measuring surface tension by the direct pull method. |
| Sut, M-261 | adhesion balance | 2A10.30 | A glass plate on one end of a balance beam is in contact with a water surface. |
| Sut, M-211 | surface tension of mercury | 2A10.31 | Use a Joly balance to measure the force required to pull a razor blade out of mercury. |
| Sut, M-210 | pull on the ring | 2A10.32 | Pull a large ring away from the surface of a liquid with a spring scale. |
| PIRA 1000 | surface tension disc | 2A10.33 | |
| Disc 13-19 | surface tension disc | 2A10.33 | A flat glass disc on a soft spring is lowered onto the surface of distilled water and the extension upon pulling the disc off the water is noted. |
| PIRA 1000 | cohesion plates | 2A10.35 | |
| UMN, 2A10.35 | cohesion plates | 2A10.35 | |
| F&A, Fi-10 | cohesion plates | 2A10.35 | Two heavy glass plates stick together when a film of water is between them. |
| Sut, M-259 | cohesion plates | 2A10.36 | There is a difference in cohesion of dry and wet plate glass. |
| AJP 32(1),61 | cohesion plates fallacy | 2A10.37 | If they demonstrate cohesion, why do they fall apart when placed in a bell jar that is evacuated? |
| Disc 11-13 | adhesion plates | 2A10.37 | Atmospheric pressure holds two plate glass panes together. |
| Sut, M-260 | cohesion tube | 2A10.38 | A long (2-4 m) tube full of water and sealed at the top will support the water column against gravity. |
| PIRA 1000 | drop soap on lycopodium powder | 2A10.40 | |
| F&A, Fi-6 | surface reaction | 2A10.40 | Some soap is dropped onto a water surface covered with sawdust. |
| Sut, M-222 | drop soap on lycopodium powder | 2A10.40 | Sprinkle lycopodium powder on the surface of water, then place a drop of liquid soap on the surface. |
| D&R, F-330 | pepper and soap | 2A10.40 | Pepper is floated on water in a petrie dish on the overhead. A small amount of soap touched to the middle will make the pepper move to the perimeter. |

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| Bil&Mai, p 182 | pepper and soap | 2A10.40 | Pepper is floated on water in a petrie dish on the overhead. A small amount of soap touched to the middle will make the pepper move to the perimeter of the dish. |
| AJP 33(7),v | liquid fracture | 2A10.45 | Directions on making a tube filled with Freon 113 which will completely fill the tube on warming and fracture on cooling or when a weak neutron source is brought near after partial cooling. |
| PIRA 500 | bubbles blowing bubbles | 2A10.50 | |
| UMN, 2A10.50 | bubbles blowing bubbles | 2A10.50 | A "T" tube apparatus allows one to blow two soap bubbles of different diameters, then interconnect them. |
| AJP 46(10),978 | analysis of bubbles blowing bubbles | 2A10.50 | The complete analytical solution to the two bubbles problem. |
| F&A, Fi-3 | soap bubbles | 2A10.50 | A smaller bubble blows up a larger one when connected by a tube. |
| Sut, M-239 | bubbles blowing bubbles | 2A10.50 | Blow bubbles of different size on a "T" tube. The smaller one will blow up the larger one. |
| Disc 13-23 | two soap bubbles | 2A10.50 | The smaller soap film bubble blows up the larger one. |
| PIRA 1000 | rubber balloons | 2A10.51 | |
| UMN, 2A10.51 | rubber balloons | 2A10.51 | Do the bubbles with large rubber balloons. |
| AJP 46(10),976 | rubber balloons | 2A10.52 | The equation relating the internal pressure to the radius is derived and applied to the problem of the two interconnected unequal balloons. |
| Sut, M-240 | pressure in a bubble | 2A10.55 | Connect a slant water manometer to a tube supporting a bubble. Vary the size of the bubble and note the change of pressure. |
| Sut, M-242 | water balloon | 2A10.58 | Make a large water balloon. |
| PIRA 500 | surface tension bottle | 2A10.60 | |
| UMN, 2A10.60 | surface tension bottle | 2A10.60 | |
| F&A, Fi-2 | wet mop | 2A10.65 | Surface tension pulls the strands of a small fluffy mop together when wet. |
| Mei, 16-5.3 | sponge action | 2A10.68 | Water picked up by a wet sponge is greater than that picked up by a dry one. |
| Mei, 16-5 | surface tension | 2A10.69 | Discussion of eight surface tension demonstrations. |
| Sut, M-249 | water droplets | 2A10.70 | Small water droplets form on a surface not wet by water, droplets bounce off when sprayed on with an atomizer. Water droplets will roll across the surface of an overfull glass of water when projected out of a pipette at a small angle. |
| Sut, M-252 | rolling drops | 2A10.71 | A drop of alcohol can roll on the surface of an alcohol dish. |
| Sut, M-250 | tears of wine ??? | 2A10.72 | As 50 proof alcohol evaporates in a watch glass, the remaining liquid forms drops that run down the sides. |
| Sut, M-256 | Plateau's spherule | 2A10.73 | A method of projecting and strobing drops forming down from a vertical orifice. |
| Sut, M-257 | bursting water bubble | 2A10.74 | A jet of water directed upward against the apex of a cone will cause the water to flow around and form a bubble. A drop of ether will decrease the surface tension and the bubble will collapse. |
| Sut, M-241 | mercury bubbles | 2A10.75 | Air is blown into mercury covered by a dilute solution of ammonium chloride. Mercury bubbles rise to the surface and burst. |
| Sut, M-248 | mercury drops | 2A10.76 | Spray clear mercury into distilled water - no coalescence. Then add a little acid - coalescence. |
| PIRA 1000 | charge and surface tension | 2A10.80 | |
| F&A, Eb-14 | effect of charge on surface tension | 2A10.80 | Dripping rate is much greater from an electrically charged buret. |
| Mei, 16-5.4 | surface tension with electric field | 2A10.81 | Droplets from a orifice become a steady stream when connected to a Wimshurst generator. |
| Mei, 29-1.16 | electrostatic breakdown of surface tension | 2A10.83 | Droplets shoot out of a pond of carbon tetrachloride on a Van de Graaff generator as electrostatic breakdown of surface tension takes place. |
| Mei, 29-1.17 | elecrostatic dispersion of water drops | 2A10.84 | Water drops from a pipette at high potential are dispersed into droplets. |
| Sut, M-247 | changing drop size | 2A10.85 | As the amount of sodium hydroxide is varied in a dilute solution, the size of drops formed by a olive oil jet changes with the variation of surface tension. |
| Sut, M-258 | temperature effects | 2A10.95 | Olive oil sprayed on hot water forms droplets but on cold water forms a slick. |
| | **Minimal Surface** | **2A15.00** | |
| TPT 3(6),285 | soap film recipe | 2A15.01 | A Joy(2.5)/water(8)/glycerine(6.5) recipe. |
| AJP 69(8), 920 | soap film recipes & measurements | 2A15.01 | Experimental measurements of pressure changes inside a bubble for two different soap solutions. Surface tension is then calculated using the Young-Laplace equation. |
| PIRA 200 - Old | ring and thread | 2A15.10 | A loop of thread in the middle of a soap film forms a circle when the center is popped. |

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| UMN, 2A15.10 | pop the center | 2A15.10 | A circle will form when the center of a loop in a soap film is popped. |
| F&A, Fi-13 | ring and thread | 2A15.10 | A loop of thread forms a circle when popped in the middle of a soap film. |
| Sut, M-237 | pop the center | 2A15.10 | A loop of thread is attached to wire ring. Dip in soap and pop the center of the loop to form a circle. |
| Disc 13-24 | minimim energy thread | 2A15.10 | Dip a frame with a loop of thread in soap, then pop the film in the center of the thread. |
| Sut, M-234 | soap film minimal surfaces | 2A15.11 | Puncture various parts of the film that forms on a wire cube to get different geometrical shapes. |
| PIRA 1000 | soap film minimal surfaces | 2A15.20 | |
| UMN, 2A15.20 | soap film minimal surfaces | 2A15.20 | |
| Sut, M-236 | soap film minimal surfaces | 2A15.20 | Wire frames dipped in soap film form minimal surfaces. Pictures. |
| D&R, F-360 | soap frame minimal surfaces | 2A15.20 | Wire frames of different sizes and shapes will form minimal surfaces when dipped in soap solution. |
| Disc 13-22 | soap film shapes | 2A15.20 | A pyramid, cube, and triangular prism. |
| PIRA 1000 | catenoid soap film | 2A15.21 | |
| UMN, 2A15.21 | catenoid soap film | 2A15.21 | A soap film is established between two concentric rings which are pulled apart. |
| F&A, Fi-4 | cylindrical soap film | 2A15.21 | Two rings pulled apart with a soap film form a catenoid. |
| Mei, 16-5.9 | catenoid soap film | 2A15.21 | Picture of a catenoid. setup, some theory and diagrams. |
| Sut, M-235 | catenoid soap film | 2A15.21 | Dip two concentric circles of wire in soap and separate them to form a catenoid. |
| AJP 59(5),415 | soap films - phase transition model- | 2A15.23 | Use soap films to show phase transitions by changing sizes of variable frameworks. |
| Sut, M-232 | surface energy | 2A15.25 | A soap film on an inverted funnel ascends. |
| Mei, 16-5.8 | soap bubbles | 2A15.30 | Blow half bubbles on a glass plate. More. |
| Sut, M-251 | castor-oil drop | 2A15.42 | A large drop of castor oil is drawn under water where it forms a spherical drop. |
| F&A, Fi-14 | size of drops | 2A15.50 | Different size drops form on the ends of different O.D. capillary tubes. |
| | **Capillary Action** | **2A20.00** | |
| PIRA 500 | capillary tubes | 2A20.10 | |
| UMN, 2A20.10 | capillary tubes | 2A20.10 | Two sets of capillary tubes, one filled with water and one filled with mercury. |
| F&A, Fi-8 | capillary tubes | 2A20.10 | Sets of capillary tubes with water and mercury are compared. |
| Sut, M-214 | capillary tubes | 2A20.10 | Sets of capillary tubes of various diameters show capillary rise with water and capillary depression with mercury. |
| Hil, M-22g | capillary tubes | 2A20.10 | Two sets of capillary tubes. |
| Disc 13-26 | capillary tubes | 2A20.10 | Fill a set of capillary tubes with water. |
| F&A, Fi-11 | depression and rise in capillary | 2A20.11 | "U" tubes with a large and small bore arm are filled with water and mercury and compared. |
| Hil, M-22h | project capillary tubes | 2A20.12 | An optical setup to project capillary tubes. |
| PIRA 1000 | surface tension hyperbola | 2A20.20 | |
| F&A, Fi-9 | surface tension hyperbola | 2A20.20 | A large meniscus forms between two sheets of glass held at an angle in a pan of water. |
| Sut, M-215 | capillary hyperbola | 2A20.20 | Two glass plates are clamped on one edge and separated by a wire on the other. |
| Mei, 16-5.2 | meniscus | 2A20.21 | Project the meniscus of water and mercury at the apex of wedge shaped containers. |
| Sut, M-216 | drops in tapered tubes | 2A20.30 | A drop on water in a tapered tube moves to the narrow end and a mercury drop moves away from the narrow end. |
| PIRA 1000 | capillary action | 2A20.35 | |
| Disc 13-25 | capillary action | 2A20.35 | Touch the end of a small glass surface with a small glass tube and the water is drawn into the tube. |
| Sut, M-220 | meniscus | 2A20.40 | Add 4-penny finishing nails to a full glass of water until it overflows. |
| Sut, M-217 | meniscus | 2A20.45 | Objects floating in a vessel cling to the edge until it is over full when they go to the middle. |
| TPT, 36(7), 410 | position of objects floating in a glass | 2A20.46 | Corks floating in a container cling to the edge when a water layer is below the brim and float in the middle when the layer is above the rim. Objects with densities greater than water (floating metals) float in the middle when the water layer is below the brim and float to the edge when the layer is above the brim. |
| Sut, M-219 | capillary phenomena | 2A20.50 | Four items: dip your finger in water covered with lycopodium powder, a wet paintbrush in and out of water, pour water down a wet string, pour water in a flexible paper box. |
| | **Surface Tension Propulsion** | **2A30.00** | |
| PIRA 1000 | surface tension boat propulsion | 2A30.10 | |
| F&A, Fi-17 | surface tension boats | 2A30.10 | A crystal of camphor is attached to the back of a small boat. |

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| Sut, M-224 | surface tension boat | 2A30.11 | Pieces of camphor placed on the edges of a light aluminum propeller cause it to spin on the surface of water. |
| Sut, M-226 | surface tension boat | 2A30.12 | How to use alcohol in a surface tension boat. |
| Sut, M-225 | surface tension boat | 2A30.13 | Rub a match stick on a cake of soap or attach a piece of camphor and place in water. |
| Sut, M-223 | surface tension flea | 2A30.20 | Bits of camphor dart around on the surface of water until soap is introduced. |
| Sut, M-227 | surface tension flea | 2A30.21 | A drop of Duco cement will dart around on the surface of water, two drops will play tag. |
| PIRA 1000 | mercury heart | 2A30.30 | |
| F&A, Fi-5 | mercury amoeba | 2A30.30 | A watch glass containing mercury and a solution of sulfuric acid and potassium dichromate is touched with a nail. |
| Sut, M-230 | mercury heart | 2A30.30 | A globule of mercury is covered with 10% sulfuric acid with a few crystals of potassium dichromate. Touch the mercury with an iron wire to produce rhythmic pulsation. |
| Sut, M-228 | mercury amoeba | 2A30.31 | Place a crystal of potassium dichromate near a globule of mercury covered with 10% nitric acid. |
| Sut, M-229 | mercury heart | 2A30.32 | Cover a globule of mercury with 10% hydrogen peroxide and add 1% sodium bicarbonate. A yellow film appears on the mercury and breaks down regularly. |
| Sut, M-231 | pulsating air bubble | 2A30.35 | An inverted watch glass traps an air bubble over water. Alcohol is introduced at the edge of the bubble through a bent tube at a rate that causes pulsations. |
| | **STATICS OF FLUIDS** | **2B00.00** | |
| | **Static Pressure** | **2B20.00** | |
| PIRA 200 - Old | pressure independent of direction | 2B20.10 | Insert a rotatable thistle tube with a membrane into a beaker of water. |
| UMN, 2B20.10 | pressure independent of direction | 2B20.10 | A thistle tube covered with a diaphragm and connected to a manometer is lowered into water and oriented in different directions. |
| F&A, Fa-1 | pressure independent of direction | 2B20.10 | A rubber membrane covers a thistle tube connected to a manometer. The assembly is inserted into a beaker of water and oriented in various directions. |
| D&R, F-010 | pressure independent of direction | 2B20.10 | A funnel covered with a rubber balloon diaphragm and connected to a water manometer is lowered into water and oriented in different directions. |
| Disc 12-04 | pressure independent of direction | 2B20.10 | Membrane on a tube connected to a manometer. |
| Sut, M-273 | pressure independent of direction | 2B20.11 | Three thistle tubes filled with colored alcohol and capped with rubber membranes are joined with the thistle ends bent to be oriented in various directions. Immerse in water to show equal pressure. Or, one tube may be turned to show the same thing. |
| PIRA 1000 | pressure dependent on depth | 2B20.15 | |
| AJP 32(1),xiv | pressure dependent on depth fallacy | 2B20.15 | The manometer used in the demonstration is calibrated on the basis of the law under investigation. |
| Hil, M-20b.1 | pressure dependent on depth | 2B20.15 | Lower a small funnel covered with a rubber membrane attached to a manometer into a water filled vessel. |
| Disc 12-02 | Pressure vs. depth | 2B20.15 | A pressure sensor is connected to a LED bar graph. |
| PIRA 1000 | pressure vs. depth in water and alcohol | 2B20.16 | |
| Disc 12-03 | pressure vs. depth in water and alcohol | 2B20.16 | The electronic pressure sensor and LED bar graph display are used first in water, then in alcohol. |
| AJP 56(7),620 | electronic depth dependence | 2B20.17 | A circuit based on the Motorola MPX100AP pressure sensor displays a pressure depth curve on an XY recorder. An interesting feature is the use of two liquids showing a change of slope at the interface. |
| PIRA 500 | dropping plate | 2B20.20 | |
| UMN, 2B20.20 | dropping plate | 2B20.20 | |
| F&A, Fc-1 | dropping plate | 2B20.20 | Pressure holds a glass plate on the bottom of a glass tube inserted into a beaker of water until the pressure is equalized by another fluid poured into the tube. |
| Mei, 16-4.2 | dropping plate | 2B20.20 | A thin glass plate stays at the bottom of a glass tube immersed in water and water is poured into the tube until the plate drops off. |
| Sut, M-276 | dropping plate | 2B20.20 | Water pressure holds a plate against the bottom of a glass cylinder in a beaker of water. Pour water into the cylinder until the plate drops off. A variation uses a lead plate. |
| PIRA 1000 | Pascal's paradox | 2B20.25 | |

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| Sut, M-277 | Pascal's paradox | 2B20.25 | Two identical truncated cones are in equilibrium on a platform balance, one small end down, the other large end down. Replacing the bottoms with rubber diaphragms and supporting only the extended diaphragms on the scale does not give equilibrium. |
| Mei, 16-4.10 | lateral hydrostatic pressure | 2B20.26 | An inverted funnel with a cork on the stem floats in a beaker of water. When pushed down into a layer of mercury, it stays; but if the stem is immersed, it floats back up. |
| AJP 59(1),89 | hydrostatic paradox - vector analysi | 2B20.27 | Use the hydrostatic paradox to introduce vector analysis instead of some electromagnetism example. |
| PIRA 1000 | weigh a water column | 2B20.30 | |
| UMN, 2B20.30 | weigh a water column | 2B20.30 | Same as AJP 28(6),557. |
| AJP 28(6),557 | weigh water in a tube | 2B20.30 | Suspend a tube from a spring scale in a beaker of water and suck water up into the tube. Why does the scale reading increase? |
| Mei, 16-4.9 | hydrostatic paradox | 2B20.30 | Suspend a tube, open at the bottom, from a spring scale in a beaker of water and partially evacuate the air from the tube. |
| PIRA 1000 | chicken barometer | 2B20.32 | |
| UMN, 2B20.32 | chicken barometer | 2B20.32 | |
| PIRA 1000 | hydrostatic paradox - truncated cone | 2B20.34 | |
| Disc 12-08 | hydrostatic paradox | 2B20.34 | A glass plate is held against the large end of a truncated cone when it is placed under water. The plate drops away when placed against the small end. |
| F&A, Fd-3 | weigh a barometer | 2B20.35 | A barometer tube is weighed empty and filled with mercury, then inverted in a vat of mercury and weigh again. |
| Mei, 16-4.8 | weigh a barometer | 2B20.35 | A spring scale, barometer tube, and mercury in a glass tube that can be evacuated. |
| PIRA 200 | Pascal's vases | 2B20.40 | Six tubes of various shapes are connected to a common water reservoir. |
| UMN, 2B20.40 | Pascal's vases | 2B20.40 | A set of tubes of different geometries rising from a common reservoir of water. |
| F&A, Fa-3 | Pascal's vases | 2B20.40 | A common reservoir connecting several weirdly shaped tubes. |
| Sut, M-275 | Pascal's vases | 2B20.40 | Tubes of various shapes rise from a common horizontal tube. When filled with water, the level is the same in each tube. |
| Hil, M-22f.1 | Pascal's vases | 2B20.40 | Six tubes of various shapes are connected to a common water reservoir. |
| Disc 12-01 | same level tubes | 2B20.40 | A commercial device. |
| F&A, Fa-2 | Pascal's vases | 2B20.42 | A commercial device with a pressure gauge and interchangeable vessel shapes. |
| Hil, M-22e.2 | Pascal's vases | 2B20.42 | Vessels of various shapes are interchangeable on a base equipped with a pressure gauge. |
| D&R, F-005 | Pascal's vases | 2B20.42 | A commercial device with a pressure gauge and interchangeable vessel shapes. |
| AJP, 75 (10), 915 | Pascal's vases | 2B20.42 | A short article with picture describing an antique set of Pascal's vases with leak type pressure gauge. |
| AJP 53(11),1106 | simplified hydrostatic paradox | 2B20.43 | Replace the sloped side vessels with stepped sides that include only horizontal and vertical components. |
| F&A, Fa-4 | water level | 2B20.45 | Two open tubes are connected by a long water filled hose. |
| PIRA 1000 | Pascal's fountain | 2B20.50 | |
| F&A, Fb-2 | Pascal's fountain | 2B20.50 | A piston applies pressure to a round glass flask with small holes drilled at various points. |
| Sut, M-271 | Pascal's fountain | 2B20.50 | Water squirts out equally in all directions when forced out of a sphere by a tube fitted with a piston. |
| F&A, Fb-1 | Pascal's fountain | 2B20.51 | A piston applies pressure to a flask with vertical jets originating at various points on the flask. |
| Sut, M-272 | Pascal's diaphragms | 2B20.52 | A closed container has several protruding tubes capped with rubber diaphragms. Push on one and the others go out. |
| Mei, 16-2.3 | squeeze the flask | 2B20.53 | Squeeze a flask capped with a stopper and small bore tube. |
| TPT 17(9),595 | squeeze the flask | 2B20.53 | Fill a whisky flask with a stopper and a small bore tube. Squeeze the bottle and watch the colored water rise in the tube. |
| PIRA 500 | hydraulic press | 2B20.60 | |
| UMN, 2B20.60 | hydraulic press | 2B20.60 | A hydraulic press is used to break a piece of wood. |
| Sut, M-282 | hydraulic press, etc. | 2B20.60 | Use a large hydraulic press to break a 2x4. Glass models show the action of valves of suction and force pumps. |
| Hil, M-20e | hydraulic press | 2B20.60 | A hydraulic press with a pressure gauge breaks a board or compresses a large spring. |
| Disc 12-07 | hydraulic press | 2B20.60 | Break a piece of wood in a hydraulic press. The press has a pressure gauge. |
| PIRA 1000 | two syringes | 2B20.61 | |

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| F&A, Fb-3 | two syringes | 2B20.61 | Two syringes of different size are hooked together and passed around the class for students to feel the pressure difference. |
| Bil&Mai, p 184 | two syringes | 2B20.61 | Two syringes of different size are connected together with tubing. Pass the system around the class so that the students can feel that the smaller diameter syringe will always be able to move the larger diameter syringe. |
| PIRA 1000 | hydraulic can crusher | 2B20.62 | |
| PIRA 1000 | garbage bag blowup | 2B20.65 | |
| UMN, 2B20.65 | garbage bag blowup | 2B20.65 | |
| D&R, F-060 | garbage bag lift | 2B20.65 | Lift a person sitting on a garbage bag by inflating with an air blower. |
| Disc 11-17 | air pressure lift | 2B20.65 | Lift a person supported by two hot water bottles by blowing them up with the mouth. |
| PIRA 1000 | weight on a beach ball | 2B20.66 | |
| UMN, 2B20.66 | weight on a beach ball | 2B20.66 | Place a 45 lb weight on a circular wood disc on a beach ball and blow up the beach ball per os. |
| Mei, 16-4.6 | weight on the beach ball | 2B20.66 | Lift a 25 lb weight with your lungs by blowing it up on a beach ball. |
| Sut, M-268 | incompressibility of liqiuds | 2B20.66 | Pound in a nail with a bottle completely filled with boiled water. |
| Sut, M-274 | hydraulic balance | 2B20.67 | A 2m vertical glass tube is connected to a hot water bottle. Have students sit on the bottle. |
| PIRA 1000 | compressibility of water | 2B20.70 | |
| F&A, Fn-1 | compressibility of water | 2B20.70 | A piston in a heavy walled glass cylinder is screwed in causing mercury to move in a capillary in a second enclosed container. |
| Mei, 16-3.1 | compressibility of water | 2B20.70 | A heavy walled glass cylinder filled with water is pressurized mechanically and mercury in the capillary tube of a internal water bottle indicates the compression. |
| Sut, M-270 | compressibility of water | 2B20.70 | An apparatus to show compressibility of water. |
| PIRA 1000 | water/air compression | 2B20.71 | |
| Disc 12-05 | water/air compression | 2B20.71 | A syringe filled with air is compressed when a large weight is placed on it, but a water filled syringe does not compress. |
| Mei, 16-3.3 | Weinold piezometer | 2B20.72 | Diagram. Complicated and delicate. |
| Mei, 16-3.2 | near-incompressibility of water | 2B20.75 | Shoot a .22 at a water filled half pint paint can and the cover flies off. ALSO - Hammer a nail with the side of a glass bottle filled with water. |
| Sut, M-269 | incompressibility of liquids | 2B20.76 | With a hammer, strike the stopper of a large bottle completely filled with water and shatter the bottle. |
| D&R, F-065 | incompressibility of fluids | 2B20.76 | A baggie taped onto a jar cannot be forced into or pulled out of the jar. |
| PIRA 500 | hovercraft | 2B20.80 | |
| UMN, 2B20.80 | hovercraft | 2B20.80 | |
| D&R, M-282 | hovercraft | 2B20.80 | Three cushion hovercraft made from motorcycle innertubes and plywood. |
| | **Atmospheric Pressure** | **2B30.00** | |
| PIRA 1000 | lead bar | 2B30.05 | |
| UMN, 2B30.05 | lead bar | 2B30.05 | A 1"x1" lead bar 35" long weighs 14.7 lbs. |
| PIRA 200 | crush the can | 2B30.10 | Boil water in a can and cap. As the vapor pressure is reduced by cooling, the can collapses. |
| Sut, H-77 | crush the can | 2B30.10 | Boil water in a can and cap. As the vapor pressure is reduced by cooling, the can collapses. |
| Sut, M-326 | crush the can | 2B30.10 | Boil water in a can and seal it. Or, pump out a can slightly, put it in a vacuum chamber and blow it back up. |
| Hil, M-22d | crush the can | 2B30.10 | Boil some water in a one gallon can, then stopper and pour water over it. ALSO - evacuate. |
| D&R, F-025, H-068 | crush the can | 2B30.10 | Boil water in a soft drink can or one gallon can, then stopper and plunge into cold water. |
| PIRA 1000 | crush the soda can | 2B30.15 | |
| UMN, 2B30.15 | crush the soda can | 2B30.15 | |
| Sprott, 2.4 | crush the soda can | 2B30.15 | A soft drink can is crushed by rapid condensation of steam. |
| AJP 47(11),1015 | crush the soda can | 2B30.15 | Heat water in the bottom of an aluminum soft drink can, then invert it over a pan of water. |
| TPT 28(8),550 | crush the soda can | 2B30.15 | Boil water in a soda can, invert it over water, and then calculate the thermal efficiency during the collapse. |
| PIRA 500 | crush a 55 gal drum | 2B30.20 | |
| UMN, 2B30.20 | crush a 55 gal drum | 2B30.20 | Boil water in a 55 gal. drum using three LP gas burners. A vacuum gage in the smaller bung hole is optional. The barrel crushes at about a half atmosphere. |
| D&R, F-025 | crush a 55 gal drum | 2B30.20 | Boil water in a 55 gal drum, seal, and cool. Force approaches 3-4 tons. |
| Sprott, 2.4 | crush a 55 gallon drum | 2B30.20 | Boil water in a 55 gal drum, seal, and cool. |
| Disc 11-16 | barrel crush | 2B30.20 | Boil water in a 55 gal drum, seal, and cool. |
| PIRA 1000 | crush the can with vacuum pump | 2B30.25 | |

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| UMN, 2B30.25 | crush the can with pump | 2B30.25 | A 1 gallon can is evacuated with a pump. A pop can heated with water and inverted on cold water. |
| F&A, Fd-1 | crush the can | 2B30.25 | Pump on a gallon can to collapse it. |
| Disc 11-14 | crush can with pump | 2B30.25 | A one gallon can is evacuated with a vacuum pump. |
| Mei, 16-2.2 | blow up the crushed can | 2B30.26 | Take a deep breath and blow up a crushed can. |
| Bil&Mai, p 186 | vacuum pack a student | 2B30.28 | A garbage bag with a hole in it for your head is place over a student with their arms crossed over their chest. Seal around the neck and the waist with tape and remove the air in the bag with a vacuum. When vacuum packed, the student will not be able to move their arms. |
| PIRA 200 | Magdeburg hemispheres | 2B30.30 | Evacuate Magdeburg hemispheres and try to separate them. |
| UMN, 2B30.30 | Magdeburg hemispheres | 2B30.30 | A set of Magdeburg hemispheres are evacuated with a pump. |
| AJP 36(3),ix | Magdeburg flat plates | 2B30.30 | Pump out flat plates separated by an o ring and hang weights. |
| TPT 3(6),285 | Magdeburg hemispheres | 2B30.30 | Separate the hemispheres by placing in a bell jar and evacuating. |
| F&A, Fd-2 | Magdeburg hemispheres | 2B30.30 | Evacuate Magdeburg hemispheres and try to separate them. |
| Hil, M-22b.3 | Magdeburg hemispheres | 2B30.30 | Picture of two Magdeburg hemispheres. |
| D&R, F-015 | Magdeburg hemispheres | 2B30.30 | A set of Magdeburg hemispheres are evacuated with a pump. Try to separate. |
| Sprott, 2.1 | Magdeburg hemispheres | 2B30.30 | Evacuate Magdeburg hemispheres and try to separate them. |
| Disc 11-12 | Magdeburg hemispheres | 2B30.30 | An evacuated Magdeburg hemisphere set supports a large stack of weights. |
| Sut, M-323 | Magdeburg hemispheres | 2B30.31 | Pump out a cylinder at least 5" in diameter and lift a student. |
| PIRA 1000 | Magdeburg hemisphere swing | 2B30.33 | |
| UMN, 2B30.33 | Magdeburg hemisphere swing | 2B30.33 | Evacuate two Plexiglas plates with a 7.5" "O" ring in between. Hook to the ceiling, grab onto the bottom plate and swing. |
| PIRA 1000 | Magdeburg tug-of-war | 2B30.34 | |
| UMN, 2B30.35 | Magdeburg tug-of-war | 2B30.35 | Evacuate two Plexiglas plates with a 12" "O" ring in between and hook a 2" rope to each plate. Have students do the tug of war. |
| AJP 48(11),987 | Magdeburg hemispheres | 2B30.35 | A fifteen inch set used in a pull off between a Clydesdale and small 4-wheel drive. |
| PIRA 1000 | suction cups | 2B30.36 | |
| UMN, 2B30.36 | suction cups | 2B30.36 | Lift a 6" cube of aluminum with a glass handler's suction cup. |
| PIRA 1000 | soda straw contest | 2B30.40 | |
| UMN, 2B30.40 | soda straw contest | 2B30.40 | Ask how far a person can suck. Start with a 3' tube, then try 6', 12', and 18'. |
| AJP 44(6),604 | inverted glass | 2B30.45 | A 2 m long Plexiglas tube is used for the inverted glass demo. More on dissolved gases in liquid and cavitation using the same tube. |
| D&R, F-310 | inverted glass | 2B30.45 | Fill a glass or funnel with water, place a stiff card over opening and invert. Card remains in place due to atmospheric pressure below card. |
| D&R, F-315 | inverted glass spoof | 2B30.45 | A pop bottle with a hole drilled in the side can be made to release water when inverted by uncovering the hole with a finger. |
| AJP 29(10),711 | card on inverted glass modification | 2B30.46 | Replace the glass by a tube of 50 cm and when half filled, it cannot be inverted. Explanation. |
| D&R, F-305 | egg in a bottle | 2B30.47 | A lit match is put into a milk bottle and a hardboiled egg put on the mouth of the bottle. The egg is pushed into the bottle by atmospheric pressure. |
| TPT, 37(3), 178 | the jumping pencil | 2B30.48 | Atmospheric pressure pushes a pencil out of a bottle. |
| Sut, M-322 | atmospheric pressure demos | 2B30.49 | Four demos: 1) Hollow out a "suction cup" in the bottom of a cork so it will stay stuck at the bottom of a beaker as water is poured in. 2) Lift a heavy object by using rubber suction cups. 3) A smaller test tube is pulled into a larger water filled one as the system is inverted and the water runs out. 4) An aspirator is attached to a glass tube coming out of a sealed bottle of water. |
| PIRA 500 | lift a stool | 2B30.50 | |
| UMN, 2B30.50 | lift a stool | 2B30.50 | Place a square foot of 1/16" rubber on a chair and lift the chair by pulling up on a handle attached to the rubber sheet. |
| Disc 11-19 | rubber sheet lifting chair | 2B30.50 | Lift a chair by placing a thin sheet of rubber with a handle on the seat and pulling up. |
| PIRA 1000 | adhesion plates | 2B30.55 | |
| PIRA 500 | stick and newspaper | 2B30.60 | |
| Mei, 16-4.5 | stick and newspaper | 2B30.60 | Hit and break the protruding part of a stick covered with a newspaper. |
| Disc 11-18 | inertia shingles | 2B30.60 | Break a wood stick protruding from under a paper. |
| PIRA 1000 | vacuum bazooka | 2B30.70 | |
| AJP 74(12), 1071 | vacuum bazooka | 2B30.70 | Simulations and measurements of the shock wave that is produced by the Ping-Pong ball accelerator. |
| AJP 72(7), 961 | vacuum bazooka | 2B30.70 | An analysis of the vacuum cannon and the theoretical maximum velocity the projectile can attain. |

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| Disc 11-15 | vacuum bazooka | 2B30.70 | Put a rubber ball in a tube, seal the ends, evacuate, and puncture the end with the ball. |
| Sut, M-325 | pressure due to height | 2B30.80 | Flames burn the same at ends of a tube when horizontal but with different heights when the tube is vertical. |
| | **Measuring Pressure** | **2B35.00** | |
| PIRA 1000 | mercury barometer | 2B35.10 | |
| UMN, 2B35.10 | mercury barometer | 2B35.10 | A simple mercury barometer. |
| PIRA 1000 | barometer in a tall bell jar | 2B35.15 | |
| Hil, M-22b.1 | barometer in a tall bell jar | 2B35.15 | A tall bell jar containing a mercury barometer is evacuated. |
| Disc 11-10 | barometer in vacuum | 2B35.15 | Evacuate a bell jar containing a barometer. |
| AJP 29(6),369 | balance barometer | 2B35.16 | A very sensitive barometer results when a balance which carries a mercury barometer, in addition to reading the weight of the glass tube, also reads the weight of the mercury column (1671). |
| F&A, Fd-4 | low barometric pressure | 2B35.18 | A bell jar with a 10" barometer is evacuated. |
| PIRA 500 | pull up a mercury barometer | 2B35.20 | |
| UMN, 2B35.20 | pull up a mercury barometer | 2B35.20 | Pull a barometer tube up out of a tall reservoir of mercury. |
| AJP 30(11),807 | pull up mercury barometer | 2B35.20 | Apparatus Drawings Project No.31: A mercury filled tube apparatus with a reservoir deep enough to immerse the entire tube. |
| F&A, Ff-3 | constant height of a barometer | 2B35.20 | A deep vat of mercury allows the height of the tube to be changed. |
| Sut, M-324 | mercury barometer | 2B35.20 | Pull up a mercury filled tube until the mercury falls away. Also the weigh the barometer demo. |
| AJP 57(5),467 | water/gas barometer | 2B35.26 | An accurate, easy to build water/gas barometer of similar size to the usual mercury barometer. |
| PIRA 200 | manometer | 2B35.30 | |
| PIRA 1000 - Old | manometer | 2B35.30 | |
| UMN, 2B35.30 | manometer | 2B35.30 | Simple water and mercury manometers. |
| Mei, 16-4.1 | overhead projector manometer | 2B35.31 | A horizontal manometer for the overhead projector. |
| AJP 29(2),123 | magnifying manometer | 2B35.35 | A mercury manometer that when tipped over backward to an inclined position, has an angle whose sine is 1/10. |
| PIRA 1000 | aneroid barometer | 2B35.40 | |
| F&A, Ff-2 | aneroid barometer | 2B35.40 | A large open aneroid barometer. |
| Hil, M-22b.2 | aneroid barometer | 2B35.40 | Picture of two aneroid barometers. |
| Disc 11-11 | aneroid barometer | 2B35.40 | Blow and suck on a chamber containing an aneroid barometer. |
| TPT 33(4), 224 | balloon barometer | 2B35.45 | A pressure indicator made from a balloon and a 2 liter soda bottle. |
| Mei, 16-4.7 | plastic Torricelli type barometer | 2B35.50 | A Torricelli type barometer made out of Lucite. Diagram. |
| F&A, Ff-1 | bourdon gauge | 2B35.60 | An open Bourdon gauge with a large element. |
| | **Density and Buoyancy** | **2B40.00** | |
| PIRA 200 | weigh submerged block | 2B40.10 | Lower a 3 Kg block of aluminum suspended from a spring scale into water and note the new weight. |
| UMN, 2B40.10 | weigh submerged block | 2B40.10 | Suspend a 3 Kg block of aluminum from a spring scale and then lower the block into water and note the new weight. |
| F&A, Fg-4 | loss of weight in water | 2B40.11 | An aluminum block on a spring scale is lowered into a beaker of water tared on a platform balance. |
| Mei, 8-1.8 | reaction balance | 2B40.12 | A beaker of water tared on a balance is displaced when an empty test tube is immersed. |
| Mei, 16-2.4 | weigh submerged block | 2B40.13 | Immerse a lead block suspended from a counterweighted balance in a beaker of water on a counterweighted platform balance and then transfer a weight to bring the system back into equilibrium. |
| PIRA 1000 | buoyant force | 2B40.14 | |
| Disc 12-11 | buoyant force | 2B40.14 | A weight suspended from a spring scale is lowered into a beaker of water suspended from a spring scale. |
| PIRA 1000 | finger in beaker | 2B40.15 | |
| UMN, 2B40.15 | finger in beaker on balance | 2B40.15 | |
| Bil&Mai, p 188 | finger in a beaker on balance | 2B40.15 | A beaker of water is placed on a balance. Have students predict what the scale reading will be when you insert your finger into the water. |
| AJP 52(2),184 | improved hydrobalance | 2B40.17 | An improvement of the Nicholson hydrometer. |
| F&A, Fg-7 | Nicholson balance | 2B40.17 | A float that allows determination of loss of weight in water very accurately. |
| PIRA 1000 | board & weights | 2B40.18 | |
| UMN, 2B40.18 | board & weights float | 2B40.18 | |
| Disc 12-13 | board and weights float | 2B40.18 | A board sinks equal amounts as equal weights are added. |
| PIRA 200 | Archimedes' principle | 2B40.20 | Suspend a pail and weight from a spring scale, lower the weight into water, collect the overflow, pour it into the pail. |
| 2B40.20 | Archimedes' principle | 2B40.20 | A mass and bucket of the same volume hang from a spring scale. Lower the mass into water, catch the overflow, and pour the overflow into the bucket. |

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| F&A, Fg-1 | Archimedes' principle | 2B40.20 | A cylinder and bucket of the same volume hang from a scale. Immerse the cylinder in water, catch the runoff, pour it back into the bucket. |
| Sut, M-283 | Archimedes' principle | 2B40.20 | Hang a cylinder turned to fit closely inside a bucket from the bottom of the bucket while suspended from the bottom of a balance. Immerse the cylinder in water and then pour water into the bucket. |
| Hil, M-20c | Archimedes' principle | 2B40.20 | The four step Archimedes' principle with a close fitting cylinder and bucket. |
| D&R, F-105 | Archimedes' principle | 2B40.20 | Suspend a pail and weight from a trip balance, lower the weight into water, collect the overflow, and pour into the pail to re-establish balance. |
| Disc 12-12 | Archimedes' principle | 2B40.20 | Suspend a pail and weight from a spring scale, lower the weight into water, collect the overflow, pour it into the pail. |
| Sut, M-284 | Archimedes' principle | 2B40.21 | A beaker with a spout is tared on a balance. As an object is lowered into the water, the overflow is run into a beaker on the table and the balance remains in equilibrium. Also, the instructor puts a hand into a beaker of water in a tared platform balance. |
| AJP 50(11),968 | Archimedes' - historical discussion | 2B40.22 | Archimedes did not experience buoyancy, only how to measure volume. |
| AJP 50(11),968 | Archimedes - historical discusson | 2B40.22 | Volume uncertainties make it impossible to show adulteration. |
| AJP 50(6),491 | Archimedes' original experiment | 2B40.22 | Letter that cautions against misunderstanding Archimedes' crown solution. |
| PIRA 1000 | battleship in a bathtub | 2B40.25 | |
| F&A, Fg-5 | float a battleship in a cup of water | 2B40.25 | A small amount of water floats a wood block shaped to just fit in a graduate. |
| Mei, 16-2.5 | float a battleship in a cup of water | 2B40.25 | A juice can with ballast floats in a 1000 ml graduate. Also - sink the can and look at the water level. |
| Mei, 16-2.6 | float a battleship in a cup of water | 2B40.25 | Float a 2500 g can in 500 g water. |
| D&R, F-130 | battleship in a bathtub | 2B40.25 | A small amount of water floats a wood block shaped to just fit in a tall beaker. |
| Disc 12-17 | battleship in bathtub | 2B40.25 | A block of wood is floated in rectangular container. |
| PIRA 1000 | ship empty and full | 2B40.26 | |
| UMN, 2B40.26 | ship empty and full | 2B40.26 | Add mass to an empty model boat and show pictures of a ship empty and full. |
| UMN, 2B40.26 | battleship in a bathtub | 2B40.26 | Same as TPT 28(7),510. |
| TPT 28(7),510 | battleship in a bathtub | 2B40.26 | Will a cup three quarters full float in a cup one quarter full? |
| TPT 25(1), 48 | metal boats | 2B40.28 | Why do metal boats float? |
| AJP, 78 (2), 139 | metal boats | 2B40.28 | Can bubbles rising through a body of water sink a ship? |
| TPT 25(4), 244 | buoyancy vs. surface area | 2B40.29 | A block with a rock or metal cube tied to the top floats in water. Measure the waterline on the block. Now turn the block over so that the rock is in the water under the block. The waterline is lower (the block floats higher) because of the increase in surface area supplied by the rock. |
| PIRA 200 - Old | Cartesian diver | 2B40.30 | Push on a diaphragm at the top of a large graduate or squeeze a stoppered whisky flask to make the diver sink. |
| UMN, 2B40.30 | Cartesian diver | 2B40.30 | A whiskey bottle version and a large bottle with a rubber bulb version of the Cartesian diver. |
| AJP 48(4),320 | cartesian diver "tricks" | 2B40.30 | Try a sharp blow on the countertop, prepare the diver with water warmer than room temp and allow it to cool during the class, set the diver so it will remain on the bottom after squeezing. |
| AJP 49(1),92 | Cartesian diver | 2B40.30 | Squeeze the flat sides to sink the diver, squeeze the narrow sides to raise the diver. |
| AJP 51(5),475 | Cartesian diver - toys | 2B40.30 | A review of two Cartesian diver toys. |
| AJP 70(7), 710 | Cartesian diver | 2B40.30 | A study of an oscillating Cartesian diver at constant pressure. It sinks if the oscillation gets too large. |
| F&A, Fg-6 | Cartesian diver | 2B40.30 | Push on a diaphragm at the top of a large graduate or squeeze a stoppered whisky flask to make the diver sink. |
| Sut, M-320 | Cartesian diver | 2B40.30 | An inverted test tube diver in a jar. |
| Sut, M-321 | Cartesian diver | 2B40.30 | A small vial Cartesian diver submerged by squeezing the bottle. |
| D&R, F-120 | Cartesian diver | 2B40.30 | A large soda bottle version and a Windex bottle version of the Cartesian diver. Medicine droppers used as the diver. |
| Disc 12-22 | Cartesian diver | 2B40.30 | A buoyant bottle in a water column. |
| AJP 49(12),1185 | double cartesian diver | 2B40.31 | |
| Hil, M-20a.2 | Cartesian diver | 2B40.33 | The picture is unclear, but the diver is in a graduate. |
| TPT 28(7),478 | Cartesian matches | 2B40.34 | Insert matches with the head down. |
| AJP 49(5),507 | buoyant force model | 2B40.37 | A Plexiglas container of agitated plastic spheres forms a "fluid" in which various objects sink or float. |

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| PIRA 500 | buoyancy of air | 2B40.40 | |
| UMN, 2B40.40 | buoyancy of air | 2B40.40 | A brass weight counterbalanced by a aluminum sphere filled with air is placed in a bell jar. |
| F&A, Fg-3 | buoyancy of air | 2B40.40 | A balance with a brass weight and a hollow sphere is placed in a bell jar and evacuated. |
| Mei, 16-2.10 | buoyancy of air | 2B40.40 | A toilet tank float is balanced against brass weights in air and in a vacuum. |
| Sut, M-327 | buoyancy of air | 2B40.40 | A glass ball is balanced with a brass weight in a bell jar and then the air is pumped out. |
| Hil, M-22c | buoyancy of air | 2B40.40 | The Leybold buoyancy of air apparatus. |
| Sprott, 2.17 | buoyancy of air | 2B40.40 | A balance with a brass weight and a hollow sphere is placed in a bell jar and evacuated. |
| PIRA 1000 | buoyancy balloon | 2B40.42 | |
| UMN, 2B40.42 | buoyancy balloon | 2B40.42 | Place a balloon with some powdered dry ice in it on a balance. Tare, and watch as the balloon expands. |
| AJP 48(4),319 | buoyancy balloon | 2B40.42 | Fill a balloon with dry ice, seal it, place it on a scale, and watch the weight decrease as the balloon inflates. Also determine the volume by immersion. |
| PIRA 1000 | helium balloon in a glass jar | 2B40.43 | |
| Disc 12-20 | helium balloon in glass jar | 2B40.43 | A helium balloon floats in an inverted container but sinks when the container is filled with helium. |
| PIRA 1000 | helium balloon in liquid nitrogen | 2B40.44 | |
| Disc 12-21 | helium balloon in liquid nitrogen | 2B40.44 | Cool a helium balloon to decrease its volume and it will no longer float. |
| PIRA 1000 | weight of air | 2B40.45 | |
| UMN, 2B40.45 | weight of air | 2B40.45 | |
| Mei, 16-4.3 | weight of air in a tire | 2B40.45 | A inflated tire is suspended from a heavy duty spring and the air is let out. |
| Sut, M-315 | weight of air | 2B40.45 | Place a large evacuated glass flask on a balance, then let air in and note the increased weight. |
| Hil, M-22a | density of air | 2B40.45 | A one liter flask is tared on a balance, then pumped out and the loss of weight is about one gram. |
| D&R, F-115 | weight of a gas | 2B40.45 | Weigh a 1 gallon deflated Baggie. Fill with air, natural gas, propane, and note changes in apparent mass. |
| Sprott, 2.17 | weight of air | 2B40.45 | Place a hollow sphere on a balance scale and balance with small weights. Evacuate the sphere and rebalance. |
| Disc 12-10 | weight of air | 2B40.45 | A glass sphere is weighed on a pan balance, then evacuated and weighed again. |
| Hil, M-22e.1 | density of hot and cold air | 2B40.46 | Heat one of two cans hanging from a balance. |
| TPT 28(6),406 | CO2 balloon method density of air | 2B40.47 | Use CO2 from carbonated water to fill a balloon for use in measuring the density of air. |
| Mei, 16-4.4 | liquid density comparison | 2B40.50 | Put one branch of a "Y" tube in brine and the other in colored water and suck. |
| F&A, Fh-2 | specific gravity of fluids | 2B40.51 | Water and an unknown liquid are raised to different heights in vertical tubes by a common low pressure. |
| TPT 36(1), 10 | specific gravity with electronic balances | 2B40.52 | Finding the specific gravity of objects using an electronic balance. |
| PIRA 1000 | water and mercury "U" tube | 2B40.53 | |
| F&A, Fh-1 | comparison of fluid densities | 2B40.53 | A "J" tube with mercury in the short side and another fluid in the longer. |
| Disc 12-06 | water and mercury u-tube | 2B40.53 | Water and mercury rise to different heights in a "J" tube. |
| PIRA 1000 | buoyancy in various liquids | 2B40.54 | |
| Disc 12-18 | buoyancy in various liquids | 2B40.54 | Iron, bakelite, and wood are dropped into a column containing mercury, carbon tetrachloride, and water. |
| PIRA 1000 | floating square bar | 2B40.56 | |
| Disc 12-19 | floating square bar | 2B40.56 | A long bar floats in one orientation in alcohol and switches to another orientation when water is added. |
| TPT 24(3), 164 | density of a soft drink | 2B40.57 | Cans of regular Coke and Pepsi sink, diet Pepsi and diet Coke float. |
| D&R, F-110 | density of a soft drink | 2B40.57 | Cans of regular Coke sink, cans of diet Coke float. Will not work with plastic bottles. |
| Bil&Mai, p 190 | density of a soft drink | 2B40.57 | Cans of regular Coke or Pepsi sink, diet Coke and diet Pepsi will float in a container of water. Add salt to the water and the regular Coke or Pepsi will rise. |
| PIRA 1000 | density ball | 2B40.59 | |
| F&A, Fg-2 | buoyancy of hot and cold water | 2B40.59 | A hydrometer is made so it sinks in warm water and floats in cold. |
| D&R, F-135 | density ball | 2B40.59 | A plastic ball will float in salt water but sink in pure water. Create a density gradient so it will float at the halfway mark |
| Disc 12-15 | density ball | 2B40.59 | A metal sphere barely floats in cold water and sinks in hot water. |
| PIRA 1000 | hydrometers | 2B40.60 | |

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| Sut, M-286 | hydrometers | 2B40.60 | A constant weight hydrometer, constant volume hydrometer (Nicholson), and Mohr-Westphal balance are used with liquids of various density. |
| Disc 12-09 | hydrometer | 2B40.60 | A hydrometer is placed in water, then in alcohol. |
| PIRA 1000 | different density woods | 2B40.61 | |
| Disc 12-14 | different density woods | 2B40.61 | Float blocks of balsa, pine, and ironwood in water. |
| Hil, M-20a.3 | density of wood | 2B40.62 | Place a wood dowel in a graduate. |
| F&A, Fi-12 | spherical oil drop | 2B40.65 | Olive oil forms a large spherical drop in a stratified mixture of alcohol and water. |
| Mei, 16-5.7 | large drop | 2B40.65 | A large drop of water is formed in a mixture of benzene and carbon disulfide. Picture. |
| Sut, M-238 | equidensity bubbles | 2B40.65 | Blow a soap bubble with air and then gas to give a bubble of the same density as the surrounding air. |
| Sut, M-245 | equidensity drops | 2B40.65 | A beaker of water has a layer of salt solution on the bottom. Place a drop of mineral oil on top and pipette in some colored salt solution. The drop in an oil sac sinks to the interface. |
| Sut, M-246 | equidensity drops | 2B40.65 | A globule of oil floats at the interface in a bottle half full of water with alcohol on top. |
| Sut, M-244 | equidensity drops | 2B40.65 | Aniline forms equidense and immiscible drops when placed in 25 C water. Pour 80 ml in cool water and heat. |
| Sut, M-243 | equidensity drops | 2B40.65 | Orthotoluidine has the same density as water at 24 C and is immiscible. |
| Mei, 16-2.8 | kerosene/carbon tet. mixtures | 2B40.66 | Kerosene and carbon tetrachloride can be mixed to give .9 g/cc to 1.6 g/cc densities. |
| Mei, 16-2.21 | chloroform bubbles | 2B40.67 | Chloroform bubbles, formed by heating a layer of chloroform covered by a lot of water, move up and down. |
| Sut, M-328 | lifting power of balloons | 2B40.70 | Fill balloons to the same diameter with different gases and show difference in lifting power. |
| Sprott, 2.18 | lifting power of balloons - the impossible balloon | 2B40.70 | A spoof on the lifting power of balloons demonstration. A balloon that has a string through it which is attached to the ceiling appears to have a lifting power greater than permitted by Archimedes' principle. |
| Sprott, 2.19 | lifting power of balloons - neutral buoyancy balloon | 2B40.70 | A helium filled balloon attached to a heavy string rises until its buoyancy just balances its weight plus the string. (Variation on lifting power of balloons). |
| Sut, M-285 | floating and density | 2B40.71 | A tall tube is filled with several immiscible liquids of various densities. Solid objects are inserted that will float at the various interfaces. ALSO, Drop an egg in a tall jar of water and add a handful of salt. |
| Hil, M-20a.4 | adding salt | 2B40.72 | Salt is added to a beaker of water to make a density ball float. |
| Mei, 16-2.7 | kerosene and water | 2B40.73 | Float a test tube in water, kerosene, and a combination. |
| TPT 1(2),82 | freon and air | 2B40.74 | Fill a pan with freon and float a balloon on it to show the difference in density with air. |
| Sut, M-316 | pouring gases | 2B40.75 | Pour sulfuric ether or carbon dioxide into one of two beakers on a platform balance. Shadow projection may be used to make it visible. |
| Sprott, 2.16 | carbon dioxide trough | 2B40.75 | Carbon dioxide pours down a trough and extinguishes candles. |
| Sut, M-317 | gasoline vapors | 2B40.76 | A teaspoon of gas placed at the top on a model staircase with a candle at the bottom. |
| Mei, 16-2.11 | sticking to the bottom | 2B40.80 | Push a rubber stopper that floats on mercury down and squeeze out the mercury between the dish and the stopper. |
| PIRA 1000 | density balls in beans | 2B40.85 | |
| TPT 28(7),500 | rising stones | 2B40.85 | Rising of rocks in the spring is the same as the sifting of fine particles to the bottom of a cereal box. |
| D&R, F-125 | density balls in beans | 2B40.85 | A ping pong ball will rise and a steel ball will sink in a bottle of shaken beans. |
| AJP 73(1), 8 | granular physics | 2B40.85 | A listing of references on the following topics: Packing, Angle of Repose, Avalanches and Granular Flow, Hoppers and Jamming, Vertically Vibrated Induced Phenomena, Avalanche Stratification, and Axial Segregation. |
| TPT 28(2),104 | Beans | 2B40.85 | The size of an aluminum ball determines whether it goes up or down in a shaking bowl of beans. |
| Bil&Mai, p 192 | density balls in beans | 2B40.85 | Bury a 40 mm Ping Pong ball in a bowl of Pinto beans and then place a 40 mm steel ball on top. Shake the bowl and the Ping Pong ball will rise to the top while the steel ball will sink to the bottom. |
| Disc 12-16 | density balls in beans | 2B40.85 | A ping pong ball in the middle of a beaker of beans will rise when the beaker is shaken. |
| | **Siphons, Fountains, Pumps** | **2B60.00** | |
| PIRA 1000 | Hero's fountain | 2B60.10 | |
| UMN, 2B60.10 | Hero's fountain | 2B60.10 | An arrangement of reservoirs connected by tubes that forces a stream of water above the highest reservoir. |

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| F&A, Fc-2 | Hero's fountain | 2B60.10 | A clever arrangement that allows water to fountain higher than the reservoir. |
| Sut, M-280 | Hero's Fountain | 2B60.10 | A variant of Hero's fountain in which water shoots up above the level of the reservoir. Diagram. |
| Bil&Mai, p10 | Hero's fountain | 2B60.10 | A Hero's fountain constructed from 4 L bottles, rubber tubing, glass tubing, and a funnel. |
| Mei, 27-3.2 | fountain in a flask | 2B60.15 | A little water is boiled in a flask, a stopper with a single tube is inserted, the whole thing is inverted into a water reservoir. |
| PIRA 1000 | siphon | 2B60.20 | |
| F&A, Fe-1 | siphon | 2B60.20 | A glass "U" tube demonstrates a siphon. |
| Disc 13-10 | siphon | 2B60.20 | Start with two beakers half full of water and with a connecting hose full of water. Lift one beaker, then the other. |
| Mei, 16-4.12 | siphon in a bell jar | 2B60.23 | Water is transferred through a "U" tube from a sealed flask to an open beaker when the assembly is placed in a bell jar and evacuated. |
| Mei, 16-4.11 | siphons | 2B60.24 | An apparatus that shows atmospheric pressure (not cohesion) to be the basis for the siphon action. |
| Sut, M-281 | pressure measurement in siphon | 2B60.25 | Hook a manometer to the upper portion of a siphon. |
| Sut, M-318 | gas siphon | 2B60.26 | Carbon dioxide is siphoned from one beaker to another. |
| Sut, M-278 | siphons | 2B60.29 | A mechanical model of a siphon consists of chain hung over a pulley to a lower level. A diagram of a intermittent siphon (Tantalus cup) is shown. |
| Mei, 15-10.12 | self starting siphon | 2B60.30 | An inverted "U" tube sealed in the side of a beaker makes a self starting siphon. |
| Sut, M-279 | self-starting siphon | 2B60.30 | A diagram of a self-starting siphon. |
| F&A, Fe-2 | intermittent siphon | 2B60.35 | A funnel with a "?" tube inside makes a self starting intermittent siphon. |
| Hil, M-20a.1 | intermittent siphon | 2B60.35 | The picture looks like the intermittent siphon. |
| PIRA 1000 | Mairotte flask and siphon | 2B60.40 | |
| F&A, Fe-3 | Mariotte flask and siphon | 2B60.40 | A Mariotte flask is used to make a siphon with a constant flow rate. |
| F&A, Fk-1 | Mariotte flask | 2B60.40 | The height of an open tube inserted through the stopper of a jug with an outlet at the bottom regulates flow. |
| PIRA 1000 | hydraulic ram | 2B60.60 | |
| UMN, 2B60.60 | hydraulic ram | 2B60.60 | Same as M-291. |
| AJP 48(11),980 | hydraulic ram | 2B60.60 | Analysis of the hydraulic ram with picture of a demonstration device. |
| Mei, 17-11.1 | hydraulic ram | 2B60.60 | A large quantity of water falling a small height pumps a small quantity of water a large height. |
| Sut, M-291 | hydraulic ram | 2B60.60 | A diagram of how to construct a demonstration hydraulic ram. |
| Hil, M-20d | hydraulic ram | 2B60.60 | A glass model of a hydraulic ram that lifts water higher than the supply. |
| Hil, M-22f.2 | spiral pump | 2B60.70 | A spiral pump made of a glass tube coil. |
| PIRA 1000 | lift pump | 2B60.75 | |
| Hil, M-22f.3 | lift pump | 2B60.75 | A glass model of a lift pump. |
| Hil, M-22f.4 | force pump | 2B60.80 | A glass model of a force pump. |
| Hil, M-22f.5 | hydraulic lift | 2B60.85 | A glass model of a hydraulic lift. |
| | **DYNAMICS OF FLUIDS** | **2C00.00** | |
| | **Flow Rate** | **2C10.00** | |
| PIRA 200 | velocity of efflux | 2C10.10 | |
| PIRA 500 - Old | velocity of efflux | 2C10.10 | |
| UMN, 2C10.10 | velocity of efflux | 2C10.10 | A tall tube of water has holes top, middle, and bottom. Compare the range of the water streams. |
| AJP 73(7), 598 | velocity of efflux | 2C10.10 | A study of the drainage of a cylindrical vessel using video capture so that stream trajectory vs. water height can be plotted. |
| TPT 1(3),126 | velocity of efflux | 2C10.10 | One page analysis and some teaching hints. |
| F&A, Fk-2 | velocity of efflux | 2C10.10 | Small holes are drilled top, bottom, and middle of a cylinder of water. |
| Sut, M-314 | velocity of efflux | 2C10.10 | A tall reservoir of water with holes at different heights. |
| Hil, M-20b.2 | velocity of efflux | 2C10.10 | A bottle has horizontal outlets at three heights. |
| D&R, F-045 | Torricelli's tank | 2C10.10 | Water streams from holes at different heights in a vertical acrylic tube. |
| Disc 13-15 | Toricelli's tank | 2C10.10 | Water streams from holes at different heights in a vertical glass tube. |
| Sut, M-313 | Toricelli's tank | 2C10.11 | Determine the velocity of efflux by the parabolic trajectory method or attach a manometer to the various openings. Holes of different size at the same height show independence of diameter. |
| Mei, 16-2.1 | Mariotte's flask | 2C10.12 | A flask with three holes drilled in the side at different heights is filled with water and closed with a stopper fitted with an open glass tube. The flow from the holes changes as the tube is moved up and down. |
| PIRA 500 | uniform pressure drop | 2C10.20 | |
| F&A, Fj-7 | pressure drop along a line | 2C10.20 | Open tubes along a drain pipe show pressure drop along a line. |
| Sut, M-58 | viscosity | 2C10.20 | A series of small holes in a long 3/4" water pipe shows pressure drop due to friction. Do the same thing with 3/8" gas pipe. |

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| Disc 13-12 | uniform pressure drop | 2C10.20 | Water flows in a horizontal glass tube with three pressure indicating standpipes fitted with wood floats. |
| Sut, M-59 | viscosity | 2C10.22 | Run a water pipe around the lecture hall with pressure gauges at the top and bottom of each side. Show the difference between static and kinetic pressure. |
| PIRA 1000 | syringe water velocity | 2C10.26 | |
| Disc 13-11 | syringe water velocity | 2C10.26 | Squirt water out of a syringe. The water moves faster through the constriction. |
| | **Forces in Moving Fluids** | **2C20.00** | |
| Mei, 17-2.11 | hydrodynamic attraction | 2C20.05 | Move a small sphere in water and another in close proximity will move due to hydrodynamic attraction. Pictures. |
| PIRA 500 | Venturi tubes | 2C20.10 | |
| UMN, 2C20.10 | Venturi tubes | 2C20.10 | Air flows through a restricted tube. Manometers show the pressure differences. |
| F&A, Fj-1 | Venturi tubes | 2C20.10 | Air is blown through a constricted tube and the pressure measured with a manometer. |
| Hil, M-12d | Venturi tubes | 2C20.10 | A series of manometers measures pressure of flowing air at points along a restricted tube. |
| D&R, F-210 | Venturi tubes | 2C20.10 | Air is blown through a constricted tube and the pressures measured with a three-arm manometer. |
| PIRA 200 | Venturi tubes with vertical pipes | 2C20.15 | |
| F&A, Fj-8 | Venturi tubes with vertical pipes | 2C20.15 | Open vertical pipes show the drop in pressure as water flows through a constriction. |
| Sut, M-294 | Venturi tubes with vertical pipes | 2C20.15 | Vertical tubes show the pressure as water flows along a restricted tube. |
| Disc 13-13 | Venturi tubes | 2C20.15 | Three pressure indicating manometers with bright wood floats are located at and on either side of a constriction in a horizontal tube with water flow. |
| PIRA 500 | atomizer | 2C20.20 | |
| F&A, Fj-2 | atomizer | 2C20.20 | A jet of air is blown across one end of a "U" tube. |
| Sut, M-304 | aspirator, etc. | 2C20.21 | Three demos. 1) Water runs through a 1/2 " dia tube constricted to .1". The dissolved water boils in the constriction. 2) Hook a water faucet aspirator to a mercury manometer. 3) Blow one tube across the end of a second vertical tube dipped in water. |
| PIRA 1000 | pitot tube | 2C20.25 | |
| F&A, Fj-11 | pitot tube | 2C20.25 | A small Pitot tube is constructed from glass. |
| Disc 13-01 | pitot tube | 2C20.25 | A pitot tube is connected to a water manometer and the air stream velocity is varied. Graphics. |
| Sut, M-305 | venturi meter | 2C20.26 | A manometer measures the pressure difference between the restricted and unrestricted flow in a tube. |
| PIRA 200 - Old | floating ball | 2C20.30 | A ball is suspended in an upward jet of air. |
| UMN, 2C20.30 | floating ball | 2C20.30 | A ball is suspended in an upward jet of air. |
| Sut, M-292 | floating ball | 2C20.30 | A ping pong ball is supported on a vertical stream of water, air or steam. |
| Hil, M-12b | floating ball | 2C20.30 | Float a ball in an air stream. |
| D&R, F-225, F-230 | floating ball | 2C20.30 | A beach ball, plastic egg, and screwdriver suspended in a upward jet of air. |
| Sprott, 2.2 | floating ball | 2C20.30 | A balloon or ping pong ball is suspended in an upward jet of air. |
| Bil&Mai, p 198 | floating ball | 2C20.30 | A beach ball is supported on a vertical stream of air from a leaf blower. |
| Disc 13-04 | floating ball in air jet | 2C20.30 | A styrofoam ball is suspended in an air jet from a vacuum cleaner. |
| TPT 45(6), 379 | free flowing air stream | 2C20.30 | A demonstration showing that the static pressure in a free air stream is the ambient pressure. |
| F&A, Fj-9 | floating objects | 2C20.31 | Balls, screwdrivers, etc. float in a jet of air. |
| D&R, F-232 | floating object with a leaf blower | 2C20.31 | 2 liter soda bottles, small footballs, file handles, and soda cans suspended in the air stream of a commercial leaf blower with reducing nozzle. Also use the air stream to unroll toilet paper from a dowel rod type dispenser. |
| Mei, 17-2.9 | oscillating floating balls | 2C20.33 | An air jet keeps two balls at the high edge of semicircular tracks. |
| PIRA 200 - Old | funnel and ball | 2C20.35 | Support a ping pong ball by air or water streaming out of an upside-down funnel. |
| UMN, 2C20.35 | ball and funnel | 2C20.35 | Air blowing out an inverted funnel will hold up a ball. |
| F&A, Fj-4 | funnel and ball | 2C20.35 | A ball will stick in the apex of a funnel hooked to an air supply. |
| Sut, M-293 | ball in a funnel | 2C20.35 | A ping pong ball is supported by air or water streaming out of an upside-down funnel. |
| D&R, F-220 | funnel and ball | 2C20.35 | Blow air through an inverted funnel suspending a ball in the apex. |
| Sprott, 2.2 | funnel and ball | 2C20.35 | Air blowing out an inverted funnel will hold up a ball. |
| PIRA 1000 | ball in a stream of water | 2C20.36 | |
| UMN, 2C20.36 | ball in a stream of water | 2C20.36 | Same as AJP 34(5),445. |
| D&R, F-225 | ball in a stream of water | 2C20.36 | A ping pong ball suspended in an upward stream of water. |

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| AJP 34(5),445 | ball in a water stream | 2C20.36 | Drill out a clear Plexiglas tube to different diameters, connect water, and show that the ball sits at the change of diameter despite being tipped upside down. |
| PIRA 200 - Old | lifting plate | 2C20.40 | Air blows radially out between two plates, supporting weights hung from the bottom plate. |
| UMN, 2C20.40 | lifting plate | 2C20.40 | Air blowing out between two horizontal plates supports a mass. |
| F&A, Fj-5 | lifting plate | 2C20.40 | A stream of air flowing radially between two plates will lift the bottom plate. |
| AJP 71(2), 176 | lifting plate | 2C20.40 | Quantitative analysis of the levitation of a large flat plate. |
| Disc 13-05 | suspended plate in air jet | 2C20.40 | Air blows radially out between two plates, supporting weights hung from the bottom plate. |
| Sut, M-295 | lifting plate | 2C20.41 | A pin is stuck through a card and it is inserted into the hole in a wooden spool. Blow in the spool and the card sticks. This can be scaled up if higher air pressure is available. |
| Hil, M-12c | lifting plate | 2C20.41 | Blow into a spool and lift a paper with a pin stuck through into the hole in the spool. |
| D&R, F-215 | lifting plate | 2C20.41 | Blow into a spool and lift a paper with a thumb tack through it inserted into the hole in the spool. |
| AJP 47(5),450 | spin out the air | 2C20.43 | When a disc hanging from a spring scale is mounted just above an identical spinning disc, the spring scale will show an increase in force. |
| PIRA 1000 | coin in cup | 2C20.44 | |
| UMN, 2C20.44 | blow coin into cup | 2C20.44 | Place a coin in the table a few inches in front of a coffee cup, give a puff, and the coin jumps into the cup. |
| PIRA 500 | attracting sheets | 2C20.45 | |
| UMN, 2C20.45 | attracting sheets | 2C20.45 | Blow a stream of air between two sheets of aluminum or aluminum foil. |
| Sut, M-296 | attracting sheets | 2C20.45 | Blow air between two sheets of paper or two large balls and observe the attraction. |
| D&R, F-235 | attracting balls | 2C20.45 | Blow air between two suspended light bulbs or balls and observe the attraction. |
| Sprott, 2.2 | attracting sheets | 2C20.45 | Blow air between two suspended pieces of paper. Observe the attraction. |
| Disc 13-06 | suspended parallel cards | 2C20.45 | Blow an air stream between two parallel cards on bifilar suspensions. |
| F&A, Fj-6 | sticking paper flap | 2C20.46 | A stream of air blown between a paper and a surface will cause the paper to cling to the surface. |
| PIRA 1000 | airplane wing | 2C20.50 | |
| AJP 28(8),ix | airplane wing projection | 2C20.50 | A small cross section of an airplane wing with manometers at various locations is built into a projector assembly. A vacuum cleaner provides the air source. |
| F&A, Fl-1 | wind tunnel | 2C20.50 | An airplane wing element in a small wind tunnel shows lift. |
| Sut, M-302 | airplane wing | 2C20.50 | A balanced model airplane shows lift when a stream of air is directed onto it. |
| Sut, M-301 | airplane wing | 2C20.51 | Hold one edge of a sheet of paper horizontally and let the rest hang. Blow across it and watch the sheet rise. |
| Sut, M-303 | airplane wing | 2C20.52 | Connect a slant manometer to holes on the top and bottom of an airfoil. |
| Mei, 17-2.5 | raise the roof | 2C20.53 | Air blown over a model house raises the roof. Picture. |
| AJP 44(8),780 | paper dirigible | 2C20.54 | A paper loop in an air stream and a falling card. |
| Mei, 17-2.13 | Rayleigh's disk | 2C20.54 | A lightweight disk turns perpendicular to the air flow. |
| AJP 53(6),524 | straight boomerang | 2C20.55 | Make a light straight boomerang from balsa. The theory is different from the usual one. |
| TPT 28(3),142 | boomerang flight | 2C20.55 | An article explaining boomerang flight along with directions for throwing and building one. |
| AJP 45(3),303 | fly wing mechanism | 2C20.56 | How to build a working model of Pringle's fly wing mechanism. |
| AJP 29(7),459 | flying umbrella | 2C20.57 | A motor mounted inside an umbrella is attached to a centrifugal fan mounted above the umbrella pulling air through a hole in the top so it flows down over the side. Develops a few oz of lift. |
| Mei, 17-2.10 | dropping wing sections | 2C20.58 | A folded index card, a paper pyramid, or a paper cone are stable when dropped apex down. |
| AJP 55(1),50 | explaining lift | 2C20.59 | Explain lift based on repulsive forces. |
| TPT 28(2),84 | aerodynamic lifting force explained | 2C20.59 | An article explaining that the longer path length does not cause lift. |
| TPT 28(2),78 | aerodynamic lifting force | 2C20.59 | Lift is explained as a reaction force of the airstream pushed down by the airfoil. Several demonstrations are shown. |
| PIRA 200 - Old | curve ball | 2C20.60 | Use a "V" shaped launcher to throw curve balls. |
| UMN, 2C20.60 | curve ball | 2C20.60 | A sandpaper covered wood track helps give a ball lots of spin. |
| TPT 3(7),320 | curve ball | 2C20.60 | Throw a 3" polystyrene ball with a "V" shaped launcher lined with emery cloth. |

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| F&A, Fj-3 | curved ball trajectory | 2C20.60 | A ping pong ball is thrown with a sandpaper covered paddle. |
| Mei, 17-2.12 | curve ball | 2C20.60 | A "V" shaped launcher lined with styrofoam is used to launch curve balls. |
| Sut, M-299 | autorotation | 2C20.60 | A half round stick used as a propeller will rotate in either direction given a start. |
| Sut, M-297 | curve ball | 2C20.60 | A mailing tube lined with sandpaper helps give spin while throwing curve balls. |
| D&R, F-260 | curve balls | 2C20.60 | A PVC tube lined with sand paper gives spin to Styrofoam balls when thrown. |
| Bil&Mai, p 196 | curve ball | 2C20.60 | Use a sandpaper covered "V" shaped launcher to throw curve balls. |
| Disc 13-03 | curve balls | 2C20.60 | Throw a styrofoam ball with a throwing tube. Animation. |
| Mei, 17-2.1 | spinning ball | 2C20.61 | Direct a high speed stream of air at a ball spinning on a rotating rod free to pivot perpendicular to the air stream. Pictures. |
| Mei, 17-2.3 | spinning ball device | 2C20.62 | A device to spin and throw a ping pong ball. Diagrams and details. |
| AJP 76 (2), 119 | spinning baseball | 2C20.62 | Measurements of the Magnus force on a spinning baseball using a pitching machine and high speed motion analysis system. |
| PIRA 1000 | Bjerknes' tube | 2C20.70 | |
| UMN, 2C20.70 | Bjerknes' tube | 2C20.70 | Cloth webbing wrapped around a mailing tube is jerked out causing the tube to spin through a loop the loop motion. |
| F&A, Fj-10 | Bjerknes' tube | 2C20.70 | Pulling a cord wrapped around a mailing tube spins it into a loop the loop path. |
| Sut, M-298 | Bjerknes' tube | 2C20.70 | Wrap three feet of cloth tape around the middle of a mailing tube and give a jerk. The tube does a loop-the-loop. |
| D&R, F-265 | foam cup loop the loop | 2C20.72 | A stretched rubber band wrapped around two Styrofoam cups attached bottom to bottom will spin through a loop the loop motion. A string wrapped mailing tube will also display this motion when the string is quickly jerked. |
| AJP 47(2),200 | foam cup loop the loop | 2C20.72 | Glue the rims of two Styrofoam cups together and launch by letting them roll off the fingers while throwing. Four glued together works better. |
| PIRA 500 | spinning pen barrel | 2C20.75 | |
| UMN, 2C20.75 | spinning pen barrel | 2C20.75 | Remove the filler from a ball point pen, place under your thumbs at the edge of the lecture bench. Pop the barrel out from under your thumbs giving it lots of spin. |
| PIRA 1000 | Flettner rotator | 2C20.80 | |
| AJP 55(11),1040 | Flettner rotor ship on air track | 2C20.80 | An aluminum can spun with a battery operated motor (and reversing switch) is mounted on an air track cart. A vacuum cleaner exhaust provides the cross wind. |
| Sut, M-300 | Flettner rotator | 2C20.80 | Direct an air stream at a rotating vertical cylinder on a light car. The car will move at right angles to the air stream. |
| Disc 13-02 | Flettner rotator | 2C20.80 | A car with a spinning styrofoam cylinder moves perpendicular to an air stream. Animation. |
| Mei, 17-2.4 | Magnus effect | 2C20.85 | Construction details for a very light cylinder and a method of spinning and releasing. Diagram. ALSO - Vertical motorized cylinder on a cart. |
| TPT 21(5), 325 | frisbee | 2C20.95 | Of frisbees, can lids, and gyroscopic effects. |
| TPT 24(8), 502 | flying ring, Aerobie | 2C20.96 | A description and the aerodynamics of the Aerobie flying ring. |
| TPT 27(5), 406 | flying ring | 2C20.96 | A flying ring that is thrown like a football. Description and construction details. |
| TPT 16(9), 662 | flying ring | 2C20.96 | Why does a cylindrical wing fly? Also construction details. |
| TPT 17(5), 286 | flying ring | 2C20.96 | More on the flying cylinder. |
| | **Viscosity** | **2C30.00** | |
| PIRA 1000 | viscosity disc | 2C30.10 | |
| Sut, M-62 | viscosity disc | 2C30.10 | A horizontal disc is hung on a single thread and a second disc is spun below it causing deflection. |
| Sut, M-61 | viscosity disc | 2C30.11 | A disc is spun between two parallel plates of a platform balance and the deflection is noted. |
| Sut, M-56 | viscosity disc | 2C30.12 | A metal sheet and a disc are mounted parallel in a container of fluid. Rotate the disc and observe the displacement of the sheet by projection. |
| Sut, M-55 | viscosity - viscosimeter | 2C30.13 | Coaxial cylinders are separated by a fluid. As the outer cylinder is rotated, the drag induced motion of the inner cylinder is observed by optical lever magnification. |
| Mei, 17-3.1 | pulling an aluminum plate | 2C30.15 | Use a string and pulley to a mass to pull an aluminum plate out of a viscous fluid ( GE Silicone Fluid, SF-96/10,000). |
| AJP 33(10),848 | viscocity in capillary | 2C30.20 | A Mariotte flask with a capillary out on the bottom permits varying the pressure at cm of water. |
| PIRA 1000 | viscosity of oil | 2C30.25 | |
| F&A, Fm-2 | viscosity of oil | 2C30.25 | Invert several sealed tubes filled with oil. Air bubbles rise. |
| Disc 14-06 | oil viscosity | 2C30.25 | Quickly invert tubes of oil and watch the bubbles rise to the top. |

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| Mei, 17-3.3 | temperature and viscosity | 2C30.30 | Tubes filled with motor oil and silicone oil are inverted at room temperature and after cooling with dry ice/alcohol. |
| Sut, M-57 | viscosity and temperature | 2C30.30 | Rotate a cylinder of castor oil in a water bath on a turntable. Heated from 5-40 C, the viscosity falls 15:1. |
| F&A, Mb-32 | termimal velocity - drop balls | 2C30.45 | Precision ball in a precision tube. |
| PIRA 500 | terminal velocity in water, glycerin | 2C30.50 | |
| UMN, 2C30.50 | terminal velocity in water, glycerin | 2C30.50 | Drop balls in large 1 meter test tubes, one filled with water, the other with glycerine. |
| F&A, Fm-1 | terminal velocity - drop balls | 2C30.50 | A steel ball is dropped into a graduate filled with oil. |
| Disc 14-02 | viscous drag | 2C30.50 | Steel, glass, and lead balls are dropped in a tall cylinder filled with glycerine. |
| Mei, 17-4.1 | terminal velocity - diameter | 2C30.51 | Steel balls of different diameters are dropped in glycerine. |
| Mei, 17-4.3 | terminal velocity - diameter | 2C30.52 | Three steel balls of different diameters are sealed in a 4' tube. Illuminate with a lamp at the bottom. |
| Mei, 17-4.2 | terminal velocity - specific gravity | 2C30.53 | Four balls of the same diameter with carefully adjusted specific gravity are dropped in glycerine. |
| PIRA 1000 | ball drop | 2C30.55 | |
| AJP 34(4),xvii | terminal velocity - styrofoam ball | 2C30.55 | A 2" dia. styrofoam ball reaches terminal velocity in 5 1/2 m. |
| Disc 14-03 | ball drop | 2C30.55 | Several balls including styrofoam balls of three diameters are dropped four meters. Use stop frame and take data. |
| AJP 35(2),xx | terminal velocity - dylite beads | 2C30.56 | Dylite beads reach terminal velocity quickly in water, and when expanded by heating in boiling water, are also useful in air. |
| PIRA 500 | terminal velocity - styrofoam | 2C30.60 | |
| UMN, 2C30.60 | terminal velocity - styrofoam | 2C30.60 | Drop styrofoam half round packing pieces. |
| PIRA 1000 | terminal velocity coffee filters | 2C30.65 | |
| UMN, 2C30.65 | terminal velocity coffee filters | 2C30.65 | Drop a coffee filter and it descends with low terminal velocity. Crumple one and drop it. |
| D&R, M-136 | coffee filters | 2C30.65 | Drop coffee filters with masses of 1and 4 simultaneously. Hold 4 mass filters at twice the height of 1 mass filter. |
| Bil&Mai, p 31 | terminal velocity coffee filters | 2C30.65 | Coffee filters, one crumpled, are dropped over a motion sensor. Compare the graphs. |
| TPT, 37(3), 181 | measuring friction on falling muffin cups | 2C30.65 | Using a set-up of muffin cups and a motion detector to explore terminal velocity. |
| Disc 14-01 | air friction | 2C30.65 | Drop crumpled and flat sheets of paper. |
| | **Turbulent and Streamline Flow** | **2C40.00** | |
| AJP 45(1),3 | swimming bacteria | 2C40.01 | A transcription of an interesting talk about the world of low Reynolds number. |
| PIRA 1000 | streamline flow | 2C40.10 | |
| UMN, 2C40.10 | streamline flow | 2C40.10 | The Cenco streamline flow apparatus. |
| AJP 59(11),1051 | streamline and turbulent flow | 2C40.10 | A simple streamline apparatus for use on the overhead projector that uses a ganged syringe ink source. |
| Sut, M-306 | streamline flow | 2C40.10 | A commercial apparatus to show flow around objects in projection cells. |
| Mei, 17-2.2 | streamline flow | 2C40.11 | Directions for construction a streamline flow apparatus that uses several potassium permanganate tracers. |
| Mei, 17-2.6 | streamlines | 2C40.12 | a simple gravity streamline apparatus. |
| AJP 37(9),868 | streamlines on the overhead | 2C40.14 | Flow is shown between two glass plates from a source point to a collection point. Dilute NaOH passes a ring of phenophthalein beads around the source generating colored trails. |
| Mei, 17-8.2 | inverse square law patterns | 2C40.14 | Inverse-square-law field patterns are illustrated by dyed streamlines of water flowing between two glass plates. Construction details in appendix, p. 620. |
| Sut, M-307 | dry ice fog | 2C40.16 | Some dry ice in a flask of warm water will produce a jet of fog that can be used with a fan to show the effects of various objects on air flow. |
| Sut, M-312 | streamline design | 2C40.17 | The effect of moving air on a disc and streamlined object of the same cross section is demonstrated. |
| Mei, 17-8.1 | fluid mappers | 2C40.18 | Several types of fluid mappers. Pictures and diagrams. Construction details in appendix, p. 614. |
| Sut, M-308 | streamline flow - blow out candle | 2C40.20 | Place a lighted candle on one side of a beaker and blow on the other side to put out the candle. |
| Bil&Mai, p 194 | streamline flow - blow out candle | 2C40.20 | Place a lighted candle on one side of a beaker and blow on the other side to put out the candle. |
| Sut, M-309 | streamline flow - blow over a card | 2C40.21 | A technique to blow a card over using upward curling streamlines. |
| PIRA 1000 | Poiseuille flow | 2C40.25 | |

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| Mei, 17-5.1 | Poiseuille flow | 2C40.25 | Colored glycerine is placed on top of clear glycerine in a square cross sectioned tube and a stopcock is opened at the bottom to adjust flow. |
| Sut, M-310 | streamline flow | 2C40.25 | Watch the interface between clear oil on the bottom of a glass tube and colored oil on top as oil is drawn off the bottom. |
| Sut, M-254 | vena contracta | 2C40.30 | As a liquid emerges vertically downward, its jet contracts in diameter. |
| PIRA 1000 | laminar and turbulent flow | 2C40.50 | |
| UMN, 2C40.50 | laminar and turbulent flow | 2C40.50 | An ink jet is introduced at different rates into a tube of flowing water. |
| F&A, Fk-3 | turbulent flow | 2C40.50 | The velocity of a stream of ink is varied in smoothly flowing water. |
| AJP 28(2),165 | Reynold's number | 2C40.51 | A tapered nozzle introduces tracer fluid into a tube at the bottom of a reservoir. |
| Mei, 17-7.1 | Reynold's number | 2C40.51 | A device for varying the flow in a tube and introducing a tracer into the flow. Several hints. Reference: AJP 28(2),165. |
| Mei, 17-7.2 | Reynold's number | 2C40.52 | A funnel feeds methylene blue into a vertical tube with adjustable water flow. |
| Mei, 17-7.5 | Reynolds' number | 2C40.52 | Water with potassium permanganate flows through a vertical tube. Flow is varied and rate is determined by timing 1 liter. |
| Mei, 17-7.3 | Reynolds' number | 2C40.53 | The flow rate in a long thin brass tube is adjusted until spitting starts. Flow rate is determined by collecting water for a given time. |
| Mei, 17-2.7 | laminar and turbulent flow | 2C40.60 | Shadow project rising warm air flowing around objects. |
| Sut, M-311 | streamline vs. turbulent flow | 2C40.61 | Drop a ball into a viscous liquid or water. Shadow project a hot iron ball in slowly or rapidly moving air. |
| Mei, 17-2.8 | laminar and turbulent flow | 2C40.63 | The Krebs apparatus is used to show flow of water around objects. |
| TPT 12(5),297 | laminar & turbulent flow | 2C40.71 | A discussion of the various types of friction involving the air track. |
| AJP 44(10),981 | stero shadowgraph | 2C40.73 | On viewing fluid flow with stereo shadowgraphs. |
| Hil, M-22c | weather maps | 2C40.80 | Daily weather maps show large scale fluid dynamics. |
| AJP 53(5),484 | Rayleigh-Taylor instability in Prell | 2C40.90 | A air bubble rising in a tube of Prell shampoo demonstrates Rayleigh-Taylor instability. Other examples are given. |
| | **Vorticies** | **2C50.00** | |
| PIRA 200 - Old | smoke ring | 2C50.10 | Tap smoke rings out of a coffee can through a 1" dia. hole. |
| UMN, 2C50.10 | smoke ring | 2C50.10 | Smoke rings are tapped out of a coffee can through a 1" dia. hole. |
| F&A, Fp-1 | vortex rings | 2C50.10 | Tap smoke rings out of a can with a rubber diaphragm on one end and a hole in the other. |
| Sprott, 2.24 | smoke ring | 2C50.10 | A cardboard box with a hole in one side produces smoke ring vortices. |
| Mei, 17-8.6 | smoke rings | 2C50.11 | A rubber sheet at the back on a large wooden box is struck with a hammer to produce smoke rings capable of knocking over a plate. Fuming HCL and conc. ammonia produce the smoke. |
| Hil, S-2i | vortex box | 2C50.12 | A 15 inch square, 4 inch deep vortex box with a 4 inch diameter hole. |
| PIRA 1000 | vortex cannon | 2C50.15 | |
| D&R, F-285, W-005 | vortex cannon | 2C50.15 | Use a large box with a hole in one end and a heavy plastic diaphragm in the other is used to blow smoke rings and blow out candles. |
| Bil&Mai, p 200 | vortex cannon | 2C50.15 | Blow smoke rings with a 5 gallon bucket that has a hole in the bottom and a plastic diaphragm over the top. Use a fog machine to make the "smoke". |
| Disc 13-07 | vortex cannon | 2C50.15 | Use a large barrel to generate a smoke ring. Blow out a candle with the vortex. Animation. |
| PIRA 1000 | liquid vortices | 2C50.20 | |
| Sut, M-253 | liquid vortices | 2C50.20 | A drop of inky water is allowed to form on a medicine dropper 1" above a beaker of water. This height is critical. The vortex will rebound if the beaker is less than 4" deep. |
| Mei, 17-8.4 | ring vortices on liquid | 2C50.21 | Bursts of colored water are expelled from a glass tube in a beaker of water. Also a drop of aniline sinks in a beaker of water. |
| Mei, 17-8.5 | semicircular vortex in water | 2C50.22 | A skill demonstration. Use a small paddle to form vortices in a small dish on the overhead projector. |
| TPT 28(7),494 | detergent vortex | 2C50.23 | A few drops of detergent in a jar of water are shaken and given a twist to form a vortex lasting several seconds. |
| Mei, 17-8.7 | whirlpool | 2C50.25 | Water is introduced tangentially into a cylinder with a hole in the bottom. |
| PIRA 1000 | tornado tube | 2C50.30 | |
| UMN, 2C50.30 | tornado tube | 2C50.30 | |
| F&A, Fp-2 | tornado vortex | 2C50.30 | A vortex forms in a large cylinder on a magnetic stirrer. |
| D&R, F-280 | tornado vortex | 2C50.30 | A vortex forms in a gallon jug when inverted and swirled about the vertical axis. |
| Disc 13-09 | tornado tube | 2C50.30 | Couple two soft drink bottles with the commercial tornado tube coupler and spin the top bottle so the water forms a vortex as it drains into the bottom bottle. |
| PIRA 1000 | flame tornado | 2C50.35 | |
| AJP 37(9),864 | paraboloids and vortices | 2C50.35 | A transparent cylinder is rotated at speeds up to 1000 RPM. |

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| F&A, Fo-1 | growing a large drop | 2C50.40 | A vortex is formed in an air stream allowing one to form a large water drop. |
| | **Non-Newtonian Fluids** | **2C60.00** | |
| Mei, 17-10.1 | fluidization | 2C60.10 | A bed of silica powder acts like a fluid when air is forced through it. Diagram. |
| PIRA 1000 | cornstarch | 2C60.30 | |
| UMN, 2C60.30 | cornstarch | 2C60.30 | Add water to cornstarch until it is goo. Pour it, throw it, punch it. |
| PIRA LOCAL | cornstarch on a speaker | 2C60.32 | Cover a large speaker with Saran wrap. Pour the cornstarch mixture into it and make the mixture "dance" when you run the speaker with a wave generator or music. |
| PIRA 1000 | slime ball | 2C60.35 | |
| D&R, M-846 | slime ball | 2C60.35 | Borax and resin glue will produce an elastic ball. |
| Disc 15-19 | slime ball | 2C60.35 | A commercial product "Slime" flows like a liquid under normal conditions but bounces on impact. |
| PIRA 1000 | silly putty | 2C60.40 | |
| UMN, 2C60.40 | silly putty | 2C60.40 | |
| Sut, M-267 | fluids vs. solids | 2C60.50 | Asphalt splinters when smashed but flows gradually, sand flows when poured but remains in a conical pile. |
| PIRA 1000 | ketchup uzi | 2C60.55 | |
| UMN, 2C60.55 | ketchup uzi | 2C60.55 | Fill a super soaker with ketchup. Shoot it across the room and it blobs on the wall. |

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| | **OSCILLATIONS** | **3A00.00** | |
| | **Pendula** | **3A10.00** | |
| PIRA 200 | simple pendulum | 3A10.10 | Suspend a simple pendulum from a ringstand. |
| UMN, 3A10.10 | simple pendulum | 3A10.10 | Suspend a simple pendulum from a ringstand. |
| D&R, M-900 | simple pendulum | 3A10.10 | A pendulum made from a hacksaw blade with a mass on the end. Length of the pendulum is easily adjusted with a clamp. |
| Bil&Mai, p 172 | simple pendulums | 3A10.10 | A set of 5 pendulums hung from the same support. Three have different lengths strings so that their periods can be compared. Three have different mass bobs but the same length strings so that the effect of mass can be observed. |
| AJP 74(10), 892 | simple pendulum bobs | 3A10.13 | An accurate formula for the period of a simple pendulum oscillating beyond the small angle regime. |
| TPT 15(5),300 | simple pendulum bobs | 3A10.13 | An apparatus for open-ended investigation of the simple pendulum. Bobs have adjustable length and are of different shape. |
| PIRA 1000 | 4:1 pendulum | 3A10.14 | |
| D&R, M-896 | 4:1 pendulum | 3A10.14 | 8 pendula of differing lengths designed to lead students to the conclusion that length and period are related by the square of the period. |
| Disc 08-15 | 4:1 pendula | 3A10.14 | 4:1 pendula have 2:1 period. |
| PIRA 500 | bowling ball pendulum | 3A10.15 | |
| UMN, 3A10.15 | bowling ball pendulum | 3A10.15 | Suspend a bowling ball from the ceiling. |
| PIRA 1000 | different mass pendula | 3A10.17 | |
| Sut, M-81 | lead and cork pendula | 3A10.17 | Long pendula made of lead and cork are released simultaneously. |
| Disc 08-14 | different mass pendula | 3A10.17 | Pendula of the same length and different mass oscillate together. |
| PIRA 500 | upside-down pendulum | 3A10.20 | |
| UMN, 3A10.20 | upside-down pendulum | 3A10.20 | A vertical leaf spring supported at the base has a movable mass. |
| F&A, Mx-6 | inverted pendulum | 3A10.20 | A piece of clock spring mounted vertically on a heavy base has an adjustable mass to change the period. |
| F&A, So-1 | metronome as a pendulum | 3A10.21 | The metronome as an adjustable pendulum. |
| PIRA 500 | torsion pendulum | 3A10.30 | |
| UMN, 3A10.30 | torsion pendulum | 3A10.30 | A metal spoked wheel is suspended as a torsional pendulum by a wire attached to the axle. |
| F&A, Mz-1 | torsion pendulum | 3A10.30 | A wheel is suspended as a physical pendulum by a flexible axle. |
| D&R, M-904 | torsion pendulum | 3A10.30 | A brass disk or bar is suspended as a torsion pendulum by a wire attached to the axle. |
| Disc 08-13 | torsion pendulum | 3A10.30 | Add weight to a torsion pendulum to decrease the period. |
| Mei, 11-2.3h | torsion pendulum | 3A10.31 | A large clock spring oscillates an air bearing supported disc. Vary mass, damping, etc. |
| Hil, M-14g | torsion pendulum | 3A10.31 | A large clock spring oscillates a vertical rod with an adjustable crossbar. |
| Mei, 15-7.1 | torsion pendulum | 3A10.32 | Calculate angular velocity and acceleration with a large slow torsion pendulum that has movable timer contacts. |
| Mei, 15-5.1 | crossed dumbell pendulum | 3A10.34 | Crossed dumbbells with adjustable masses are mounted on an axle as spokes of a wheel. Show the dependence of the period on rotational inertia and on the distance between the center of gravity and axis of the pendulum. |
| Mei, 15-7.2 | torsion pendulum | 3A10.35 | Strobe photography of a torsion pendulum. |
| PIRA 1000 | variable g pendulum | 3A10.40 | |
| Hil, M-14f.2 | variable g pendulum | 3A10.40 | A pendulum with a bifilar support of solid rods can be inclined to decrease apparent g. |
| Disc 08-19 | variable angle pendulum | 3A10.40 | A physical pendulum is mounted on a bearing so the angle of the plane of oscillation can be changed. |
| AJP 52(1),85 | variable g pendulum | 3A10.42 | Use an electromagnet under the pendulum bob to increase the apparent g. |
| Sut, M-129 | variable g pendulum | 3A10.42 | A hidden electromagnet causes a variation in period of a iron pendulum bob. |
| TPT 13(6),365 | variable g pendulum | 3A10.44 | An evaluation of the model M110 Variable g Pendulum manufactured by Physics Apparatus Research Inc. Good pictures of the device for those interested in building their own. |
| Mei, 15-4.1 | cycloidal pendulum | 3A10.50 | Demonstrate that a cycloidal pendulum with any amplitude has a period identical to a equal length simple pendulum at small amplitude. Construction details p. 603. |
| Sut, M-94 | cycloidal pendulum | 3A10.50 | A pendulum made to swing at large amplitude in the cusp of an inverted cycloid is compared to a simple pendulum. |
| Mei, 15-1.14 | nonisochronism of pendulum | 3A10.55 | Two identical pendula, started with large and small amplitudes, have different periods. |

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| AJP 28(1),76 | sliding pendulum | 3A10.61 | A block of dry ice is placed on a large parabolic mirror or bent sheet metal trough or other (i.e., cycloidal) curves. |
| | **Physical Pendula** | **3A15.00** | |
| PIRA 200 | physical pendulum | 3A15.10 | Any distributed mass pendulum. |
| AJP 48(6),487 | physical pendulum set | 3A15.10 | A reconstruction of a nineteenth-century physical pendulum set of four shapes of equal length mounted from a common bar. |
| TPT 28(1),51 | other symmetrical shaped pendula | 3A15.10 | Twenty various physical pendula and are shown. |
| AJP 55(1),84 | balancing man physical pendulum | 3A15.12 | The balancing man usually used to show stable equilibrium is used here as a physical pendulum. |
| Mei, 15-5.2 | rocking stick | 3A15.13 | A meter stick with small masses at the ends rocks on a large radius cylinder. Derivation. |
| PIRA 500 | oscillating bar | 3A15.20 | |
| UMN, 3A15.20 | oscillation bar | 3A15.20 | A bar is suspended from pivots at 1/6 and 1/4 of its length. A companion simple pendulum is used for comparison. |
| TPT 17(1),52 | oscillating bar | 3A15.20 | Analysis of the oscillating bar with a graph of typical data. |
| TPT 12(8),494 | oscillating bar | 3A15.20 | Analysis of the oscillating bar includes suspending the bar from a string. |
| Sut, M-203 | oscillating bar | 3A15.20 | Suspend the meter stick from one end and find the center of oscillation with a simple pendulum of the same period. |
| D&R, M-904 | physical pendulum | 3A15.20 | A board 2 m long with holes drilled every 4 cm from one end to the center. Find the minimum period. |
| Disc 08-18 | physical pendulum | 3A15.20 | Compare the period of a bar supported at the end with a simple pendulum of 2/3 length. |
| Hil, M-14d | two rods and a ball | 3A15.21 | A rod pivots at a point 2/3 l, a second rod 2/3 l pivots at the end, and a simple pendulum has length 2/3 l. Then pivot the long rod from the end and compare periods. |
| PIRA 500 | oscillating hoop | 3A15.25 | |
| UMN, 3A15.25 | oscillating hoop | 3A15.25 | A hoop and pendulum oscillate from the same point. |
| F&A, My-3 | oscillating hoop | 3A15.25 | Adjust a simple pendulum to give the same period as a hoop. |
| PIRA 1000 | paddle oscillator | 3A15.30 | |
| UMN, 3A15.30 | paddle | 3A15.30 | A physical pendulum that oscillates with the same frequency from any of a series of holes. |
| F&A, My-1 | paddle | 3A15.30 | An odd shaped object oscillates from conjugate points that give the physical pendulum equal periods. |
| Mei, 12-3.8 | triangle oscillator | 3A15.31 | Suspend a meter stick four different ways with the same period of oscillation. Holes are drilled on two concentric circles about the center of mass of a large triangle such that the period of oscillation is always the same. |
| F&A, My-8 | bent wire | 3A15.35 | Measure the period of a two corks on a bent wire physical pendulum with the wire bent to various angles. |
| PIRA 500 | truncated ring | 3A15.40 | |
| UMN, 3A15.40 | truncated ring | 3A15.40 | Same as AJP 35(10),971. |
| AJP 35(10),971 | truncated ring | 3A15.40 | Removing any part of the hoop will not change the period. |
| Disc 08-16 | hoops and arcs | 3A15.40 | A hoop oscillates with the same period as arcs corresponding to parts of the hoop. |
| PIRA 1000 | oscillating lamina | 3A15.45 | |
| UMN, 3A15.45 | oscillating lamina | 3A15.45 | Same as TPT 4(2), 78. But where is the reference? |
| PIRA 500 | sweet spot | 3A15.50 | |
| UMN, 3A15.50 | sweet spot | 3A15.50 | A baseball bat on a frame is rigged to show the motion of the handle end when the bat is hit on and off the center of percussion. |
| AJP 44(8),789 | center of percussion | 3A15.50 | Hang a rod from a thin steel rod that acts as both a support and a pivot. A styrofoam ball on the thin rod is an indicator of the motion of the end of the hanging rod. |
| AJP, 73 (4), 330 | a better bat | 3A15.50 | Experimental results on the large amplitude motion of a double pendulum are presented and analyzed. Results show how a "perfect" bat could be designed. |
| F&A, My-7 | sweet spot | 3A15.50 | Hit a baseball bat on a rail suspension at points on and off the center of percussion. |
| D&R, M-694 | sweet spot | 3A15.50 | A baseball bat on a pivot where the hands would be is hit on and off the center of percussion. |
| Bil&Mai, p 214 | sweet spot | 3A15.50 | A baseball bat on a pivot where the hands would be is hit on and off the center of percussion by a baseball suspended from a string. |
| Disc 06-12 | center of percussion | 3A15.50 | Hang a long metal bar by a string from one end. Strike the bar with a mallet at various points. |

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| Mei, 15-6.2 | sweet spot | 3A15.52 | Fire a spring powered gun at a meter stick loosely supported on one end. The top jumps one way or the other when hit off the center of percussion. |
| Sut, M-204 | sweet spot | 3A15.53 | Strike a meter stick supported by a matchstick at its center of percussion. Repeat off the center of percussion and break the matchstick. May be scaled up. |
| Mei, 15-6.1 | sweet spot | 3A15.54 | A bunch of corks sit on a meter stick on the lecture bench. Hit the stick near the end and as it moves down the table the cork at the center of percussion will remain on the stick. |
| F&A, My-5 | sweet spot | 3A15.55 | A rectangular bar suspended by a thread along with an adjustable simple pendulum. Strike the bar. |
| Sut, M-205 | sweet spot | 3A15.55 | Strike a heavy metal bar suspended by a string at various points. |
| F&A, My-4 | sweet spot | 3A15.56 | A rectangular bar is supported as a physical pendulum from one of two pivots along with a simple pendulum. |
| PIRA 1000 | sweet spot of a meter stick | 3A15.57 | |
| UMN, 3A15.57 | sweet spot of a meter stick | 3A15.57 | |
| Mei, 15-3.6 | sweet spot | 3A15.58 | A bat is suspended from a horizontal cable under tension. When struck off the center of percussion, vibrations in the cable cause a neon lamp to light. |
| AJP 49(9),816 | sweet spot analysis | 3A15.59 | The different definitions of the term "sweet spot" are discussed, each one based on a different physical phenomenon. |
| AJP 54(7),640 | analysis of the sweet spot | 3A15.59 | Analysis of the three sweet spots of the baseball bat and the location of the impact point that gives maximum power. |
| AJP 77 (1), 36 | measurements on the swing of a bat | 3A15.59 | Measurements on the swing of a baseball bat are analyzed to extract the basic mechanics of the swing. |
| PIRA 1000 | Kater's pendulum | 3A15.70 | |
| AJP 48(9),785 | Kater's pendulum | 3A15.70 | Modification of a Welch Kater pendulum so that it may be used more systematically and with improved precision to measure the acceleration due to gravity. |
| F&A, My-2 | Kater's pendulum | 3A15.70 | An elaborate pendulum that allows "g" to be determined accurately. |
| TPT 10(8),466 | Kater's pendulum | 3A15.72 | Analysis of: if the center of mass is halfway between the pivots, g cannot be determined from measurements of equal period alone. |
| AJP 69(6), 714 | Kater & Bessel's pendulum | 3A15.73 | A Bessel pendulum is used in the laboratory and measurements of the local acceleration of gravity made to an accuracy of 1 part in 10,000. Physical principles underlying the Kater pendulum as well as Bessel's refinement are also reviewed. |
| | **Springs and Oscillators** | **3A20.00** | |
| PIRA 200 | mass on a spring | 3A20.10 | A mass oscillates slowly on a large spring. |
| UMN, 3A20.10 | mass on a spring | 3A20.10 | A kg and other masses oscillate on a spring with a constant of about 30 N/m. |
| F&A, Mx-3 | mass on a spring | 3A20.10 | Mass on a spring. |
| Disc 08-11 | mass on spring | 3A20.10 | Double the mass on the same spring. Try identical springs in parallel. |
| AJP 49(11),1074 | bouncing students | 3A20.11 | Students are bounced from GM car hood springs. Examine the period with different students on board. |
| TPT 14(3),174 | mass on a spring | 3A20.12 | A shortcut method for constructing a vertical spring oscillator of predetermined period. |
| TPT 16(2),114 | mass on a spring | 3A20.13 | Use a Slinky for a spring and vary k by using different numbers of turns. |
| TPT 14(9),573 | mass on a spring | 3A20.16 | A discussion of the complexities of the vertical mass on the spring in comparison to the horizontal case. |
| PIRA 1000 | springs in series and parallel | 3A20.20 | |
| UMN, 3A20.20 | springs in series and parallel | 3A20.20 | Hang a mass from a spring, 1/2 mass from two springs in series, and 2m from springs in parallel. |
| Disc 08-02 | air track glider and spring | 3A20.30 | An air cart is attached to a single horizontal coil spring. |
| PIRA 200 - Old | air track glider and spring | 3A20.30 | An air cart is attached to a single horizontal coil spring. |
| UMN, 3A20.30 | air track glider and spring | 3A20.30 | An air cart is attached to a single horizontal coil spring. |
| F&A, Mx-7 | air track glider and spring | 3A20.30 | Horizontal mass and single spring on the air track. |
| Mei, 11-1.13 | air track glider and spring | 3A20.31 | Four methods of determining Hooke's law with an air cart and spring. |
| PIRA 1000 | air track glider between springs | 3A20.35 | |
| UMN, 3A20.35 | air track glider between springs | 3A20.35 | |
| Hil, S-1g | air track mass between springs | 3A20.35 | A mass between two springs on an air track. |
| Disc 08-12 | air track simple harmonic motion | 3A20.35 | Place an air track glider between two springs. A video overlay shows the sinusoidal path. |
| Mei, 10-2.13 | dry ice puck oscillator | 3A20.36 | A dry ice puck between two springs on a plate of glass. Projection, photocell velocity measurement, etc. |
| PIRA 1000 | roller cart and spring | 3A20.40 | |
| UMN, 3A20.40 | roller cart and spring | 3A20.40 | Attach a large horizontal compression spring to a large heavy roller cart. |

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| PIRA 1000 | oscillating chain | 3A20.50 | |
| UMN, 3A20.50 | oscillating chain | 3A20.50 | Tie the ends of a short logging chain with heavy thread and suspend the thread over a pulley. |
| F&A, Mz-4 | oscillating chain | 3A20.50 | A chain suspended on both ends by a string which runs over a pulley. |
| Mei, 15-7.3 | oscillating chain | 3A20.50 | Ends of a chain are connected with string and hung over a large pulley. |
| F&A, Mz-5 | "U" tube | 3A20.55 | An open "u" tube filled with mercury. |
| Hil, S-1h | ball in spherical dish | 3A20.60 | A ball oscillates in a clear spherical dish on the overhead. |
| Mei, 15-1.17 | differences in harmonic motion | 3A20.65 | A plastic hemisphere rocking in water has a higher frequency than when rocking on a level surface. |
| Mei, 10-2.14 | diatomic molecule oscillator | 3A20.70 | Two dry ice pucks coupled with vertical hacksaw blades attached to a steel bar. |
| Sut, S-7 | simple non-harmonic motion | 3A20.90 | A light car is fastened between two springs and then between two pulleys with hanging weights. In the second case the period is dependent on amplitude. |
| | **Simple Harmonic Motion** | **3A40.00** | |
| PIRA 200 | circular motion vs. mass on a spring | 3A40.10 | Shadow project a ball at the edge of a disc rotating at the same frequency as a mass on a spring. |
| UMN, 3A40.10 | projected SHM | 3A40.10 | A rotating disc with a ball and a mass on a spring are shadow projected on the wall. |
| Bil&Mai, p 170 | circular motion vs. mass on a spring | 3A40.10 | Shadow project the motion of a dowel on the edge of a turntable rotating at the same frequency as a mass on a spring. |
| D&R, M-876 | projected SHM | 3A40.10 | Shadow project a rotating disk with arrow and a mass on a spring with identical frequencies. |
| Disc 08-20 | circular motion vs. spring and weight | 3A40.10 | Front on view of a marker on a disc and a mass on a spring. |
| Sut, S-5 | circular motion vs.pendulum/spring | 3A40.12 | A bike wheel with a ball mounted on the rim can be oriented with the axle vertical when shadow projected with a pendulum or with the axis horizontal when shadow projected with a mass on a spring. |
| Mei, 10-2.12 | pendulum vs. mass on spring | 3A40.15 | A dry ice puck between two horizontal springs oscillates under a long pendulum. |
| PIRA 200 - Old | circular motion vs. pendulum | 3A40.20 | Shadow project a pendulum and turntable which have identical frequencies. |
| UMN, 3A40.20 | circular motion vs. pendulum | 3A40.20 | Shadow project a pendulum and a turntable with a ball mounted on the rim. |
| Mei, 15-1.2 | pendulum SHM | 3A40.20 | Shadow project a pendulum and turntable which have identical frequencies. |
| Mei, 15-1.4 | pendulum SHM | 3A40.20 | Using a 78 rpm phonograph turntable to synchronize a pendulum and ball on a turntable. |
| Sut, S-3 | pendulum SHM | 3A40.20 | A pendulum bob and shadow projection of circular motion of the same frequency appear coupled. |
| D&R, M-884 | pendulum SHM | 3A40.20 | Shadow project a pendulum and turntable with an arrow on the rim which have identical frequencies. |
| Disc 08-21 | circular motion vs. pendulum | 3A40.20 | Front view of a marker on a disc and a pendulum. |
| TPT 3(3),127 | pendulum SHM | 3A40.21 | A pendulum bob is shadow projected along with a post rotating on a turntable. |
| PIRA 1000 | ball on track vs. pendulum | 3A40.25 | |
| AJP 49(6),557 | portulum | 3A40.27 | In a variation of the simple swinging pendulum, the "portulum", a ball, driven by short blasts of air, rolls along a curved tube. The oscillations of the rolling ball have the same mathematical form as the oscillations of a ball swinging along the same path, but with a lower frequency. |
| PIRA 1000 | arrow on the wheel | 3A40.30 | |
| UMN, 3A40.30 | arrow on the wheel | 3A40.30 | An arrow that can be oriented tangentially or radially is mounted at the edge of a rotating disc and shadow projected on the wall. |
| F&A, Mx-1 | arrow on mounted wheel | 3A40.30 | A large arrow that can be oriented either tangentially or radially is mounted on the periphery of a rotating disc and shadow projected on a screen. |
| Mei, 15-1.1 | mounted wheel | 3A40.30 | An arrow at the edge of a rotating disc that can be oriented radially or tangentially is shadow projected onto a wall. |
| D&R, M-194 | arrow on the wheel | 3A40.30 | Place an arrow on a rotating disk. Project the shadow of the arrow on a screen to show SHM. |
| Sut, S-1 | arrow on the wheel | 3A40.31 | Shadow project a crank handle oriented perpendicular to the wall or screen. |
| AJP 30(6),470 | SHM vectors | 3A40.32 | Three arrows are soldered on a rotating spindle: acceleration, velocity, and displacement vectors. The device is shadow projected on a screen. |
| D&R, M-892 | SHM vectors | 3A40.32 | Same setup as in 3A40.10 but with arrow pointed tangentially to indicate SHM velocity and radially inward to indicate SHM acceleration. |

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| PIRA 1000 | SHM slide | 3A40.35 | |
| UMN, 3A40.35 | SHM slide | 3A40.35 | A motorized device inserted in a lantern slide projector shows a rotating spot and a SHM spot. |
| F&A, Mx-2 | SHM slide | 3A40.35 | A motorized lantern slide showing both rectilinear SHM and uniform circular motion. |
| Sut, S-4 | SHM Slide | 3A40.35 | A projection slide device that shows one spot moving in circular motion and another in SHM. |
| Sut, S-2 | SHM slide | 3A40.36 | Use a scotch cross mechanism (drawing) and mount colored discs on the circular pin and SHM pin. |
| TPT 15(7),436 | SHM on CRO | 3A40.38 | Using electronics and three oscilloscopes to show a spot moving in a circle, up and down with SHM, and a sine wave. A method for doing this sequentially on only one oscilloscope is also given. |
| Sut, S-6 | project SHM | 3A40.40 | Project a beam of light off a mirror on a tuning fork to a rotating mirror onto a screen. |
| PIRA 1000 | tuning fork with light | 3A40.41 | |
| Disc 08-10 | tuning fork with light | 3A40.41 | Attach a small light to a large slow fork and pan it by a video camera. A sine wave is visible by camera retention. |
| AJP 54(10),953 | pendulum interface - Apple II | 3A40.45 | An induced EMF from the magnet bob and an ADC forms the basis for this interface. |
| TPT 17(1),58 | displaying pendulum motion | 3A40.45 | The free end of the pendulum carries a pin electrode in a water trough with electrodes at each end. The signal is displayed on a oscilloscope. |
| Mei, 15-1.7 | plotting SHM | 3A40.48 | A bifilar pendulum with a marker traces on a sheet of wrapping paper advanced by a motor. |
| PIRA 1000 | strain gauge SHM | 3A40.50 | |
| UMN, 3A40.50 | strain gauge SHM | 3A40.50 | A spring and mass are suspended from a Pasco dynamic force transducer and the force is displayed on an oscilloscope. |
| F&A, Mx-4 | strain gauge SHM | 3A40.50 | Mass on spring hangs from a Pasco strain gauge with the output to a oscilloscope. |
| TPT 20(3),186 | mass-spring on scope | 3A40.52 | An optoelectronic device to display the displacement of a mass-spring system on the oscilloscope. |
| Mei, 15-1.6 | mass-spring accelerometer | 3A40.53 | A "U" tube manometer is placed on a cart between springs to show acceleration in SHM. |
| TPT 16(6),404 | acceleration in a pendulum | 3A40.60 | Use the Project Physics accelerometer as a pendulum with a ballistic pendulum suspension. |
| PIRA 1000 | phase shift disc | 3A40.65 | |
| Disc 08-22 | phase shift | 3A40.65 | Shadow project two balls mounted on the edge of a disc. Vary the angle between the balls to vary the phase shift. |
| Mei, 15-1.11 | plotting SHM on the overhead projector | 3A40.71 | An acetate roll is motorized on the overhead projector. Another motor drives a pen in SHM. |
| Mei, 15-1.8 | plotting SHM with spray paint | 3A40.72 | A can of spray paint oscillating between two springs traces on a roll of paper towels pulled uniformly by the instructor. |
| D&R, M-876 | plotting SHM with spray paint | 3A40.72 | A can of spray paint oscillating in unison with a mass on a spring traces on a roll of butcher paper. |
| Mei, 15-1.9 | plotting SHM | 3A40.75 | A large ball oscillates on a spring and a pen on a rider below the ball traces on a roll of moving paper. |
| D&R, M-880 | plotting SHM | 3A40.75 | A salt filled funnel on bifilar suspension traces a sine wave as a piece of paper is moved at constant speed underneath. |
| TPT 10(7),377 | analysis,etc | 3A40.80 | A collection of 16 physical systems which oscillate with SHM and one that does not. Analyses are given for several. |
| Mei, 15-1.5 | plate on drums | 3A40.81 | A plate resting on two oppositely rotating drums (wheels) exhibits SHM. Includes Derivation. |
| AJP 56(12),1151 | "Atwood's" oscillator | 3A40.82 | An advanced SHM system of a weight hanging from the edge of a solid disk weighted with an additional off center mass. |
| TPT 11(1),46 | photographing SHM | 3A40.90 | How to photograph a mass on a spring using a camera and a strobe. Also a hint about using a slit in a cardboard mask in front of an oscilloscope with a sine wave. |
| Mei, 15-1.3 | photographing SHM | 3A40.91 | Take strobe wheel photographs of a pendulum light and a mass on a spring light. |
| Mei, 15-1.10 | photographing SHM | 3A40.93 | Photograph a blinky that translates and oscillates. |
| | **Damped Oscillators** | **3A50.00** | |
| PIRA 500 | dash pot | 3A50.10 | |
| UMN, 3A50.10 | dash pot | 3A50.10 | A mass on a spring has a paddle that can be placed in water for damping. |
| F&A, Mx-9 | dash pot | 3A50.10 | A mass on a spring has an attached dash pot for critical damping. |
| Mei, 15-2.2 | dash pot | 3A50.10 | Three identical masses on springs with different size vanes in water provide under, over, and critically damped oscillations. |

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| Bil&Mai, p 178 | damped mass on spring | 3A50.15 | A 200 gram mass is connected to a digital force probe with a spring and some string. Observe the position-time graph when the system oscillates in air, and then when the mass oscillates in a water filled graduated cylinder. |
| PIRA 1000 | damped SHM tracer | 3A50.20 | |
| UMN, 3A50.20 | damped SHM tracer | 3A50.20 | A mass on a spring holds a magic marker that traces on paper the instructor pulls off a roll. |
| Mei, 11-1.8 | double spring damped air cart | 3A50.40 | A long spring is attached to each end of the air track. Magnets are used for damping. |
| AJP 51(10)954 | small air track oscillator | 3A50.42 | A small specially constructed air track and optoelectric transducer provide output of position vs. time. Details of circuit and description of air track construction are included. |
| PIRA 1000 | oscillating guillotine | 3A50.45 | |
| UMN, 3A50.45 | oscillating guillotine | 3A50.45 | Sets of magnets provide variable damping of an oscillating aluminum sheet. |
| AJP 73(11), 1079 | damped physical pendulum | 3A50.45 | A damped physical pendulum is measured with a data acquisition system. |
| TPT 20(3),188 | bouncing magnets | 3A50.50 | Magnets are levitated on a rod. A large area photocell is used to detect the position of the levitated magnet as it oscillates. |
| Mei, 15-2.1 | tuning fork | 3A50.60 | Display tuning fork vibrations on an oscilloscope. Modeling clay between the forks increases damping. |
| Mei, 15-2.4 | steel bar | 3A50.65 | Apparatus to displace a small steel bar and pick up the vibrations electromagnetically for display on an oscilloscope. |
| Mei, 15-2.3 | ship stabilizer | 3A50.70 | A rocking closed circuit "U" tube half filled with colored water has a rubber hose and tube clamp for adjusting the damping. Demonstrates a ship stabilizing system |
| AJP 30(9),654 | water balloon oscillator | 3A50.75 | Two balloons full of water are mounted on the ends of a glass tube. Flatten one balloon and the system will oscillate about six times. |
| Mei, 15-9.7 | analog computer simulation | 3A50.90 | Simulating an automobile suspension system with an analog computer. |
| | **Driven Mechanical Resonance** | **3A60.00** | |
| PIRA 200 | Tacoma Narrows film | 3A60.10 | A film of the collapse of the bridge due to resonance. |
| UMN, 3A60.10 | Tacoma Narrows film/videodisc | 3A60.10 | The film loop lasts 4:40. The first eleven minutes of the video disc is excellent. |
| TPT 15(3),189 | Tacoma Narrows | 3A60.11 | On building a model of the Tacoma Narrows bridge. |
| AJP 74(8), 706 | engineering analysis of the bridge | 3A60.12 | A physical model for the failure of the Tacoma Narrow bridge. Computational, experimental, and historical data support the model. |
| AJP 59(2),118 | engineering analysis of the bridge | 3A60.12 | Understanding gained from full, dynamically scaled models of the bridge is fundamentally different form the explanation in most physics texts. |
| PIRA 500 | driven glider on air track | 3A60.20 | |
| UMN, 3A60.20 | driven glider on air track | 3A60.20 | A cart is placed between two long springs driven by a variable speed motor. |
| Mei, 11-1.9 | driven glider on air track | 3A60.20 | Drive an air glider between two springs. |
| AJP 31(12),xiii | driven cart between springs | 3A60.24 | A PSSC cart is driven by a ratio motor between two springs. Use eddy current damping. |
| Mei, 15-10.14 | driven cart between springs | 3A60.24 | A more complex driven cart between two springs with eddy current damping and recording. Construction details p. 549. |
| Mei, 15-10.8 | driven cart between springs | 3A60.24 | A cart between stretched rubber bands is driven by an eccentric on a variable speed motor. Eddy current damping. |
| TPT 20(4),257 | driven glider on air track | 3A60.25 | A driven air track cart has an adjustable vane in a tank of water. Graphs of amplitude with varying damping are generated the old fashioned way. |
| PIRA 500 | Barton's pendula | 3A60.30 | |
| UMN, 3A60.30 | Barton's pendula | 3A60.30 | A set of pendula of increasing length are driven in common at varying frequencies. |
| TPT 12(3),178 | Barton's pendula | 3A60.30 | A simple implementation of Barton's pendula. |
| F&A, Sd-1 | Barton's pendula | 3A60.30 | Several pendula of graduated length are hung from the same driven support. |
| Sut, S-20 | Barton's pendula | 3A60.30 | Many of different length small pendula are hung from a rod driven by an adjustable heavy pendulum. |
| PIRA 1000 | resonant driven pendula | 3A60.31 | |
| Disc 09-02 | resonant driven pendula | 3A60.31 | A massive pendulum drives three different length bifilar pendula. |
| PIRA 1000 | bowling ball pendulm resonance | 3A60.35 | |
| TPT 21(5),333 | torsion resonance | 3A60.35 | Driving a torsion pendulum with a jigsaw. |
| Mei, 11-2.3i | torsion resonance | 3A60.35 | An air bearing supported disc/large clock spring arrangement is variably driven. Also vary damping, mass. |
| Disc 09-01 | bowling ball pendulum resonance | 3A60.35 | Strike a bowling ball pendulum with random blows, then with blows at the normal frequency. |

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| AJP 30(2),115 | impulse driven torsional oscillator | 3A60.36 | Apparatus Drawings Project No. 23: Plans for a simple impulse driven torsion pendulum with a natural period of 2 sec. |
| Mei, 15-10.9 | driven torsional oscillator | 3A60.37 | Upper and lower discs are connected by an axial wire. The upper is driven in SHM and the resulting motion of the lower is studied. |
| PIRA 1000 | driven mass on spring | 3A60.40 | |
| Mei, 15-10.11 | driven spring | 3A60.40 | A small DC motor with an eccentric on the shaft is suspended from a spring and run up through the various resonances. |
| Sut, S-13 | driven mass on a spring | 3A60.40 | The vibrator in S-9 is used to drive a vertical mass on a spring to show phase differences above and below resonance. |
| Sut, A-22 | mechanical analog of electrical res. | 3A60.41 | A driven system of a mass hanging between two springs. |
| F&A, Mx-8 | driven resonance tracer | 3A60.42 | A driven mass between two springs carries a felt tip marker that traces on graph paper pulled at a steady rate. |
| PIRA 1000 | driven spring weight | 3A60.43 | |
| Disc 09-03 | driven spring weight | 3A60.43 | Drive a mass hanging from a spring. |
| PIRA 1000 | drunken sailor | 3A60.44 | |
| UMN, 3A60.44 | drunken sailor | 3A60.44 | A hollow toy "Donald Duck" is driven between two vertical springs. Enough "wine" is poured in to reach resonance and then enough "coffee" is poured in to overshoot resonance. |
| F&A, Mx-5 | drunken sailor | 3A60.44 | A bottle (sailor) between two springs is driven at resonance when half full of water. Start empty, add wine to half full, fill with coffee to sober him up. |
| Mei, 15-10.1 | hand driven rubber tube | 3A60.45 | Longitudinal oscillations are induced by hand on a long rubber tube with a wood block attached in the middle. |
| Mei, 15-10.7 | spring driven spring on a spring | 3A60.46 | A large spring and adjustable mass on a lever arm drives a small mass on a spring with provisions for damping. |
| AJP 28(6),534 | driven mass on spring | 3A60.47 | Apparatus Drawings Project No.8: A vertical mass on a spring with a variable frequency driver and adjustable damping. |
| AJP 56(4),352 | driven mass spring apparatus | 3A60.48 | Optical transmission wedges are used to measure positions of both sides of the spring. |
| AJP 55(12),1126 | electromagnetically driven apparatus | 3A60.48 | A magnet hanging on a spring oscillates in a tube with several windings, one serves as a pickup to an oscilloscope, another as a driver, others as means of introducing damping forces. |
| AJP 53(3),278 | electromechanical shaker/accelerometer | 3A60.48 | A small accelerometer is placed on a mass driven by a commercial electromagnetic shaker. |
| PIRA 500 | resonance reeds | 3A60.50 | |
| UMN, 3A60.50 | resonance reeds | 3A60.50 | |
| F&A, Mx-13 | resonance reeds | 3A60.50 | A set of steel reeds is mounted on a common excited strip. |
| Mei, 15-10.4 | resonance reeds | 3A60.50 | A large scale resonance reed set is driven by a motor. |
| Sut, S-15 | resonance reeds | 3A60.50 | A set of resonance reeds is mounted on a slightly unbalanced gyrowheel. |
| Hil, S-4a.2 | resonance reeds | 3A60.50 | A set of resonance reeds is mounted on a out of balance gyroscope. |
| D&R, M-968 | resonance reeds | 3A60.50 | A set of hacksaw resonance reeds clamped to a board are driven by a variable speed drill strapped to the board. |
| Disc 09-05 | reed tachometer | 3A60.50 | A set of reeds is attached to a small unbalanced gyro. |
| Mei, 15-10.3 | resonance reeds | 3A60.51 | A steel bar has pairs of inverted pendula attached along its length. Vibrating a particular rod will cause its mate to vibrate but not the others of different length. |
| Mei, 15-10.5 | resonance reeds | 3A60.53 | A vacuum cleaner motor with an eccentric mass is clamped to a long steel strip hanging over the edge of the lecture bench. |
| PIRA 1000 | driven torsion pendulum | 3A60.55 | |
| AJP 56(9),839 | galvanometer movement resonance | 3A60.56 | A galvanometer movement (observed by reflected laser beam) driven by a slow function generator (observed on an oscilloscope) shows both driving and driven motions. |
| AJP 45(11),1113 | galvanometer movement oscillations | 3A60.56 | Record the motion of the galvanometer movement by modulating the radial magnetic field at a frequency beyond the response of the movement and detecting the induced current. |
| AJP 43(10),926 | galvanometer movement oscillations | 3A60.57 | Drive a wall mount galvanometer (period 20 sec.) with a low frequency signal generator. |
| Sut, S-16 | water dropper resonance | 3A60.58 | The frequency of drops striking a bar clamped at one end is adjusted so that they match the natural frequency of a bar. |
| PIRA 1000 | upside-down pendulum | 3A60.60 | |
| UMN, 3A60.60 | upside-down pendulum | 3A60.60 | Same as Mz-9. |
| F&A, Mz-9 | upside-down pendulum | 3A60.60 | A variable speed motor provides vertical undulatory motion for a vertical rod with an adjustable mass. |
| AJP 53(11),1079 | inverted pendulum - portable jigsaw | 3A60.61 | Strobe pictures along with some theory of an inverted pendulum driven with a portable jigsaw. |

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| AJP 37(9),941 | inverted pendulum - sabre saw | 3A60.61 | Mount a short stick on the blade of an inverted saber saw. |
| AJP 59(9),816 | inverted pendulum - liquid | 3A60.62 | Demonstration and theory of an inverted liquid pendulum. |
| AJP 50(10),924 | inverted pendulum - an analog | 3A60.63 | The inverted pendulum is presented as an analog of the quadrupole mass filter. Theory of the inverted pendulum is discussed. |
| AJP 38(7),874 | inverted pendulum - speaker driven | 3A60.64 | The inverted pendulum is analyzed using a series of short impulses instead of sinusoidal excitation. A large loudspeaker with a 3/4" movement is used to drive simple and compound inverted pendula. |
| Mei, 15-10.2 | upside-down pendulum | 3A60.67 | A massive (20 lb.) weight is bolted to an upright leaf spring from an auto and excited by a thread. |
| PIRA 1000 | lamppost resonance | 3A60.70 | |
| AJP 52(7),662 | lampost resonance | 3A60.70 | A three meter steel rod model of a lampost weighted at the top is easily resonated by hand until a bolt in the support platform breaks. |
| Sut, S-14 | driven conical pendulum | 3A60.75 | A variable length conical pendulum is driven at a single frequency and the phase is compared to a reference. |
| Mei, 15-10.10 | Calthrop resonance pendulum | 3A60.80 | Drive a heavy compound pendulum which in turn drives a light simple pendulum. |
| Sut, S-21 | Rayleigh's driven pendulum | 3A60.81 | Lord Rayleigh's method of suspending a light pendulum from a heavy driving pendulum. |
| Sut, S-140 | pendulum in a dish ???? | 3A60.85 | Some more Phil Johnson humor which reads: "This is a model of aeolian sounds. Read it yourself". A description is: An adjustable period pendulum is dipped into a shallow washbasin of water near the periphery. Rotate the pan until the pendulum reaches maximum oscillations due to eddies forming first on one side, and then on the other. |
| TPT 28(6),417 | paddleball - non SHM | 3A60.89 | A paddleball is a non-SHM system that can be used to demonstrate resonance. |
| | **Coupled Oscillations** | **3A70.00** | |
| PIRA 200 - Old | Wilberforce pendulum | 3A70.10 | Energy transfers between vertical and torsional modes. |
| UMN, 3A70.10 | Wilberforce pendulum | 3A70.10 | A mass on a spring with outriggers is tuned so the three modes of oscillation will couple. |
| F&A, Mx-11 | Wilberforce pendulum | 3A70.10 | The Wilberforce pendulum. |
| Sut, S-18 | Wilberforce pendulum | 3A70.10 | Transfer of energy between torsional vibration and vertical oscillation in the Wilberforce pendulum. |
| Hil, M-14f.1 | Wilberforce pendulum | 3A70.10 | Shows two Wilberforce pendula. |
| Hil, S-4a.4 | Wilberforce pendulum | 3A70.10 | A small Wilberforce pendula. |
| D&R, M-964 | Wilberforce pendulum | 3A70.10 | The Wilberforce pendulum and directions to make one out of a doorspring. |
| Sprott, 1.19 | Wilberforce pendulum | 3A70.10 | A spring pendulum constructed such that the torsional and longitudinal frequencies are nearly identical. Energy is transferred back and forth between the two modes of oscillations. |
| Disc 09-08 | Wilberforce pendulum | 3A70.10 | Energy transfers between vertical and torsional modes. |
| AJP 58(9),833 | Wilberforce pendulum analysis | 3A70.11 | Analysis of the Wilberforce pendulum. Compare theory with experiment. |
| TPT 21(4),257 | Wilberforce pendulum | 3A70.12 | Directions for making an inexpensive Wilberforce pendulum, including winding the spring. |
| AJP 46(1),110 | swinging mass on a spring | 3A70.14 | Derivation with the additional hint that you can use a weak spring by adding a length of string to increase the period of the pendulum motion. |
| PIRA 1000 | swinging mass on a spring | 3A70.15 | |
| UMN, 3A70.15 | swinging mass on a spring | 3A70.15 | The oscillation mode of a mass on a spring couples with the pendulum mode. |
| AJP 44(12),1121 | swinging mass on a spring | 3A70.15 | Analysis of autoparametric resonance that occurs when the rest length of a spring is stretched by about one third by a mass. |
| Mei, 15-1.12 | swinging mass on a spring | 3A70.15 | Oscillations couple if the frequency of a mass on a spring is twice the pendulum mode frequency. |
| AJP 48(6),488 | swinging mass on a spring - uncoupled | 3A70.16 | The special case in which the angular frequency of the spring and the frequency of the pendulum are equal, where the equations of motion actually uncouple and yield independent vertical and pendular motion. The simple apparatus is shown. |
| Mei, 15-1.13 | spring pendulum | 3A70.17 | Time the period of a 12" pendulum, take a 12" spring and add mass until the period is the same. Show the extension is 12" |
| PIRA 200 | coupled pendula | 3A70.20 | Hang two or three pendula from a flexible metal frame. |
| UMN, 3A70.20 | coupled pendula | 3A70.20 | Two pendula are hung from a flexible metal frame. A third can be added. |
| Mei, 15-9.2 | coupled pendula | 3A70.20 | Two bobs suspended from a suspended horizontal dowel. |
| Hil, S-4a.3 | coupled pendula | 3A70.20 | Rods and spring steel support two pendula. The picture is less than clear. |
| F&A, Mx-12 | coupled pendula | 3A70.21 | Three identical pendula are coupled by a slightly flexible support. |
| F&A, Sa-1 | coupled pendula | 3A70.21 | Three identical pendula hang from a slightly flexible stand. |
| F&A, Sa-2 | projection coupled pendula | 3A70.22 | Two small coupled pendula hang from a slightly flexible stand on a clear base. |

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| AJP 70(10), 992 | synchronizing metronomes | 3A70.23 | Multiple metronomes are spaced atop a foam board and started. When the board and metronomes are placed onto two empty soda cans set on their sides, the metronomes quickly synchronize. |
| PIRA 500 | spring coupled pendula | 3A70.25 | |
| UMN, 3A70.25 | spring coupled pendula | 3A70.25 | Two pendula are coupled with a light spring. |
| F&A, Mx-10 | spring coupled pendula | 3A70.25 | Two equal adjustable pendula coupled with a light spring. |
| Mei, 15-9.1 | spring coupled pendula | 3A70.26 | Two identical bobs are coupled with a leaf spring. |
| PIRA 1000 | spring coupled physical pendula | 3A70.27 | |
| Mei, 15-9.3 | coupled pendula | 3A70.27 | Two bowling ball bobs on aluminum rods allowing for length adjustments are coupled with a light spring between the rods. |
| Sprott, 1.18 | coupled pendula | 3A70.27 | A rubber band connects two pendula causing the energy to transfer back and fourth between the two. |
| Disc 09-07 | coupled pendula | 3A70.27 | Two physical pendula are coupled by a spring. |
| PIRA 1000 | string coupled pendula | 3A70.30 | |
| UMN, 3A70.30 | string coupled pendula | 3A70.30 | Pendula are suspended from a horizontal string. |
| AJP 49(12),1245 | string coupled pendula | 3A70.30 | Theory and diagram of the string-coupled pendula. |
| Sut, S-17 | string coupled pendula | 3A70.30 | Two pendula are coupled on a string. Coupling time depends on the string tightness, amplitude depends on the mass. |
| Hil, S-4a.1 | string coupled pendula | 3A70.30 | Two pendula are suspended from a common string. |
| D&R, M-960 | coupled pendula | 3A70.30 | Pendula of the same and different lengths are suspended from a loosely supported horizontal string. |
| Bil&Mai, p 174 | string coupled pendula | 3A70.30 | Six pendula are suspended from a horizontal string. |
| AJP 45(11),1022 | triple pendula | 3A70.31 | A spring coupled triple pendulum used to demonstrate the character of normal modes and in particular a mode that has high Q even with the center pendulum highly damped. This is mathematically similar to the equations of three coupled quantum mechanical levels. |
| AJP 53(11),1114 | resonant double pendulum | 3A70.32 | This double pendulum system with modes that differ by a factor of two has not yet been completely solved. |
| Mei, 15-9.4 | varied length coupled pendula | 3A70.33 | A symmetrical arrangement of seven steel balls are coupled 6" below their anchor points with a long wooden bar through which the cords pass. Energy transfers from one end to the other. |
| AJP 38(4),536 | double simple pendulum | 3A70.35 | Analysis of two masses on the same string with combinations of the masses and strings being equal or unequal. |
| Mei, 15-9.6 | over-under pendula | 3A70.36 | A light pendulum suspended from a heavy pendulum. |
| Mei, 29-4.9 | electrostatically coupled pendula | 3A70.38 | Two pith ball pendula couple only when they are charged with the same polarity. |
| PIRA 1000 | inverted coupled pendula | 3A70.40 | |
| Hil, A-8b | inverted coupled pendula | 3A70.40 | Two vertical hacksaw blades with weights at the top are coupled at the bottom. |
| AJP 69(11), 1191 | inverted coupled pendula | 3A70.40 | Weakly magnetically coupled pendula are studied experimentally, computationally, and theoretically. |
| Mei, 15-9.5 | coupled upside down pendula | 3A70.41 | Two adjustable upside down pendula are coupled with a rubber band. Also shows beats. |
| PIRA 1000 | coupled masses on springs | 3A70.45 | |
| PIRA 1000 | oscillating magnets | 3A70.50 | |
| TPT 18(1),39 | oscillating magnets | 3A70.50 | You really have to see the picture of this to believe it. |
| AJP 76 (2), 125 | oscillating magnets | 3A70.50 | A demonstration of coupled oscillations on magnets suspended by a thread which can act as a pendulum and also exhibit torsion as the magnets align with the Earth's magnetic field. |
| TPT, 36(7), 417 | cheap and easy coupled-oscillations demonstration | 3A70.51 | Long term and accurate coupled oscillations are produced with magnets and a hall probe. |
| AJP 56(3),200 | coupled compass needles | 3A70.55 | Oscillations of two compass needles couple. |
| D&R, M-960, B-060 | coupled compass needles | 3A70.55 | Compasses or magnets in horizontal cradles. Start one oscillating and a nearby one will start oscillating . |
| AJP 28(8),744 | coupled magnets | 3A70.56 | Two magnets are suspended from a suspended wooden wand, all horizontal. Oscillations couple and attain a final north-south alignment. |
| AJP 56(4),345 | ball & curved track pendulum | 3A70.60 | Analysis of the peculiar motion of a quarter circle track pendulum with a ball bearing. |
| AJP 37(8),841 | rotating 2D coupled oscillations | 3A70.70 | Examine the oscillations of a "Y" pendulum as it is rotated at varying speeds. |
| | **Normal Modes** | **3A75.00** | |
| PIRA 500 | coupled harmonic oscillators | 3A75.10 | |
| UMN, 3A75.10 | coupled harmonic oscillators | 3A75.10 | Many identical air track gliders are coupled with springs and driven with a variable frequency motor. |
| AJP 31(12),915 | coupled harmonic oscillators | 3A75.10 | Article on identical spring coupled air gliders includes theory. |
| F&A, Mx-14 | coupled harmonic oscillators | 3A75.10 | Several identical air track gliders are coupled with identical springs. |

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| Mei, 11-1.17 | coupled harmonic oscillators | 3A75.10 | A driven chain of air gliders and springs. Big write up. |
| Mei, 11-1.16 | coupled harmonic oscillators | 3A75.11 | Five blocks coupled with coil springs ride in an air trough. |
| AJP 35(11),1065 | coupled harmonic oscillators | 3A75.12 | A six meter chain of air supported pucks connected by a Slinky. |
| Mei, 10-2.18 | coupled harmonic oscillators | 3A75.12 | Six meters of dry ice pucks on a driven slinky. |
| PIRA 1000 | masses on a string | 3A75.30 | |
| Sut, S-19 | masses on a string | 3A75.30 | Clamp 1,2,3, or 4 equal masses to a variably driven wire to show normal modes. |
| Mei, 18-7.2 | weighted string | 3A75.31 | Small lead weights on a string driven by a large motor show the lower normal modes of a many body system. |
| PIRA 1000 | bifilar pendulum modes | 3A75.40 | |
| Mei, 15-8.2 | bifilar pendulum | 3A75.40 | All three modes of oscillation are discussed for horizontal rods supported with bifilar suspensions. |
| Mei, 15-8.1 | bifilar pendulum | 3A75.40 | Discusses two of three modes - transverse in the plane of the cords and twisting. |
| Mei, 15-10.15 | selsyn motor pendula | 3A75.45 | Pendula are hung from the shafts of two selsyn motors. The second mode can be demonstrated. |
| Mei, 15-10.6 | double pendulum | 3A75.50 | Normal modes of a two pendula spring coupled driven system. |
| AJP 45(9),882 | exposing normal modes | 3A75.80 | When two modes are simultaneously exited, strobing the system at the frequency of one normal mode will allow the other to be observed independently. A double hacksaw system is used as an example. |
| | **Lissajous Figures** | **3A80.00** | |
| PIRA 1000 | Lissajous sand pendulum | 3A80.10 | |
| UMN, 3A80.10 | Lissajous sand pendulum | 3A80.10 | A sand filled compound pendulum traces out a Lissajous pattern. |
| F&A, Sn-2 | sand track Lissajous figures | 3A80.10 | A compound pendulum drops sand out of the pendulum bob in a Lissajous pattern. |
| Sut, S-43 | Lissajous sand pendulum | 3A80.10 | A simple sand pendulum made by passing a bifilar suspension through an adjustable collar. |
| D&R, M-926 | Lissajous sand pendulum | 3A80.10 | A sand or salt filled compound pendulum traces out a Lissajous pattern on black paper. |
| F&A, Sn-1 | Lissajous figures in sand | 3A80.11 | A compound pendulum bob traces a Lissajous figure in sand. |
| AJP 59(4),330 | Blackburn pendulum | 3A80.13 | A historical note on Blackburn's role in the "Y suspended" pendulum. ref: AJP 49,452-4 |
| AJP 38(9),1116 | double pendulum "art machine" | 3A80.15 | Design for a double pendulum machine that draws with a pen. |
| Mei, 15-3.1 | Lissajous figures - double pendulum | 3A80.15 | Two adjustable physical pendula at right angles coupled to a pen. Diagram. |
| PIRA 500 | Lissajous figures - scope | 3A80.20 | |
| UMN, 3A80.20 | Lissajous figures - scope | 3A80.20 | Two generators are fed into the x and y channels of a scope. |
| F&A, Sn-3 | Lissajous figures on the scope | 3A80.20 | Two oscillators generate Lissajous figures of the X and Y channels on an oscilloscope. |
| D&R, M-930 | Lissajous figures - scope | 3A80.20 | Two function generators are fed into the x and y channels of a scope. |
| Disc 08-26 | Lissajous figures - scope | 3A80.20 | Use two independent generators to show Lissajous figures on a scope. |
| Hil, S-1e | Lissajous figures | 3A80.21 | Lissajous figures on a scope and three other methods in a reprint. |
| Mei, 15-3.3 | Lissajous figures - scope | 3A80.22 | Two sine waves are produced by coupling a variable speed motor to one pot in each of two Wheatstone bridge circuits. |
| Sut, S-8 | Lissajous bar | 3A80.30 | An oscillating one meter long bar with the width to length ratio a small integer will show a Lissajous pattern when clamped at one end and viewed from the other. |
| Sut, S-44 | Lissajous figure vibrations | 3A80.35 | A rectangular cross section rod is mounted vertically and the top is bent over at right angles. When the protruding end is struck it will describe Lissajous patterns. |
| PIRA 1000 | Lissajous figures - laser | 3A80.40 | |
| Sut, S-45 | Lissajous figures - projected | 3A80.40 | Use small mirrors on tuning forks to project a beam of light on the wall. |
| Sprott, 6.2 | Lissajous figures - laser | 3A80.40 | A laser beam is reflected off small mirrors glued to two speakers and then onto a screen. Vary the frequency of each speaker with a frequency generator. |
| TPT 17(9),593 | Lissajous figures - projected | 3A80.41 | Bounce a laser off a soap film excited by a audio speaker and a Lissajous figure can be projected onto a screen. |
| Sut, S-46 | Lissajous figures - harmonograph | 3A80.43 | An elaborate apparatus made to reflect beams off mirrors - two oscillations in SHM and one that is the combination. |
| Mei, 15-3.2 | Lissajous figures - projected | 3A80.44 | A sine wave of an integral number of periods is drawn on a clear cylinder. When projected on an overhead, any phase may be obtained by turning the cylinder |
| AJP 47(11),1014 | Lissajous figures - mechanical | 3A80.46 | Chains, gears, etc., that allow control of amplitude, initial phase, and frequency of the two component vibrations. |
| Sut, S-48 | Lissajous figures - 3d | 3A80.50 | An elaborate setup that uses three motors to produce a spot of light on a card that is the result of three mutually perpendicular SHM's. |

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| Sut, S-47 | Lissajous figures - 3d | 3A80.51 | A slit in a lantern projector is driven in SHM and the resulting light beam is projected onto a white pencil mounted on a disc rotated by a motor in the perpendicular direction. |
| AJP 52(7),657 | textbook corrections | 3A80.60 | Most Lissajous figures illustrated in textbooks are wrong. |
| Mei, 15-3.4 | characteristic triangle method | 3A80.90 | A Lissajous ellipse is drawn using the characteristic triangle method. Fully derived instructions. |
| F&A, Sn-3 | Lissajous coordinate system | 3A80.91 | A coordinate system with the grid proportional to the sines of 0, 30, 60, and 90 degrees is sketched on the board. |
| | **Non-Linear Systems** | **3A95.00** | |
| PIRA 1000 | water relaxation oscillator | 3A95.10 | |
| Mei, 33-1.4 | water relaxation oscillator | 3A95.10 | A cylinder is filled with water at a constant rate and periodically empties. |
| AJP 39(5),575 | electrical and water relaxation osc. | 3A95.12 | A water relaxation oscillator models a neon flasher relaxation oscillator. |
| AJP 40(2),360 | pipet rinser oscillator | 3A95.13 | The commercial pipet rinser is a much better relaxation oscillator than that in AJP 39(5),575. |
| UMN, 3A95.15 | wood relaxation oscillator | 3A95.15 | A wood block rides up and slides back on the inside of a turning hoop. |
| PIRA 1000 | wood block relaxation oscillator | 3A95.20 | |
| Mei, 15-10.13 | water feedback oscillator | 3A95.20 | A tubing and bellows arrangement to generate oscillations by feedback. Picture. |
| AJP 45(10),994 | compound pendulum | 3A95.22 | A driven, damped, adjustable compound pendulum for intermediate demonstrations and labs. |
| AJP 51(7),655 | stopped spring | 3A95.25 | Complete discussion and analysis of a stopped spring system. |
| AJP 32(2),xiii | non-linear springs | 3A95.26 | Two springs are attached in a "Y" arrangement, tie a string at two points along a spring so it becomes taut when extended, commercial "constant tension springs". |
| AJP 42(8),699 | rubber band oscillations | 3A95.28 | A review of the foundations a of the rubber band force law and how it applies to the oscillations of a loaded rubber band. |
| TPT 13(6),367 | beyond SHM | 3A95.31 | Shadow project an inertial pendulum onto a selenium photocell and display the resulting voltage on an oscilloscope. Distortion at large amplitude is apparent. |
| AJP 44(7),666 | beyond SHM | 3A95.32 | The design of a pendulum that can demonstrate the dependence of period on amplitude. Common laboratory supplies are used for construction, and timing is done with a stopwatch. Agreement between experimental data and theory to 1 in 1000 is conveniently obtainable. |
| AJP 45(4),355 | large amplitude pendulum | 3A95.32 | Use a rod instead of a string to support the bob and angles can reach 160 degrees. Construction details are given. |
| PIRA 1000 | pendulum with large amplitude | 3A95.33 | |
| Disc 08-17 | pendulum with large amplitude | 3A95.33 | Vary the from 5 to 80 degrees. |
| AJP 40(5),779 | non-harmonic air glider | 3A95.35 | A Jolly balance spring is attached from a point above the middle of an air track to the top of a glider. |
| AJP 50(3),220 | nonlinear air track oscillator | 3A95.36 | A length of rubber perpendicular to the air track axis provides a restoring force. Relative strengths of linear and nonlinear terms can be easily varied. |
| AJP 59(2),137 | saline nonlinear oscillator | 3A95.37 | A small cup with a hole in the bottom and filled with salt water is placed in a large vessel of pure water. The system does all sorts of nonlinear stuff that can be reproduced by numerical simulation. |
| PIRA 1000 | perodic non-simple harmonic motion | 3A95.38 | |
| Disc 08-23 | periodic non-simple harmonic motion | 3A95.38 | A large pendulum drives a restricted vertical pendulum. |
| AJP 53(6),574 | anharmonic LRC circuit | 3A95.41 | A linear LRC circuit demonstrates "soft" and "hard" spring nonlinear resonant behavior. |
| AJP 52(9),800 | anharmonic oscillator | 3A95.43 | An op amp with RC feedback network that behaves as a SHM oscillator for small inputs and then shifts to anharmonic when slew limiting occurs. |
| PIRA 1000 | amplitude jumps | 3A95.45 | |
| AJP 35(10),961 | amplitude jumps | 3A95.45 | Non linear oscillators driven by a variable periodic force: two systems are described. |
| AJP 36(4),326 | anharmonic air track oscillator | 3A95.46 | A driven air cart between two springs has a magnet on top. Perturbations are introduced by other magnets. Jump effect is shown. |
| AJP 38(6),773 | amplitude jumps | 3A95.46 | Use the small Cenco string vibrator to demonstrate amplitude jumps. |
| PIRA 1000 | chaos systems | 3A95.50 | |
| AJP 55(12),1083 | five chaos systems | 3A95.50 | Five simple systems, both mechanical and electronic, designed to demonstrate period doubling, subharmonics, noisy periodicity, and intermittent and continuous chaos. |
| AJP 77 (3), 216 | double pendulum | 3A95.50 | A variation of the simple double pendulum where the two point masses are replaced by square plates. |

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| AJP 60(6), 491 | double pendulum | 3A95.50 | Chaos in the double pendulum system is discussed and experiments to evaluate the sensitive dependence on initial conditions of the motion of the double pendulum are described. |
| Sprott, 1.20 | chaos systems | 3A95.50 | Other chaos systems available for lecture or laboratory exploration. |
| Sprott, 2.26 | chaos system - dripping faucet | 3A95.50 | A dripping faucet illustrates periodic and chaotic behavior |
| AJP 58(1),58 | chaos in the bipolar motor | 3A95.51 | A simple bipolar model demonstrates chaos on the overhead projector. Plots require a digital scope or other equipment. |
| TPT, 37(3), 174 | a chaotic pendulum | 3A95.52 | A cheap and simple chaotic pendulum made with magnets and fishing line. |
| Sprott, 1.20 | a chaotic pendulum | 3A95.52 | A simple chaotic pendulum made with disk magnets, string, and another magnet concealed in a tennis ball. Can be scaled up or down for use on the overhead projector or for a large classroom demonstration. |
| AJP 69(9), 1016 | a chaotic pendulum | 3A95.52 | A cheap magnetically driven chaotic pendulum is analyzed with data acquisition equipment. |
| AJP 71(3), 250 | a chaotic pendulum | 3A95.52 | A commercially available chaotic pendulum connected to an interface. Used to study nonlinear dynamics including the determination of Poincare sections, fractal dimensions, and Lyapunov exponents. |
| TPT 28(1),26 | mechanical chaos demonstrations | 3A95.53 | Three mechanical chaos demonstrations: paperclip pendulum over two disk magnets, balls in a double potential well, ball rolling on a balanced beam. |
| AJP 59(11),987 | inverted pendulum chaos | 3A95.54 | A driven inverted pendulum goes through the transition from periodic to chaotic motion and a sonic sensor is used to get data to a computer which does a FFT to get the power spectrum. |
| Sprott, 4.9 | electronic chaos circuit | 3A95.55 | A specially constructed electrical circuits produce chaotic output that can be seen and heard. |
| AJP 58(10),936 | double scroll chaotic circuit | 3A95.55 | A simple electronic circuit shows double scroll chaotic behavior on an oscilloscope. A simple program to display computer simulation is also included. |
| AJP 53(4),332 | electronic chaos circuit | 3A95.55 | An electronic circuit implementing a coupled logistic equation is used to demonstrate chaotic behavior in one or two dimensions on an oscilloscope |
| AJP 35(1), 31 | chaos of a diode | 3A95.55 | A simple circuit built around a diode that exhibits chaos. |
| PIRA 1000 | parametric resonance | 3A95.60 | |
| AJP 50(6),561 | parametric resonance | 3A95.60 | A connecting-rod crank system to give vertical SHM to a pendulum. The parametric resonance state occurs when the pendulum is driven vertically at twice its frequency. |
| AJP 39(12),1522 | parametric phenomena | 3A95.61 | Parametric excitation of a resonant system is self excitation caused by a periodic variation of some parameter of the system. A brief history. |
| AJP 28(5),506 | pendulum parametric amplifier | 3A95.62 | On using a self-oscillating pendulum driver to demonstrate parametric amplification. |
| AJP 28(2),104 | hula-hoop theory | 3A95.63 | The hula-hoop as an example of heteroparametric excitation. |
| AJP 29(6),374 | magnetic dunking duck | 3A95.66 | Beak on a dunking duck is a magnet that triggers the driving circuit. |
| PIRA 1000 | pump a swing | 3A95.70 | |
| UMN, 3A95.70 | pump a swing | 3A95.70 | Periodically pull on the string of a pendulum. |
| Mei, 15-1.15 | pump a swing | 3A95.70 | A ball on a string hangs over a pulley. Increase the amplitude by pulling on the string periodically. |
| Sut, M-182 | pump a swing | 3A95.70 | Diagram. A electromagnet on a swing allows one to raise and lower the center of mass by a switch. |
| Sut, M-181 | pump a swing | 3A95.70 | Work up a swing by pulling on the cord at the right time. |
| Disc 09-04 | pump pendulum | 3A95.70 | Periodically pull on the string of a pendulum. |
| AJP 38(7),920 | more on pumping a swing | 3A95.71 | A pumped swing is analyzed and demonstrated as a simple pendulum whose length is a function of time. |
| AJP 37(8),843 | pumping a swing comments | 3A95.71 | Also discuss as an example of parametric amplification. Demonstration of the amplification process is shown. |
| AJP 36(12),1165 | pump a swing | 3A95.72 | Analysis and a picture tracing out three and one half cycles. |
| AJP 44(10),924 | swinging | 3A95.73 | Parametric amplification and starting from rest. |
| AJP 38(3),378 | pump a swing | 3A95.73 | The point-mass model of AJP 36(12),1165 prohibits starting from rest. This simplified rigid body model is sufficient to demonstrate the start from rest. |
| AJP 39(3),347 | pump a swing | 3A95.73 | More on the first pump. |
| AJP 40(5),764 | start a swing | 3A95.73 | Now we use a rigid swing support instead of a rope. |
| PIRA 1000 | parametric instability | 3A95.80 | |
| UMN, 3A95.80 | parametric instability | 3A95.80 | Same as AJP 48(3),218. |
| AJP 48(3),218 | parametric instability | 3A95.80 | Two springs in parallel support a block from which a "Y" pendulum swings. The two lowest order resonances are described in detail. |
| | **WAVE MOTION** | **3B00.00** | |

| | Transverse Pulses and Waves | 3B10.00 | |
|---|---|---|---|
| AJP 37(1),52 | Klein-Gordon equation wave model | 3B10.01 | A physical realization of the Klein-Gordon equation. Sort of looks like half a bell labs model but the rods hang down out of a horizontal coil spring. |
| PIRA 1000 | the wave - transverse | 3B10.05 | |
| UMN, 3B10.05 | the wave - transverse | 3B10.05 | Have students in the class do the standard stadium wave. |
| PIRA 200 | pulse on a rope | 3B10.10 | Give a heavy piece of stretched rope a quick pulse. |
| UMN, 3B10.10 | pulse on a rope | 3B10.10 | Create pulses and waves by hand on a long rope stretched across the lecture bench. |
| F&A, Sa-3 | pulse on a rope | 3B10.10 | A heavy piece of stretched rope is given a quick pulse. |
| Sut, S-34 | shake a rope | 3B10.10 | Fix one end of a rope and shake the other. |
| Hil, S-2a.1 | pulse on a spring | 3B10.10 | Two students stretch a spring and one student hits it to give a transverse pulse. |
| D&R, W-010 | pulse on a rope | 3B10.10 | A heavy piece of stretched rope is given a quick pulse. |
| D&R, W-025 | pulse on a spring | 3B10.10 | Stretch a helical spring to show transverse and longitudinal pulses. |
| Disc 09-09 | wave on a rope | 3B10.10 | A long rope is attached to a wall. |
| AJP 35(3),xxi | slow pulse | 3B10.11 | Epoxy split-shot fishing sinkers on model airplane elastic (1/16" x 3/16") every inch to give a wave speed of about 15 m/sec. |
| AJP 43(7),651 | speed of a pulse - stretched string | 3B10.12 | Mount two small pieces of paper on a stretched string so they will interrupt a photocell gate when a pulse from plucking passes by. |
| Mei, 18-3.6 | speed of a pulse in a rope | 3B10.12 | Microswitches at two ends of a stretched rope trigger a timer as a pulse passes. Weights are used at one end to vary the tension. |
| TPT 28(1),57 | pulse speed on a string | 3B10.13 | A pulse on a steel string passes between two magnets and an oscilloscope is used to measure the time between voltage peaks due to the passing pulse. |
| PIRA 1000 | tension dependence on wave speed | 3B10.15 | |
| Sut, S-23 | rope | 3B10.15 | Use pairs of ropes or tubes to compare speed of pulses as tension and mass per unit length are changed. |
| Disc 09-11 | tension dependence of wave speed | 3B10.15 | Hold a rubber tube under different tensions and send a pulse along it. |
| PIRA 1000 | speed of torsional waves | 3B10.16 | |
| Disc 09-13 | wave speed | 3B10.16 | Show the difference in wave speed and pulse shape on Shive machines with long and short rods. |
| PIRA 1000 | speed of a Slinky pulse | 3B10.17 | |
| UMN, 3B10.17 | speed of a Slinky pulse | 3B10.17 | Critically damp one end of a stretched Slinky by hooking over a steel bar. Measure mass per unit length, time a pulse, etc. |
| AJP, 78 (1), 35 | Slinky walking down stairs | 3B10.17 | Motion of a Slinky walking down a set of stairs is modeled. The motion exhibits a periodic gait. |
| PIRA 1000 | speed of pulses on ropes | 3B10.18 | |
| UMN, 3B10.18 | speed of a pulse | 3B10.18 | Pluck two ropes of different mass per unit length, each under the same tension, and compare the speed of the pulses. |
| Sprott, 3.1 | wave speed on a rope | 3B10.18 | The difference in wave propagation speed for transverse waves on ropes of different masses and tensions is illustrated. |
| Mei, 18-8.1 | chain | 3B10.19 | Transverse pulses and waves are demonstrated on a tilted board. ALSO - hanging Slinky. |
| PIRA 500 | Slinky on the table | 3B10.20 | |
| UMN, 3B10.20 | Slinky on the table | 3B10.20 | Create pulses and waves by hand on a Slinky stretched down the lecture bench. |
| F&A, Sa-14 | Slinky on the table | 3B10.20 | A transverse pulse is sent down a Slinky on the table. |
| Sprott, 3.7 | Slinky on the table | 3B10.20 | Show transverse and longitudinal modes with a Slinky. |
| Bil&Mai, p 204 | Slinky on the table | 3B10.20 | Create pulses and waves by hand on a Slinky stretched down the lecture bench. |
| PIRA 1000 | standing pulse | 3B10.25 | |
| UMN, 3B10.25 | standing pulse | 3B10.25 | Same as Sa-5. |
| F&A, Sa-5 | standing pulse | 3B10.25 | A pulse in a loaded rubber tube driven by a motorized pulley remains almost stationary. |
| Mei, 18-3.1 | standing pulse | 3B10.25 | An endless belt running at constant speed over two pulleys is struck with a sharp blow and the pulse is nearly stationary. Picture. Reference AJP 16(4)248; Sutton p.139. |
| Mei, 18-3.3 | stationary pulse | 3B10.25 | A 12' loop of bead chain is suspended over and driven by a large motorized pulley. Ball bearing rollers deform the chain and the pulse moves slowly. |
| Sut, S-29 | stopping a pulse | 3B10.25 | Run a belt over a pulley at a high enough speed so a wave traveling along it appears to stand still. |
| Hil, S-2f | stationary transverse wave | 3B10.25 | An endless belt running over two pulleys. Reference: AJP 16(4),248. |

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| Disc 09-10 | pulse on moving chain | 3B10.25 | A motor drives a large loop of chain suspended between horizontal pulleys. |
| Sut, S-30 | stopping a pulse | 3B10.26 | Suspend a heavy cord formed into a circle from strings below a rotating disc. Spin at speed sufficient that a pulse will appear stationary. |
| PIRA 200 | Shive (Bell Labs) wave model | 3B10.30 | Excite a horizontal torsional wave machine by hand. The other end is open, clamped, or critically damped. |
| UMN, 3B10.30 | Bell Labs wave model | 3B10.30 | Excite a horizontal torsional wave machine by hand. The other end is open, clamped, or critically damped. |
| AJP 31(11),xvi | Bell Labs wave machine | 3B10.30 | Bell Telephone Company wave machine - source of film, booklet, and apparatus (as of 1963). |
| Mei, 18-2.1 | Bell Labs model | 3B10.30 | A long article on the Bell Labs torsional wave model. |
| D&R, W-030 | Bell Labs wave model | 3B10.30 | A horizontal torsion wave machine that is excited by hand. |
| Disc 09-12 | torsional waves | 3B10.30 | Show a torsional wave on a Shive wave machine. |
| AJP 37(1),104 | toothpick wave machine | 3B10.31 | A method of looping No. 32 rubber bands through toothpicks to make a traveling wave machine. |
| AJP 49(4),375 | horizontal torsion bars | 3B10.31 | Use soda straws and seamless elastic to make an inexpensive bell wave motion machine. |
| Mei, 18-8.3 | horizontal torsion bars | 3B10.31 | Wood dowels are mounted to a section of steel tape. |
| TPT, 36(7), 392 | making waves: a classroom torsional wave machine (part 1) | 3B10.31 | Directions for constructing a large scale torsional wave machine. |
| TPT, 36(8), 466 | making waves: a classroom torsional wave machine (part 2) | 3B10.31 | Further discussion of experiments to do using a large scale torsional wave device. |
| F&A, Sa-6 | traveling wave | 3B10.32 | A torsion wave machine hangs from the ceiling. Also, a rope from the ceiling. |
| PIRA 1000 | Kelvin wave apparatus | 3B10.40 | |
| Sut, S-31 | Kelvin wave machine | 3B10.40 | A ladder style hanging wave apparatus with strings for the two sides. |
| Mei, 18-3.2 | stationary pulse - lariat | 3B10.41 | A variable speed motor driven brass chain lariat is struck with a stick and the pulse is stationary at all speeds. simpler version also shown. Diagram and construction details. |
| Mei, 18-2.2 | hanging torsional waves | 3B10.41 | A vertical torsion wave machine made with electrical terminal clips on a rubber tape. Pictures. |
| Sut, S-32 | damped Kelvin wave machine | 3B10.45 | A long steel band with metal crossbars carrying balls on the ends is suspended from a copper disc between the poles of an electromagnet. |
| PIRA 500 | vertical rods wave model | 3B10.50 | |
| Sut, S-26 | vertical rods wave model | 3B10.50 | A wave template is slid under an array of vertical rods. |
| TPT 28(7),508 | transverse wave machine | 3B10.51 | A cheap modern version of a nineteenth century wave machine with vertical rods driven from the bottom by an eccentric. |
| Sut, S-27 | vertical rods wave model | 3B10.51 | The bottoms of a series of identical rods rest on a series of discs mounted eccentrically on a common shaft. The tops of the rods execute a wave when the shaft is rotated. |
| Hil, S-2a.3 | wave generator | 3B10.53 | Picture of a series of balls at different phase angles that seem to be connected to rotating rods. Demonstrates both transverse and longitudinal waves. |
| TPT 3(8),376 | transverse waves on the overhead | 3B10.55 | Four demos: a rotating coil, wave templates, a sinusoidal wave plotter, and a superposition wave adder. |
| Mei, 18-8.4 | project rotating wire | 3B10.56 | A wire spiral is rotated by a motor and projected to demonstrate transverse waves. Construction details. |
| Sut, S-22 | water waves | 3B10.60 | Water waves in a long trough with glass sides. Put a cork in to show particle motion. Show standing waves with proper timing. |
| TPT 28(5),337 | traveling wave on a scope | 3B10.65 | Show a traveling wave near 60 Hz on a line triggered scope and switch to internal triggering to stop the wave, then hold a slit in front of the traveling wave. |
| Sut, S-38 | pendulum waves | 3B10.70 | A row of rods with balls on the ends are hung from pivots that can swing either in the plane of the row or perpendicular to it. Adjustable collars permit varied coupling. Read it. |
| PIRA 1000 | pendulum waves | 3B10.75 | |
| AJP 59(2),186 | uncoupled pendulum waves | 3B10.75 | A set of pendula, started in phase, exhibit a sequence of traveling waves, standing waves, and random motion. Each in the set of successively shorter pendula executes one additional oscillation in the same time interval. |
| AJP 69(7), 778 | pendulum waves | 3B10.75 | The cycling of the pendulum wave patterns arise from aliasing. |
| Disc 08-25 | pendulum waves | 3B10.75 | The apparatus from AJP 59(2),186. |
| AJP 52(9),826 | solitons in a wave tank | 3B10.80 | A 5.5 m wave tank is described along with analysis. |
| UMN, 3B10.85 | non-recurrent wavefronts | 3B10.85 | See Mechanical Universe #18 ch 3-5, film loop Ealing #217. |
| | **Longitudinal Pulses and Waves** | **3B20.00** | |

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| PIRA 1000 | the wave - longitudinal | 3B20.05 | |
| UMN, 3B20.05 | the wave - longitudinal | 3B20.05 | Not the standard stadium wave. The students bump into each other to propagate the wave. |
| PIRA 200 | hanging Slinky | 3B20.10 | A long Slinky is supported on bifilar suspension every four inches. |
| UMN, 3B20.10 | hanging Slinky | 3B20.10 | A long Slinky is supported on bifilar suspension every four inches. |
| F&A, Sa-12 | hanging Slinky | 3B20.10 | Compression pulses are sent along a hanging Slinky. |
| Mei, 18-3.4 | hanging Slinky | 3B20.10 | Time a longitudinal pulse and compare to calculated. ALSO normal mode. |
| Sut, S-39 | hanging Slinky | 3B20.10 | A long helical spring suspended every few turns with a bifilar suspension. Directions for making the spring. |
| Disc 09-15 | longitudinal Slinky waves | 3B20.10 | Show longitudinal waves on a bifilar suspended Slinky with paper flags every fifth coil. |
| Hil, S-2a.2 | stretched Slinky | 3B20.11 | Students stretch a Slinky and send longitudinal waves down from one end. |
| AJP 57(10),949 | wave cutoff with a hanging Slinky | 3B20.12 | Waves do not propagate below a critical frequency if the Slinky is supported by short strings. |
| PIRA 1000 | longitudinal wave on air track | 3B20.20 | |
| F&A, Sa-13 | longitudinal wave on the air track | 3B20.20 | A pulse is sent down a set of gliders coupled with springs on the air track. |
| AJP 33(4),269 | traveling & standing waves/air track | 3B20.21 | Complete discussion of traveling and standing waves on an air track with the critical point being the special mass and damping necessary for the last glider in the traveling case. |
| AJP 50(6),569 | air tube magnetic waves | 3B20.25 | An air tube support magnetically coupled beads for demonstrating longitudinal waves. Replacing half the beads with larger mass demonstrates a different medium. |
| PIRA 1000 | longitudinal wave model (PASCO) | 3B20.30 | |
| UMN, 3B20.30 | springy snow fence | 3B20.30 | The Pasco longitudinal wave machine has vertical rods pivoted at the center and coupled with springs. |
| Disc 09-14 | longitudinal wave model | 3B20.30 | The Pasco device. |
| PIRA 1000 | longitudinal wave machine | 3B20.35 | |
| UMN, 3B20.35 | longitudinal wave machine | 3B20.35 | |
| Sut, S-40 | ball and spring waves | 3B20.40 | A series of croquet balls are hung from bifilar suspensions and connected with coil springs. Balls of different mass can be used. |
| Hil, S-2d | hanging magnets | 3B20.45 | About twenty magnets on bifilar suspension are used to show longitudinal waves. |
| Sut, S-41 | hear the reflection | 3B20.50 | Stretch a stiff helical spring across the room to a sounding board and listen as a longitudinal pulse strikes. |
| PIRA 1000 | speed of particles vs. waves | 3B20.60 | |
| UMN, 3B20.60 | speed of particles vs. waves | 3B20.60 | Same as Sa-11. |
| F&A, Sa-11 | speed of particles, waves | 3B20.60 | A line of sticks with small gaps is pushed from one end. |
| PIRA 1000 | Crova's disc | 3B20.70 | |
| F&A, Sa-15 | Crova's disc | 3B20.70 | Non-concentric circles ruled into a Plexiglas disc appear to be compressions when projected through a slit. |
| Hil, S-7c.2 | Crova's Disc | 3B20.70 | A projection Crova's disc. |
| | **Standing Waves** | **3B22.00** | |
| PIRA 200 | Melde's vibrating string | 3B22.10 | Drive one end of a string over a pulley to a mass with variable frequency SHM |
| UMN, 3B22.10 | Melde's | 3B22.10 | A jigsaw drives a rope at variable speed. |
| F&A, Sa-9 | Melde's | 3B22.10 | A DC motor is driven at variable speeds to generate standing waves on an attached rope. |
| Mei, 18-7.1 | Melde's | 3B22.10 | A 3 m rubber tube with a variable speed drive and high intensity strobe. |
| Mei, 18-5.1 | Melde's | 3B22.10 | A string under tension is driven to show standing waves. |
| Sut, S-35 | Melde's | 3B22.10 | Use a length of white clothesline and a mechanical vibrator to generate standing waves. |
| D&R, W-120 | Melde's vibrating string | 3B22.10 | Drive a string with an electromagnetic vibrator. Run other end of string over a pulley and produce different standing waves by adjusting the tension. |
| D&R, W-125 | Melde's vibrating string variation | 3B22.10 | Substitute the string for a Melde's apparatus with a tapered fishing leader. Decreasing diameter decreases node to node distance. |
| D&R, W-122 | Melde's - DC motor on a string | 3B22.10 | A small unbalanced DC motor and battery are attached to the end of a string and suspended vertically. Varying the string length will produce transverse standing wave patterns and amplitude changes. |
| D&R, W-150 | Melde's - standing waves in a hanging chain or spring | 3B22.10 | Standing waves can be produced in a hanging chain or heavy coil spring with a node at the upper end and an antinode at the lower or free end. Note that it does not matter if the loops in the chain or spring appear to rotate. |

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| Bil&Mai, p 210 | Melde's vibrating string | 3B22.10 | Drive a string with a variable speed hand drill. Run the other end of the string over a ring stand and produce different standing waves by adjusting the tension with a set of masses. |
| Disc 09-28 | rubber tube standing waves | 3B22.10 | A long rubber tube driven by a variable speed motor. |
| AJP 43(10),926 | Melde's driver | 3B22.11 | Bend the clapper away from the magnet of a 110 V ac buzzer. |
| AJP 33(10),856 | Melde's driver | 3B22.11 | Use a dc to ac vibrator-converter for generating ac power from batteries to drive the string. |
| AJP 33(4),340 | driving mechanism for Melde's | 3B22.11 | A quiet double solenoid driver for Melde's operates at line frequency. |
| AJP 50(10),910 | speaker driven string | 3B22.11 | Couple a loudspeaker cone to a string for a variable driver. Use two drivers to show beats. |
| AJP 50(12),1170 | Melde's driver for overhead projector | 3B22.11 | A quiet electromagnetically driven string driver suitable for use on the overhead projector. |
| AJP 36(1),63 | Melde's with fluorescent light | 3B22.11 | On the colors seen with fluorescent light illumination. |
| Mei, 18-7.6 | hair cutter driver | 3B22.11 | A hair cutter powered with a variac is modified to drive a string. |
| Hil, S-2b | Melde's | 3B22.11 | A Melde's driver. Reference: AJP 20(5),310. |
| F&A, Sa-10 | Melde's - tuning fork | 3B22.12 | A tuning fork drives a string into resonances with varied tension. |
| Sut, S-36 | Melde's - tuning fork | 3B22.12 | Vary the tension of yarn driven by an electrically driven tuning fork. |
| Hil, S-2c | tuning fork Melde's | 3B22.12 | An electrically driven tuning fork sets up standing transverse waves in a string. |
| Mei, 18-7.5 | piano wire | 3B22.13 | A motor driven, variable frequency oscillator gives transverse impulses to a stretched piano wire. |
| Mei, 18-5.5 | electromagnetically excited wire | 3B22.14 | An electromagnet is placed at the center of a stretched wire and connected to a signal generator to produce several modes of oscillations. |
| Mei, 18-7.4 | AC driven wire | 3B22.14 | The tension is changed on a wire carrying AC in the field of a magnet and the fundamental and various harmonics are shown. |
| Sut, S-37 | wire standing waves | 3B22.14 | Use iron wire and an electromagnet or AC current and a magnet to generate standing waves in wire. |
| D&R, W-270 | wire standing waves | 3B22.14 | Use iron wire, AC current supplied by a function generator, and a magnet to produce standing waves. Impedance matching may be provided by a speaker transformer. |
| PIRA 1000 | three tensions standing waves | 3B22.15 | |
| Disc 09-27 | three tensions standing waves | 3B22.15 | Three strings driven by the same driver have weights of 0.9:2:8 to produce the first, second, and third harmonics. |
| AJP 43(12),1112 | phase changes in Melde's | 3B22.16 | Show two positions of max amplitude, one red and one blue, with fluorescent lighting and a vibrator synchronous to the lamp flutter. |
| Hil, S-2e.1 | multiple Melde's | 3B22.17 | The same motor drives two horizontal strings and one vertical string of equal length. All strings are in resonance. |
| Mei, 18-5.4 | AC heated stretched nichrome wire | 3B22.18 | Standing waves are produced by stretching nichrome wire and heating with AC. |
| D&R, W-105 | wire standing waves | 3B22.18 | Run AC through a stretched iron wire. Add magnet at various locations to make desired standing waves. Turn up AC until nodes glow red. |
| Mei, 18-5.3 | air driven rubber tube | 3B22.21 | Standing waves are produced in a stretched rubber tube by a jet of air. |
| Sut, S-33 | nice wave machine | 3B22.22 | A weighted rubber tube is hung horizontally from the ends of short pivoted and counterweighted bars. Friction adjustments at the pivots allow any amount of energy to be absorbed. When driven from one end, many wave properties may be shown. |
| Mei, 18-5.11 | stroboscopic projection with wire | 3B22.25 | Waves in a wire are stroboscopically projected. |
| Mei, 18-5.10 | projecting a standing wave on a wire | 3B22.25 | A rotating mirror arrangement projects the shape of a standing wave on a wire. |
| PIRA 500 | Shive /Bell Labs standing waves | 3B22.30 | |
| UMN, 3B22.30 | Bell Labs standing waves | 3B22.30 | Excite the Bell Labs machine at various rates to obtain standing waves with one, two, and three nodes. |
| Disc 09-26 | standing waves | 3B22.30 | Drive the Shive wave machine by hand to produce standing waves. |
| PIRA 1000 | vertical vibrating bar | 3B22.40 | |
| AJP 48(9),786 | vertical vibrating bar | 3B22.40 | Vibrate a yardstick or meter stick by hand through the fundamental and first overtone. Due to the rule, the position of the node can be measured easily. |
| Mei, 18-7.3 | transverse waves in a rod | 3B22.40 | Hold a long rod at the center or at an end and vibrate it at the natural frequency with the other hand. ALSO - chalk squeak and breaking. |
| Sut, S-135 | vertical steel bar Melde's | 3B22.41 | A vertical steel bar is clamped vertically and driven mechanically through the first three harmonics. |
| Mei, 18-5.9 | free boundary hanging tube | 3B22.45 | A support designed to excite a hanging tube while maintaining free boundary conditions. |
| PIRA 1000 | Slinky standing waves | 3B22.50 | |

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| UMN, 3B22.50 | Slinky standing waves | 3B22.50 | |
| Disc 09-25 | Slinky standing waves | 3B22.50 | Drive a hanging Slinky by hand to produce standing waves. |
| AJP 55(7),666 | hanging spring standing waves | 3B22.51 | A solenoid drives a magnet attached to a hanging spring. |
| Hil, S-2e.2 | hanging Slinky standing waves | 3B22.51 | A motor oscillator drives a hanging Slinky. |
| Mei, 18-5.2 | driven jolly balance spring waves | 3B22.52 | A tuning fork drives a jolly balance spring to produce standing longitudinal waves. A lantern projector with a rotating disk slows the motion stroboscopically. |
| PIRA 1000 | longitudinal standing waves | 3B22.60 | |
| Disc 09-24 | longitudinal standing waves | 3B22.60 | Excite the Pasco longitudinal waves machine to get standing waves. |
| Mei, 18-5.8 | magnetostrictive standing waves | 3B22.65 | A feedback circuit to a coil around a nickel rod drives magnetostrictive standing waves indicated by a ball bouncing at one end. |
| PIRA 1000 | soap film oscillations | 3B22.70 | |
| Mei, 18-5.7 | soap film standing waves | 3B22.70 | Large wire frames dipped in soap film are manipulated by hand to produce standing waves. Nice pictures. |
| Sut, S-105 | standing waves | 3B22.75 | Use a sensitive flame to detect standing waves from a loudspeaker between two boards. |
| TPT, 37(4), 228 | standing microwaves on the overhead projector | 3B22.80 | Using a microwave/overhead set-up, quantitatively illustrate standing waves to a large lecture. |
| PIRA 1000 | crank slide | 3B22.90 | |
| UMN, 3B22.90 | crank slide | 3B22.90 | Same as Sa-8. |
| F&A, Sa-8 | traveling and standing wave models | 3B22.90 | A projection device that gives the appearance of waves traveling in opposite directions and the sum of the waves. |
| Sut, S-25 | crank wave model | 3B22.90 | Wire helixes turned about their axes in a lantern projector appear as waves traveling in opposite directions. An additional bent wire shows the resulting standing wave. |
| D&R, W-045, W-115 | crank wave model | 3B22.90 | Wire helixes made from a Slinky and turned about their axes on the overhead show traveling waves. |
| AJP 44(3),284 | analog computer simulation | 3B22.99 | An analog computer used with a dual trace storage scope to demonstrate traveling and standing waves. |
| | **Impedance and Dispersion** | **3B25.00** | |
| PIRA 500 | impedance matching - Shive model | 3B25.10 | |
| UMN, 3B25.10 | impedance matching - Bell model | 3B25.10 | Two sections of a horizontal torsion machine with different lengths are joined abruptly for unmatched coupling and with a section of gradually lengthening rods for matched coupling. |
| F&A, Sa-7 | wave reflection at a discontinuity | 3B25.10 | Two Bell Labs torsion machines with different length rods are hooked together. |
| Disc 09-19 | wave coupling | 3B25.10 | Shive wave machines with long and short rods are coupled abruptly or with a tapered section. |
| Sut, S-24 | impedance mismatching in rope | 3B25.15 | Pulses are sent down a cord with part of its length half the diameter of the other part. |
| PIRA 1000 | reflection - Shive model | 3B25.20 | |
| UMN, 3B25.20 | reflection - Bell labs | 3B25.20 | |
| Disc 09-17 | reflection of waves | 3B25.20 | A pulse sent down a Shive wave machine reflects from either a fixed or free end. |
| PIRA 1000 | spring wave reflection | 3B25.25 | |
| Disc 09-18 | spring wave reflection | 3B25.25 | Reflections from a long horizontal brass spring with fixed and free ends. |
| PIRA 1000 | fixed and free rope reflection | 3B25.26 | |
| UMN, 3B25.26 | fixed and free rope reflection | 3B25.26 | Tie a rope to a bar with a loose knot or tie it to a clamp. |
| AJP, 65(4), 310-313 | transverse standing waves in a string with free ends | 3B25.26 | A nice demonstration of standing waves with free ends using a long soft spring, and the Pasco mechanical wave driver. |
| PIRA 1000 | effect of bell | 3B25.30 | |
| PIRA 1000 | acoustic coupling with speaker | 3B25.35 | |
| Disc 10-17 | acoustic coupling | 3B25.35 | Sound a 2" loudspeaker alone and with an exponential horn. |
| PIRA 1000 | soundboard | 3B25.40 | |
| PIRA 1000 | dispersion in a plucked wire | 3B25.50 | |
| Mei, 18-3.5 | dispersion in a plucked wire | 3B25.50 | A crystal phonograph cartridge attached to one end of a long stretched wire will pick up the reflected waves when plucked. |
| AJP 55(2), 130 | Slinky whistlers | 3B25.51 | Audible whistlers from a Slinky. |
| AJP 55(10), 952 | Slinky whistlers | 3B25.51 | A correction to AJP 55(2), 130. |
| AJP 58(10),916 | Slinky-whistler dispersion | 3B25.51 | An analysis of and directions for performing the Slinky-whistler dispersion. |
| PIRA 1000 | space phone (spring horn toy) | 3B25.55 | |
| UMN, 3B25.55 | space phone | 3B25.55 | |
| TPT 27(3), 201 | whistlers | 3B25.55 | Producing whistlers in a stretched spring that is tapped with a pencil. |

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| Sut, S-54 | dispersion | 3B25.55 | A long helical coil of fine wire transmits sound slowly. Speak into a sound box on one end and somewhat distorted sound emerges. |
| AJP 36(11),1022 | echoes in a pipe | 3B25.62 | A 10" dia 85' tube yields five clearly discernible echoes. |
| AJP 38(3),378 | chirped handclaps | 3B25.65 | Clap your hands while standing next to a corrugated wall. |
| TPT 21(9), 605 | whistlers/chirps | 3B25.65 | How the whistler is produces by high frequency sound arriving before the low frequencies. |
| AJP 59(2),175 | racquetball court whistlers | 3B25.65 | Whistlers rise in frequency in the racquetball court. |
| AJP 41(7),857 | chirp radar | 3B25.66 | Modify a simple microwave Doppler shift apparatus to study chirp concepts. |
| AJP 59(11),1050 | dechirping Slinky whistlers | 3B25.66 | Record a single whistler on the Mac, play it backwards into the whistler-phone, and hear a "ch". |
| AJP 59(2),181 | comment on "culvert whistlers" | 3B25.67 | A comment clarifies the relationship between culvert whistlers and ionospheric whistlers. |
| AJP 56(8),752 | culvert whistlers revisited | 3B25.67 | An analysis of "echo tube" corridor demonstrations that also deals with ionospheric whistlers, tweeks and chirped handclaps. |
| AJP 39(6),610 | culvert whistlers | 3B25.67 | Long article on culvert whistlers. |
| AJP 68(6), 531 | culvert whistlers | 3B25.67 | Culvert whistlers are analyzed with both wave and geometrical ray models. |
| AJP 48(8),639 | shear, Lamb, and Rayleigh waves | 3B25.80 | A panametrics 5022 P/R pulser/receiver driving a piezoelectric transducer in a water bath directed at solid blocks is used with an oscilloscope to show traces of different waves. |
| | **Compound Waves** | **3B27.00** | |
| PIRA 1000 | Slinky and soda cans | 3B27.10 | |
| UMN, 3B27.10 | Slinky and soda cans | 3B27.10 | Persons at each end of a stretched Slinky generate a pulse. The addition of the pulses kicks one soda can out from a line of cans placed along the Slinky. Also cancel opposite pulses. |
| PIRA 1000 | wave superposition - Shive model | 3B27.15 | |
| Disc 09-16 | wave superposition | 3B27.15 | Start positive pulses from each end of a Shive wave machine. |
| PIRA 1000 | adding waves apparatus | 3B27.20 | |
| Mei, 18-8.5 | adding waves apparatus | 3B27.20 | A framework allows brass tubes representing two sine waves to be combined point by point to give the resultant. Projected on the overhead. |
| TPT 28(8),568 | harmonic sliders | 3B27.21 | A template with a sine wave shape is slid under a set of vertical wood bars cut to various lengths to forming a different sine waves. |
| Mei, 18-8.7 | adding waves | 3B27.21 | A machine with pins cut to form a sine wave riding on a plate machined to a sine wave. Picture. Construction details in appendix, p. 635. |
| Sut, S-28 | wave addition model | 3B27.21 | Stack several sets of vertical rods that describe sine waves to show the resultant. |
| Mei, 18-8.14 | carousel waves | 3B27.22 | 630 knitting needles are mounted on a bicycle wheel riding on a second coaxial bicycle wheel with a sine wave cam. Pictures. Construction details in appendix, p. 639. |
| Mei, 18-8.6 | wood block interference | 3B27.23 | A framework holds wood blocks cut to length to form a sine wave. A template in the shape of another wave is pushed against the bottom of the blocks. |
| PIRA 1000 | double pendulum beat drawer | 3B27.30 | |
| F&A, Si-6 | beat pendula | 3B27.30 | Two physical pendula with slightly different periods oscillate in parallel planes and the sum is shown by reflecting a laser beam off mounted mirrors. |
| Sut, S-42 | sand pendulum compound wave | 3B27.30 | A compound sand pendulum with both oscillations in the same plane dumps onto an endless belt. |
| Mei, 18-4.1 | beat pendula | 3B27.31 | Three mirrors are mounted on two pendula of slightly different frequencies. Two show the motion of each pendulum and one shows the combination. Pictures, Diagram. Construction details in appendix, p. 625. |
| Mei, 18-4.2 | recording beat pendula | 3B27.32 | Inductive pickup of the position of two pendula of slightly different frequencies. Construction details. |
| Mei, 18-4.3 | photo of beat pendula | 3B27.33 | Lenses on beat pendula focus spots of light on moving photographic paper. |
| AJP 35(11),1043 | turntable oscillators | 3B27.35 | A phono turntable drives a horizontal platform in SHM, and two can demonstrate beats and Lissajous figures. |
| Sut, S-106 | beats | 3B27.40 | Light is reflected off mirrors on two slightly different tuning forks to a rotating mirror and onto a screen. |
| Mei, 33-2.8 | beat lights | 3B27.45 | The output of an audio oscillator is added to line frequency through a step-up transformer with 15W lamps as indicators. |
| | **Wave Properties of Sound** | **3B30.00** | |

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| AJP 38(1),110 | ultrasonic wave phenomena | 3B30.01 | Use 40Khz transducers to show standing waves, spherical propagation, angular distribution, two source interference, etc. by observing the output on an oscilloscope. |
| AJP 52(9),854 | phase of a reflected acoustic wave | 3B30.03 | Note: Physics textbooks incorrectly state that a sound wave reflected at a rigid boundary is 180 degrees out of phase with the incident wave. |
| PIRA 500 | speed of sound by phase difference | 3B30.10 | |
| UMN, 3B30.10 | speed of sound by phase difference | 3B30.10 | A function generator drives a speaker. A dual trace oscilloscope displays both the generator output and a microphone signal as the microphone is moved on the lecture bench. |
| TPT 3(4),170 | speed of sound by phase difference | 3B30.10 | An electronic switch is used to show both speaker and microphone traces on a single sweep scope. |
| F&A, Sh-1 | wavelength of sound by phase diff. | 3B30.10 | A microphone is moved away from a speaker while an oscilloscope shows the generated and detected sine waves. |
| Mei, 19-2.1 | velocity of sound by phase shift | 3B30.10 | Measure the speed of sound by the phase shift of a trace on the oscilloscope as the source is moved back and forth. |
| D&R, W-080 | speed of sound by phase difference | 3B30.10 | A function generator drives a speaker. An oscilloscope displays both the generator output and microphone signal as the speaker is moved along the lecture bench. |
| Sprott, 3.2 | speed of sound by phase difference | 3B30.10 | The speed with which sound travels through the air is illustrated with a function generator, microphone, and an oscilloscope. |
| TPT 2(8),390 | speed of sound by phase difference | 3B30.11 | A microphone is moved back and forth in front of a speaker and the Lissajous figure from the generator and microphone is examined on an oscilloscope. |
| TPT 3(2),79 | speed of sound by phase difference | 3B30.11 | More comments on the TPT 2,390 (1964) article. Additional references. |
| AJP 52(5),465 | sound wave visualization | 3B30.12 | A probe detects the phase difference between the sampling microphone and the speaker and lights either a red or green LED. |
| AJP, 50 (11), 1025 | speed of sound and gravity | 3B30.13 | The effect of gravity on the speed of sound in a gas is shown to decrease linearly with altitude. |
| PIRA 500 | direct speed of sound | 3B30.20 | |
| UMN, 3B30.20 | direct speed of sound | 3B30.20 | |
| AJP 37(2),223 | direct speed of sound | 3B30.20 | Striking a gong with a metal rod triggers an oscilloscope and a microphone picks up the sound. |
| Hil, S-3g | direct speed of sound | 3B30.20 | Striking a gong with a metal rod triggers an oscilloscope and a microphone picks up the sound. Reference: AJP 37(2),223. |
| AJP 31(1),xiv | direct speed of sound | 3B30.21 | Spark a 10,000 V .02 microF capacitor and pick up the sound with a piezoelectric transducer. |
| AJP 57(10),920 | time of flight | 3B30.22 | A circuit triggers an oscilloscope and coincidentally produces bursts of sound from a speaker. |
| AJP 49(6),595 | time of flight - ultrasonic ranger | 3B30.23 | Polaroid Corporation's ultrasonic ranging system is used as the basis of a time of flight determination of the speed of sound. |
| AJP 48(6),498 | speed of sound by clapping | 3B30.25 | Use a clap,echo,rest,rest sequence with a second student as a director. |
| PIRA 200 - Old | bell in a vacuum | 3B30.30 | Pump air from a bell jar as a battery powered bell rings inside. |
| UMN, 3B30.30 | bell in a vacuum | 3B30.30 | Evacuate a bell jar while a ringing bell is suspended inside. |
| F&A, Sh-2 | bell in a vacuum | 3B30.30 | A doorbell is placed in a bell jar which is then evacuated. |
| Sut, S-53 | bell jar | 3B30.30 | You can hear a bell in a closed jar while air is present. |
| Sut, S-52 | bell in a jar | 3B30.30 | Ring a bell in an evacuated bell jar. Other methods and hints. |
| Hil, S-3a | bell in a vacuum | 3B30.30 | Air is pumped from a bell jar as a battery powered bell rings inside. |
| D&R, W-015 | bell in a vacuum | 3B30.30 | Pump air from a bell jar as a battery powered bell rings inside. |
| Sprott, 3.4 | bell in a vacuum | 3B30.30 | An electric bell in a jar makes a sound that decreases in intensity as the air is evacuated from the jar. |
| Bil&Mai, p 207 | bell in a vacuum | 3B30.30 | A ringing bell is placed into a container filled with air, without air, and then filled with other gases. |
| Disc 10-09 | siren in vacuum | 3B30.30 | Place an electronic siren with a LED in series in a bell jar. |
| PIRA 1000 | speaker and candle | 3B30.40 | |
| UMN, 3B30.40 | speaker and candle | 3B30.40 | Place a candle in front of a large speaker and make the candle flicker with large amplitude low frequency oscillations. |
| PIRA 1000 | bubbles and bugle | 3B30.45 | |
| UMN, 3B30.45 | bubbles and bugle | 3B30.45 | Dip a toy bugle in soap solution and blow. The size of the bubble changes imperceptibly. |
| Bil&Mai, p 206 | bubbles and trumpet | 3B30.45 | Dip the bell of a trumpet into a shallow pan of soap solution. Play the trumpet and show that the size of the bubble changes imperceptibly. |
| PIRA 1000 | helium talking | 3B30.50 | |
| UMN, 3B30.50 | helium talk | 3B30.50 | Sing, talk or laugh while breathing helium. |
| Sut, S-86 | medium and speed of sound | 3B30.50 | Fill your lungs with hydrogen or helium and speak or sing. |

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| Sprott, 3.3 | helium and sulfur hexafluoride talking | 3B30.50 | Breathing helium and sulfur hexafluoride demonstrates the variation of the speed of sound with the density of a gas. |
| Bil&Mai, p 207 | helium talking | 3B30.50 | Fill your lungs with helium from a helium filled balloon and then speak or sing. Sulfur hexafluoride gas may also be used. |
| Disc 10-14 | sound in helium | 3B30.50 | Blow an organ pipe with air and helium, then talk with helium. |
| Sut, S-85 | medium and speed of sound | 3B30.51 | Two organ pipes are adjusted to unison, then one is filled with hydrogen. A long tube is attached to a whistle and when the gas reaches it the pitch rises. |
| TPT 14(8), 510 | speed of sound in water | 3B30.52 | A classic experiment that measured the speed of sound in water. |
| TPT 15(8), 453 | speed of sound in water | 3B30.52 | More on the classic experiment in TPT 14(8), 510 |
| AJP 39(3),340 | speed of sound in liquid | 3B30.52 | Shop drawings and circuit diagram for a ultrasonic echo pulse chamber for measuring the velocity of sound in liquids. Designed for laboratory use. |
| TPT 28(2),125 | medium and speed of sound with PZT | 3B30.52 | Use a piezoelectric element as a detector for measuring the speed of sound in solids and liquids. |
| AJP 41(3),433 | speed of sound in liquid | 3B30.53 | An ultrasonic transducer is pulsed in a liquid cavity and the initial and reflected pulses are observed on an oscilloscope. |
| AJP 45(6),588 | modified circuit | 3B30.53 | Add a simple circuit to chop the initial pulse down to a low value, preventing amplifier overload. |
| PIRA 1000 | sound velocity at different temperatures | 3B30.55 | |
| Sut, S-83 | temp and speed of sound | 3B30.55 | Two organ pipes are blown simultaneously and then the air in one is heated by an internal coil. |
| Sut, S-84 | temp and speed of sound | 3B30.55 | Two whistles of the same pitch are blown and one is then heated with a match. |
| Disc 10-13 | sound velocity of different temperat | 3B30.55 | Blow two identical organ pipes from the same source, then heat the air going to one of the pipes with a Bunsen burner. |
| Mei, 19-2.4 | velocity of sound with temperature | 3B30.56 | Attach a whistle to a coil of copper tubing placed in liquid nitrogen. |
| TPT, 37(1), 53 | the speed of sound in air as a function of temperature | 3B30.57 | The speed of sound in air at room temperature is found and compared to the speed of sound in the air of a walk-in freezer. |
| PIRA 1000 | speed of sound in rod and air | 3B30.60 | |
| UMN, 3B30.60 | speed of sound in rod and air | 3B30.60 | Hit a twelve foot aluminum rod on one end with a hammer. Trigger an oscilloscope with a microphone at the hammer end and display the signal from microphones at the end of the rod and at the same distance. |
| Mei, 19-2.3 | velocity of sound in a rod | 3B30.61 | A timer is triggered by metal balls bouncing off brass blocks mounted one meter apart on a brass rod when one end of the rod is struck with a hammer. |
| D&R, W-365 | velocity of sound in a rod | 3B30.61 | Excite fundamental in a rod, then compute the wavelength by measuring the length of the rod. Use function generator to determine frequency. Can be used to determine speed of sound and Young's Modulus or rod material. |
| AJP 78 (12), 1429 | velocity of sound in a rod | 3B30.61 | Tap on one end of a rod with a microphone connected at the other end. Use sound analysis software to obtain the resonance spectrum of the bar. The speed of sound, Young's modulus, and the Poisson's ratio of steel are obtained. |
| AJP 38(9),1151 | direct speed of sound in a rod | 3B30.62 | A bell clapper hits one end of a rod and triggers an oscilloscope, a phonograph needle and crystal pickup on the other end generates a signal that is displayed on the scope. |
| PIRA 1000 | music box | 3B30.65 | |
| UMN, 3B30.65 | music box | 3B30.65 | Sound is transmitted through a long wood rod from a music box in the basement to a sounding box in the classroom. |
| F&A, Sf-3 | transmission of sound through wood | 3B30.65 | A long 1"x1" wood bar is placed on top of a music box in the basement, through a hole in the floor, to a sounding box in the classroom. |
| Sut, S-87 | medium and speed of sound | 3B30.66 | Stand near a railroad track and listen as a hammer is struck against the rail 200' away. |
| | **Phase and Group Velocity** | **3B33.00** | |
| PIRA 500 | group velocity on scope | 3B33.10 | |
| UMN, 3B33.10 | group velocity on scope | 3B33.10 | Two sine waves of almost equal frequencies and their sum are displayed on a oscilloscope. |
| AJP 31(12),xiii | wave and group velocity on scope | 3B33.10 | Directions for showing wave and group velocities on the oscilloscope. |
| AJP 46(5),579 | phase and group velocity | 3B33.10 | This article spells out the subtleties for getting both traces to move in one direction. |
| F&A, Sl-2 | phase and group velocity | 3B33.10 | An oscilloscope shows signals from two oscillators and the sum. |

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| Mei, 38-6.1 | group and phase velocity | 3B33.10 | Two sine waves are added and displayed on an oscilloscope. Picture, Diagram. |
| Mei, 38-6.2 | group velocity | 3B33.11 | Measuring group velocity using two sine waves and an oscilloscope. Diagram. |
| AJP 41(11),1283 | group velocity - gated pulse | 3B33.12 | An amplifier circuit is given that gates a sine wave generator with a square wave generator. The resulting packets of sine waves are found to be superior to the beat method. |
| Hil, S-2k | group and phase vel.- apple peeler | 3B33.18 | This group and phase velocity device was made from an apple peeler. |
| PIRA 1000 | two combs | 3B33.20 | |
| AJP 37(8),842 | two combs | 3B33.20 | Superimpose two combs on the overhead projector to show phase and group velocity. |
| AJP 38(4),547 | two combs | 3B33.20 | This was published in AJP,21,388 (1953). |
| Mei, 18-8.9 | two combs | 3B33.20 | Move two combs across each other on an overhead projector to demonstrate phase and group velocity. Picture. |
| Mei, 18-8.10 | phase and group velocity with bars | 3B33.21 | Two sheets of bars of ratio 9:10 are superimposed on the overhead projector. A revolving model works too. |
| Mei, 18-8.13 | densimeter comb | 3B33.22 | Two densimeter plates are used in place of combs. Pictures. |
| Mei, 18-8.8 | phase and group velocity on the overhead projector | 3B33.25 | A sheet with black bands is pulled across an overhead projector covered except for slits parallel, perpendicular, and at 45 degrees to the motion. Picture, diagram, construction details in appendix, p. 635. |
| AJP 54(12),1064 | R H Good software | 3B33.30 | Free Apple II software showing, among other things, group and wave velocity. This is the best Apple II software ever written. |
| AJP 54(7),656 | group velocity software | 3B33.31 | A short review of group velocity that happens to mention some software. |
| AJP 41(10),1203 | group and phase velocity in a pool | 3B33.40 | Make a large scale demonstration in a fountain pool (14' x 25' x 1'). |
| | **Reflection and Refraction (Sound)** | **3B35.00** | |
| PIRA 1000 | gas lens | 3B35.10 | |
| Mei, 19-8.1 | gas lens | 3B35.10 | Hydrogen and carbon dioxide balloons are used as diverging and converging lenses. Picture. |
| Sut, S-95 | refraction lens - CO2 | 3B35.10 | Make an acoustical lens by cementing the edges of two circular sheets of cellophane and filling the space between with CO2. |
| AJP 77 (3), 197 | gas lens | 3B35.10 | A demonstration showing that scattering theory is required to understand a gas filled balloon used as an acoustic lens. |
| PIRA 1000 | refraction prism - CO2 | 3B35.20 | |
| Sut, S-96 | refraction prism - CO2 | 3B35.20 | Direct a beam of sound through a prism of CO2. |
| Sut, S-97 | refraction with CO2 | 3B35.22 | Set up a source, reflector, and detector. Then pour CO2 into the path of the incident beam to scatter the sound. |
| PIRA 1000 | parabolic reflector and sound source | 3B35.30 | |
| Sut, S-93 | curved reflectors | 3B35.30 | Place a watch at the focal point of a mirror and project the beam around the class. |
| F&A, Sg-2 | directional transmission | 3B35.35 | A Galton whistle at the focus of a parabolic mirror produces a beam detected by a microphone placed at the focus of a second parabolic mirror. |
| Sut, S-92 | curved reflectors | 3B35.36 | Place a whistle and sensitive flame several meters apart, then place a parabolic reflector behind the whistle. |
| Sut, S-91 | reflection of sound waves | 3B35.37 | A whistle and detector are placed in a line parallel with a reflector. Precautions may have to be taken to insure directionality of the sound waves. |
| Sut, S-94 | curved reflectors | 3B35.39 | Take a field trip a dome to observe the "whispering gallery" effect. |
| Sut, S-90 | wave properties of sound | 3B35.50 | Using a shrill whistle of wavelength from 2-8 cm, many properties of waves usually shown only with optics can be demonstrated. Many diagrams. |
| PIRA 1000 | refraction of water waves | 3B35.60 | |
| Disc 09-20 | refraction of water waves | 3B35.60 | Plane waves refract in a tank with deep and shallow sections. |
| | **Transfer of Energy in Waves** | **3B39.00** | |
| PIRA 1000 | water wave model | 3B39.10 | |
| UMN, 3B39.10 | water wave model | 3B39.10 | A row of short rods mounted on the side of a box rotate at the same rate with equal phase shift between successive rods. The combined motion simulates a traveling water wave. |
| F&A, Sa-4 | water wave model showing phase velocity | 3B39.10 | Balls that rotate vertically on the end of rods hooked to horizontal shafts and are coupled together with a regular phase difference. |

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| Mei, 18-8.15 | water wave model | 3B39.12 | A set of 28 rotating arms driven in circular motion with constant successive phase difference. Pictures. Construction details in appendix, p.644. |
| Mei, 18-8.12 | rotating phasors | 3B39.14 | Synchronous motors drive a set of balls in a circle with phase relationship such that the balls describe a sine wave. |
| PIRA 1000 | dominoes | 3B39.20 | |
| D&R, W-010 | dominoes | 3B39.20 | Dominoes illustrate energy transfer mechanism. |
| AJP, 78 (7), 721 | dominoes | 3B39.20 | The physics of a row of toppling dominoes is discussed and analyzed, including the effect of friction. |
| Mei, 18-8.11 | multiple wave types | 3B39.30 | A machine demonstrates transverse, longitudinal, and water wave motion. Picture. Construction details in Appendix, p.636. |
| Hil, S-2j | seismograph | 3B39.52 | The output from seismographs are shown on an oscilloscope. |
| | **Doppler Effect** | **3B40.00** | |
| PIRA 200 | Doppler buzzer | 3B40.10 | Swing a battery powered buzzer on a string around in a horizontal circle. |
| UMN, 3B40.10 | Doppler buzzer | 3B40.10 | A battery powered buzzer on a string is swung around in a horizontal circle. |
| AJP 29(10),713 | Doppler buzzer | 3B40.10 | Mount a buzzer and a battery on opposite ends of a meter stick and rotate about the center of mass. |
| AJP 41(5),727 | Doppler buzzer | 3B40.10 | Attach a Sonalert to a 2 m string and the shift is almost a minor third. MORE: interference and radiation resistance. |
| Bil&Mai, p 222 | Doppler buzzer | 3B40.10 | A battery powered buzzer is placed inside a Nerf ball on a string. Swing in a horizontal circle. |
| F&A, Si-3 | Doppler speaker on turntable | 3B40.10 | A battery operated oscillator drives a speaker mounted on a 3' turntable. |
| Disc 10-21 | Doppler effect | 3B40.10 | Mount two speakers on a rotating frame and attach to an audio oscillator through slip rings. |
| AJP 30(4),307 | Doppler speaker pendulum | 3B40.12 | Swing an earphone driven by an audio oscillator suspended as a pendulum. |
| Mei, 19-6.6 | intermittent Doppler speaker | 3B40.13 | A rotating speaker is switched on and off so sound is emitted only when the speaker is moving towards or away from the observer and arranged so the cone of sound is directed at the observer only. Reference: AJP 21(5)407. |
| PIRA 1000 | Doppler whistle | 3B40.15 | |
| UMN, 3B40.15 | Doppler whistle | 3B40.15 | A whistle on the end of a tube is blown while swung around in a horizontal circle. |
| F&A, Si-1 | Doppler whistle | 3B40.15 | A small whistle at the end of a rubber tube is twirled around the head while being blown. |
| Mei, 19-6.2 | Doppler whistle | 3B40.15 | A compressed air whistle on the end of a rubber tube is twirled around the head. |
| Mei, 19-6.1 | Doppler rocket | 3B40.16 | A whistling rocket mounted on a rod is rotated in a three foot radius circle. |
| Sut, S-150 | Doppler effect | 3B40.18 | A moving tuning fork, rotating reed, rotating whistle, and rotating speaker all show the Doppler effect. |
| D&R, W-380 | Doppler effect | 3B40.18 | A whirled tuning fork, rotating reed, and moving aluminum rod, all show the Doppler effect. |
| PIRA 500 | Doppler spear | 3B40.20 | |
| UMN, 3B40.20 | Doppler spear | 3B40.20 | Stroke a twelve foot aluminum rod until it sings, then hold it at the midpoint and thrust it toward the class. |
| PIRA 1000 | Doppler reed | 3B40.25 | |
| UMN, 3B40.25 | Doppler reed | 3B40.25 | A reed is turned at the end of a motorized shaft. |
| F&A, Si-2 | Doppler reed | 3B40.25 | A reed on an arm is rotated by a motor. |
| Hil, S-6b | Doppler reed | 3B40.25 | An adjustable speed motor rotates an arm with a reed at the end. |
| Sprott, 3.5 | Doppler reed | 3B40.25 | A reed mounted on the end of a rotating arm produces a tone whose pitch wobbles up and down as the arm rotates. |
| PIRA 1000 | Doppler beats | 3B40.30 | |
| Mei, 19-6.3 | Doppler beats | 3B40.30 | A naked tuning fork is moved back and forth in front of a wall; a poster board is moved back and forth behind a fork. Reference: AJP 10(2),120. |
| Mei, 19-6.5 | Doppler beats | 3B40.30 | The complete discussion of Doppler beats: swinging tuning forks and speakers of equal or unequal frequencies, moving reflector. Diagrams. |
| AJP 39(2),229 | Doppler radio on air track | 3B40.32 | Modulate an rf generator and tune two transistor radios to the frequency. Mount one on an air track and listen to the beats with the stationary radio. |
| AJP 69(12), 1231 | Doppler speaker on air track | 3B40.32 | Direct acquisition of Doppler shifted sound intensity as a function of time using a computer sound card. |
| AJP 35(6),530 | moving detector Doppler | 3B40.33 | A moving microphone detector is tuned to the Doppler shifted frequency of a loudspeaker. |
| Mei, 19-6.4 | Doppler speakers | 3B40.35 | The difference tone between a stationary speaker and a pendulum speaker is amplified through a third speaker. Diagrams. Reference: AJP 12(1),23. |

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| Sut, S-151 | Doppler effect analog | 3B40.50 | A student drops paper riders on an endless string over two pulleys and the instructor picks them up while walking toward the student. |
| | **Shock Waves** | **3B45.00** | |
| PIRA 200 - Old | ripple tank film loops | 3B45.10 | A 3:45 film loop shows Doppler effect and shock waves. |
| UMN, 3B45.10 | ripple tank film loop - shock waves | 3B45.10 | The film loop lasts 3:45. |
| AJP 48(6),498 | continuous ripple-tank Doppler | 3B45.11 | A loudspeaker wave generator is used with a large slowly turning disk of water for continuous generation of Doppler and shock waves. Only the small portion of the disk of interest is illuminated at one time. |
| Mei, 17-9.4 | shock wave in water | 3B45.13 | A film of water flowing down an incline is interrupted by a point, producing waves. |
| PIRA 1000 | shock waves in ripple tank | 3B45.15 | |
| AJP 43(1),101 | ripple tank Doppler and bow shock | 3B45.15 | Mount a burette on a carriage over a large pan of water. |
| PIRA 1000 | pop the champagne cork | 3B45.20 | |
| Mei, 17-9.3 | pop the champagne cork | 3B45.20 | Pop a plastic cork out of a water filled champagne bottle by hitting the base on a pine board. |
| PIRA 1000 | solition tank | 3B45.30 | |
| AJP 58(11),1100 | nonpropagating hydrodynamic solitons | 3B45.31 | Theory and apparatus for producing solitons of (0,1) and (0,2) modes are discussed. |
| TPT, 36(8), 498 | build your own soliton generator | 3B45.32 | A soliton is easily produced with a frequency-generator driven speaker under a tank of water/chemical solution. |
| Mei, 17-9.1 | water trough tidal bore | 3B45.35 | Water in a long tank is given a sudden impulse with a paddle and a shock wave is produced. |
| PIRA 1000 | tsunami tank | 3B45.40 | |
| AJP 44(11),1073 | tsunamis | 3B45.40 | A simple sloping tank with ground glass side for recording the peak profile. |
| Mei, 17-9.5 | supersonic jet | 3B45.60 | Schleirin optics are used to project the flow of a supersonic jet. |
| TPT 31(6), 376 | bull whip and towel snap | 3B45.61 | The audible crack of a bull whip or snapped towel is produced when the tip breaks the sound barrier. |
| Mei, 17-9.2 | shock waves in argon | 3B45.65 | An elaborate setup to introduce helium into a low pressure argon tube and cause a yellow glow from the compressed argon. |
| | **Interference and Diffraction** | **3B50.00** | |
| PIRA 500 | ripple tank - single slit | 3B50.10 | |
| UMN, 3B50.10 | ripple tank - single slit | 3B50.10 | The film loop lasts 3:30. |
| F&A, Sm-4 | ripple tank - single slit | 3B50.10 | Diffraction from a plane wave passing through a single slit on the ripple tank. |
| Disc 09-21 | single slit diffraction of water wave | 3B50.10 | Ripple tank single slit diffraction with varying slit and wavelength. |
| Sut, S-144 | ripple tank diffraction | 3B50.12 | Use the ripple tank to show radiation patterns from different baffle, pipe, and horn configurations. |
| PIRA 500 | ripple tank - two point | 3B50.20 | |
| UMN, 3B50.20 | ripple tank - two point | 3B50.20 | Two point sources show interference. A plane wave through a slit shows diffraction. |
| F&A, Sm-2 | ripple tank - double source | 3B50.20 | A ripple tank with two point sources in phase. |
| Mei, 18-6.3 | ripple tank - two point | 3B50.20 | Waves produced by audio oscillators drive beads attached to earphone diaphragms. Picture. More. |
| AJP, 50 (2), 136 | ripple tank - two point | 3B50.20 | Two point sources are used to display dynamic interference patterns responsible for producing beats. |
| PIRA 1000 | ripple tank - double slit | 3B50.25 | |
| F&A, Sm-5 | ripple tank - double slit | 3B50.25 | Interference from a plane wave passing through a double slit in the ripple tank. |
| Disc 09-22 | double slit interference of water waves | 3B50.25 | Ripple tank double slit interference with varying wavelength and slit separation. |
| AJP 34(2),170 | mechanical double slit | 3B50.28 | Lead shot drops from two hoppers and shows a single distribution with no interference pattern. |
| PIRA 500 | ripple tank - film loops | 3B50.30 | |
| UMN, 3B50.30 | ripple tank film loop | 3B50.30 | |
| PIRA 200 | Moire pattern transparencies | 3B50.40 | A double slit representation of Moire patterns from two sheets of semicircular ruled transparencies. |
| UMN, 3B50.40 | Morie pattern transparencies | 3B50.40 | Transparencies with identical circular patterns are placed on top of each other with a slight offset. |
| Mei, 35-2.1 | Moire pattern | 3B50.40 | Moire patterns from two sheets of semicircular ruled transparencies form a double slit representation. |
| D&R, W-325, O-420 | Moire pattern | 3B50.40 | A pattern of concentric rings that can be copied for use on the overhead. |

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| Bil&Mai, p 348 | Moire pattern | 3B50.40 | Moire patterns from two sheets of semicircular ruled transparencies form a double slit representation. |
| Disc 09-23 | Moire pattern | 3B50.40 | Two transparencies of equally spaced circles on the overhead. |
| AJP 32(4),247 | Morie pattern - complete treatment | 3B50.42 | All you ever wanted to know about Morie patterns. |
| AJP 30(5),381 | Moire' pattern | 3B50.43 | Electronic chassis covers (with holes kind) are mounted several inches apart and the pattern changes as your viewing distance changes. |
| Mei, 34-1.24 | Moire pattern | 3B50.43 | Moire patterns with chassis boxes. Pictures. |
| PIRA 1000 | double slit transparency | 3B50.50 | |
| UMN, 3B50.50 | double slit transparency | 3B50.50 | Two strips of clear acetate with identical sine waves are pivoted from two points representing two slits to demonstrate constructive and destructive interference. |
| Mei, 18-8.2 | two ropes | 3B50.51 | Two ropes mounted on the wall 3' apart and painted with 6" black and white sections are stretched and crossed by the demonstrator to simulate constructive or destructive interference. |
| PIRA 1000 | interference model | 3B50.55 | |
| AJP 59(9),857 | interference model | 3B50.55 | Painted wave trains on wood lath are attached to magnets for use on a steel blackboard |
| D&R, W-320 | interference model | 3B50.55 | Corrugated strips with painted troughs and crests will show constructive and destructive interference. |
| Sut, S-149 | ripple tank scattering | 3B50.80 | A brass disc is used as an obstacle for various wavelength plane waves to show scattering. |
| | **Interference and Diffraction of Sound** | **3B55.00** | |
| PIRA 200 | two speaker bar | 3B55.10 | Two speakers driven from a common source are mounted at the ends of a long bar. |
| UMN, 3B55.10 | speaker bar | 3B55.10 | Two speakers driven from a common source are mounted at the ends of a long bar. The bar can be moved slightly or the students can move their heads to hear the interference pattern. |
| AJP 42(5),413 | large speaker bar | 3B55.10 | Use high power speakers and a 50 Watt amplifier. |
| F&A, Sl-3 | speaker bar | 3B55.10 | Two speakers 2m apart are driven from the same oscillator while students move their heads around to hear the interference pattern. |
| Mei, 19-5.1 | speaker bar | 3B55.10 | Two speakers mounted at the ends of a board on a turntable are fed the same high frequency audio signal. |
| Mei, 19-5.2 | speaker bar | 3B55.10 | The pattern from two speakers 3' apart is investigated with a microphone and microammeter. |
| Sut, S-102 | interference | 3B55.10 | Two speakers fed from the same source at the ends of a 12' bar. Project the pattern into the room and move the bar. |
| D&R, W-330 | two speaker interference | 3B55.10 | Speakers in phase are mounted on a turn table or lazy susan. |
| Disc 10-20 | two speaker interference | 3B55.10 | Speakers in phase are mounted at the ends of a rotatable bar. |
| Sut, S-101 | interference | 3B55.11 | Investigate the diffraction pattern from two rectangular aperture megaphones hooked to the same source. |
| AJP 32(2),xiv | speaker bar, etc. | 3B55.12 | A set of interference from two coherent sources demonstrations: slides, ripple tank, speaker bar, microwave, homemade handout optics double slits. |
| Sut, S-104 | interference | 3B55.13 | Send a parallel beam against a board with two slits and investigate the result with a sensitive flame. |
| AJP 44(12),1120 | speaker bar room acoustics problems | 3B55.14 | The effects of reflections from the room surfaces are often underestimated. |
| AJP 44(4),400 | speakers on a bar | 3B55.15 | Mount twelve 3" diameter speakers on a bar with a 25' radius. |
| PIRA 500 | baffle and speaker | 3B55.30 | |
| UMN, 3B55.30 | baffle and speaker | 3B55.30 | Hold up a 1" speaker oscillating at 350 Hz, then add a baffle in front of the speaker. |
| D&R, W-335 | baffle and speaker | 3B55.30 | Play a small speaker with a tape player. Intensity increases with the addition of a baffle with speaker cone size hole. |
| Mei, 19-4.10 | baffles and resonators | 3B55.31 | A baffle is held between the forks of a tuning fork on a resonator box with the open end facing toward and away from the class. |
| Sut, S-109 | interference of a tuning fork | 3B55.31 | Hold a tuning fork in the hand with and without a cardboard baffle. |
| PIRA 200 | trombone / Quinckes' tube | 3B55.40 | A speaker drives two tubes, one variable , that come together into a common horn. |
| UMN, 3B55.40 | trombone | 3B55.40 | A speaker drives two tubes, one variable , that come together into a common horn. |
| F&A, Sg-4 | trombone | 3B55.40 | A horn driver is connected to tubing that splits into two variable path lengths and is recombined at a horn. |

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| Mei, 19-5.3 | trombone | 3B55.40 | Two identical trombone slide assemblies are connected in parallel between a driver and detector. One of the slides is lengthened to produce a path length difference of one half wavelength. |
| Sut, S-103 | trombone | 3B55.40 | Two "U" tubes , one of them of variable length, are both connected to the same source and ear piece. |
| TPT 3(6),282 | large trombone interference | 3B55.41 | A large trombone interferometer made out of 1' copper tubing. |
| AJP 28(1),77 | Herschel divided tube | 3B55.42 | Interference of sound in a double tube, one side of variable length. Made of Plexiglas. |
| AJP 34(10),946 | acoustical interferometer | 3B55.45 | A speaker is mounted at one end of telescoping plastic tubes, and a microphone is mounted at one end of the inner tube. |
| Sut, S-99 | diffraction | 3B55.51 | A board with a variable slit is placed in a parallel sound beam. The detector is moved about and the slit width is varied. |
| Sut, S-98 | diffraction | 3B55.51 | A whistle and parabolic mirror form a parallel beam. Interrupt the beam with a barrier and move the detector back until it responds again. Or - use successively smaller barriers until the detector responds but is still in the shadow of the barrier. |
| PIRA 1000 | diffraction pattern of a piston | 3B55.55 | |
| Mei, 19-7.2 | diffraction pattern of a piston | 3B55.55 | A speaker cone is removed and replaced with a Lucite disc. The intensity is measured with a microphone as the speaker assembly is rotated. |
| Sut, S-100 | diffraction | 3B55.55 | Attach a megaphone of rectangular cross section 3/2 wavelength by wavelength/3 to a whistle. A detector off to the side is placed so it will respond only when the long dimension is vertical. |
| AJP 54(7),661 | hearing around a corner | 3B55.58 | Things aren't simple, seeing and hearing are different. |
| PIRA 1000 | diffraction fence | 3B55.60 | |
| F&A, Sg-3 | diffraction of sound | 3B55.60 | The beam from a Galton whistle at the focus of a parabolic mirror is passed through a picket fence to a detector. |
| Mei, 19-7.3 | diffraction with a wire mesh | 3B55.60 | Parabolic reflectors are used to produce parallel sound waves that are directed through an audio diffraction grating to a movable microphone. |
| Mei, 19-7.1 | diffraction of coherent and incoherent | 3B55.80 | Plot the intensity vs. angle of four speakers driven by four oscillators and by a single oscillator. |
| AJP 40(5),697 | diffraction by ultrasound in liquid | 3B55.91 | The physical origin of the "shadow" seen in the visual display of standing wavefronts in liquids. |
| Mei, 19-7.4 | ultrasound camera | 3B55.92 | A description with construction details of a ultrasonic camera for demonstrating real image formation and Fraunhofer and Fresnel diffraction. Pictures and Diagrams. |
| | **Beats** | **3B60.00** | |
| PIRA 200 | beat forks | 3B60.10 | Two tuning forks differing by about 1 Hz are mounted on resonance boxes. |
| UMN, 3B60.10 | beat forks | 3B60.10 | Two tuning forks on resonance boxes, one adjustable. A microphone and scope can be used to display the beat pattern. |
| Hil, S-5a.1 | beat forks | 3B60.10 | Two tuning forks differ by 1 Hz but are not mounted on resonance boxes. |
| D&R, W-355 | beat forks | 3B60.10 | Two tuning forks on resonance boxes, one adjustable by up to 3 Hz. |
| Sprott, 3.8 | beat forks | 3B60.10 | Two tuning forks on resonance boxes, one adjustable. A microphone and scope can be used to display the beat pattern. |
| Disc 10-18 | tuning fork beats | 3B60.10 | Two tuning forks are on resonant boxes. Adjust the frequency of one to be slightly different. |
| PIRA 1000 | beat bars | 3B60.11 | |
| F&A, Si-4 | beat bars | 3B60.11 | Two identical bars mounted on resonator boxes are detuned by a movable weight on one. Listen to the beats and show on an oscilloscope. |
| Hil, S-4d.2 | beat bars | 3B60.11 | The standard tunable bars on a resonance box. |
| Sprott, 3.8 | organ pipe beats | 3B60.13 | Two organ pipes are slightly detuned to produce a beat frequency. |
| Bil&Mai, p 221 | singing rods - beats | 3B60.13 | Hold a long aluminum rod at the midpoint and stroke with rosined fingers. Stroke another identical rod that is 1 cm shorter and listen to the beats. |
| PIRA 1000 | beat whistles | 3B60.15 | |
| UMN, 6C30.15 | beat whistles | 3B60.15 | Two air whistles can be adjusted to the same pitch. |
| F&A, Si-5 | beat whistles | 3B60.15 | Two tunable air whistles are used to demonstrate beats. |
| Sut, S-107 | beat notes | 3B60.15 | Start two whistles in unison and change the frequency of one until the difference in frequencies is enough to produce a musical beat note. |
| Hil, S-5a.2 | Knipp singing tubes beats | 3B60.16 | Two Knipp singing tubes are tuned to produce beats. |
| Hil, S-5a.3 | Galton whistle beats | 3B60.17 | Two Galton whistles can be adjusted to produce "dog beats". |
| PIRA 200 | beats on scope | 3B60.20 | Two audio transformers are fed thru an audio interstage transformer to an oscilloscope and audio amp. |
| UMN, 3B60.20 | beats on scope | 3B60.20 | Dual function generators are used to generate a beat pattern that can be amplified and listened to and/or displayed on a scope. |

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| AJP 29(9),645 | beats on scope | 3B60.20 | The output of two audio transformers is fed into the secondary of an audio interstage transformer and from there to both an oscilloscope and an audio output transformer. |
| Mei, 19-5.5 | beats on scope | 3B60.20 | An interstage audio transformer and an audio output transformer couple two oscillators to an oscilloscope and speaker. |
| D&R, W-315 | beats on scope | 3B60.20 | Two function generators are used to generate a beat pattern or group that can be amplified and listened to and/or displayed on a scope. |
| Disc 10-19 | beats with speaker and oscilloscope | 3B60.20 | Two function generators are used to make beats that are displayed on a scope and amplified to a speaker. |
| TPT, 37(3), 177 | a visual and acoustic demonstration of beats and interference | 3B60.20 | Two function generators, a stereo system, and an oscilloscope are used to show and hear beats at the same time. |
| AJP 43(12),1103 | beat oscillator switch | 3B60.22 | A circuit to switch between inputs or the sum of the inputs to allow either the individual frequencies or the beats to be heard. |
| ref. | beats vs. diff.tone | 3B60.30 | see 3C55.35 |
| AJP 30(11),840 | reply to beats misconceptions | 3B60.31 | Beat notes are what the misconceptions are about, beats are just combined frequencies. |
| AJP 30(5),386 | beats vs. difference tones | 3B60.31 | Hey, guys, simple "mixture" of frequencies gives difference tones. Beats are only present when modulation operations are used. |
| AJP 42(7),603 | beat demodulation | 3B60.38 | Two oscillators drive a loudspeaker, switch a diode into the circuit and the modulation frequency can be detected. |
| PIRA 1000 | ripple tank beats | 3B60.40 | |
| AJP 31(10),794 | ripple tank beats | 3B60.40 | Two point sources in a ripple tank run at different frequencies. Theory included. |
| AJP 50(2),136 | ripple tank beats | 3B60.40 | Beats are demonstrated as a moving interference pattern in the ripple tank by using two separate point source generators with variable frequency controls. |
| | **Coupled Resonators** | **3B70.00** | |
| PIRA 200 - Old | coupled tuning forks | 3B70.10 | Two matched tuning forks are mounted on resonance boxes. Hit one and the other vibrates too. |
| Sut, S-115 | resonance in forks | 3B70.10 | Two identical tuning forks on resonance boxes - strike one and the other starts vibrating. |
| Sut, S-50 | sympathetic vibrations | 3B70.10 | Two tuning forks on resonance boxes: hit one and the other vibrates too. Several hints on showing this effect. |
| D&R, W-265 | resonance in forks | 3B70.10 | Two identical tuning forks on resonance boxes. Point open ends of cavities at each other and strike one, the other will start to vibrate. |
| Sprott, 3.8 | resonance in forks | 3B70.10 | Strike one tuning fork mounted on a box and a second of the same frequency will vibrate sympathetically. |
| PIRA 200 - Old | coupled speaker/tuning forks | 3B70.20 | Drive a tuning fork on a resonant box with a speaker. |
| Mei, 19-4.7 | sympathetic vibrations in forks | 3B70.25 | A horn driver directed at a box coupled to a tuning fork produces sympathetic vibrations which are detected by a crystal pickup and shown on an oscilloscope. |
| Sut, S-116 | resonance of strings | 3B70.30 | A tuning fork is held against a three string sonometer with one string tuned to the fork frequency. Only the tuned string will vibrate. |
| Hil, S-4b | tuning fork driven sonometer | 3B70.31 | Place a tuning fork on the bridge of a tuned sonometer and observe the motion of a small piece of paper placed on the wire at its center. |
| | **ACOUSTICS** | **3C00.00** | |
| | **The Ear** | **3C10.00** | |
| PIRA 1000 | model of the ear | 3C10.10 | |
| UMN, 3C10.10 | model of the ear | 3C10.10 | |
| PIRA 500 | time resolution of the ear | 3C10.20 | |
| F&A, Sl-1 | binaural hearing | 3C10.20 | Hold the ends of a long tube to each ear and have someone tap in the center and then a few centimeters to each side. |
| D&R, W-035 | time resolution of the ear | 3C10.20 | A long tube with funnels connected to the ends. Hold a funnel over each ear and have someone tap the tube in the center and then slightly off center. |
| Sut, S-153 | direction judgment of the ear | 3C10.21 | High frequency location depends on difference in intensity produced by the shadow of the head. |
| Sut, S-152 | direction judgment of the ear | 3C10.21 | Location of low pitched sounds depends on phase difference. Use a model stethoscope with one tube longer than the other. |
| PIRA 500 | bone conduction | 3C10.30 | |
| D&R, W-425, M-945 | bone conduction | 3C10.30 | A tape player sends a signal to a coil on a dowel rod that is held near a magnet. Bite down on the rod or place the end of the rod against the skull to hear the sound. Also, a tuning fork held against the skull. |
| | **Pitch** | **3C20.00** | |
| TPT 17(2), 102 | infrasound | 3C20.05 | Using infrasound to understand the atmosphere and the ocean. |

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| PIRA 200 | range of hearing | 3C20.10 | Use an oscillator driving a good audio system to demonstrate the range of hearing. |
| UMN, 3C20.10 | range of hearing | 3C20.10 | A set of good speakers is used to test the student's range of hearing. |
| F&A, Sh-3 | range of hearing | 3C20.10 | An oscillator driving a good audio system is used to demonstrate the range of hearing. |
| D&R, W-085 | range of hearing | 3C20.10 | Connect a function generator to a speaker. Adjust frequency while students plot their cutoff. Show waveforms on the oscilloscope during test. |
| Sprott, 3.7 | range of hearing | 3C20.10 | Use a function generator connected to speakers to demonstrate the range of human hearing and deterioration with age. |
| Sut, S-122 | range of hearing | 3C20.11 | Use whistles, forks, etc. to establish upper range of hearing or an audio oscillator from 10 to 30,000 Hz. |
| F&A, Sg-1 | Galton whistle | 3C20.15 | The Galton whistle can be adjusted to produce an intense sound into the ultrasonic range. |
| F&A, Sf-4 | ultrasonic waves | 3C20.16 | A set of steel rods tuned to frequencies up to 30 KHz are struck with a hammer and the sound both heard and displayed on an oscilloscope. |
| Sprott, 3.10 | ultrasonic waves | 3C20.16 | Various sources of sound with frequencies above the range of audibility illustrate the distinction between a physical sound wave and the perception of sound. |
| AJP, 75 (6), 574 | tonometers - ultrasonic rods | 3C20.16 | A short article with picture describing the tonometers as secondary frequency standards and how they are used. |
| Mei, 19-10.1 | ultrasonic vibrations of quartz | 3C20.17 | Making an ultrasonic transducer and using it to make a fountain and emulsion. |
| AJP, 75 (5), 415 | quartz tuning fork | 3C20.17 | Using a common quartz tuning fork to demonstrate the principle of shear force scanning probe microscopy on a simple profiler constructed with equipment found in a teaching laboratory. |
| PIRA 500 | zip strips | 3C20.20 | |
| PIRA 500 | bottle scale | 3C20.25 | |
| F&A, Se-4 | musical bottles | 3C20.25 | Blow across a set of bottles with water levels adjusted to give a scale. |
| D&R, W-260 | musical bottles | 3C20.25 | Participants blow across a set of bottles with water levels adjusted to give an 8 note scale which is enough to play Jingle Bells. |
| Bil&Mai, p 216 | musical bottles | 3C20.25 | Blow across an empty bottle and then add water to the bottle as you continue to blow. |
| ref. | see 3C60.30 | 3C20.30 | see 3C60.30 |
| PIRA 1000 | siren disc | 3C20.30 | |
| UMN, 3C30.20 | siren disc | 3C20.30 | |
| F&A, Sc-1 | siren disc | 3C20.30 | An air jet is directed at a rotating disc with holes. |
| Sut, S-120 | siren disc | 3C20.30 | Air is blown through concentric rows of regularly spaced holes on a spinning disc. Change of speed of the disc changes frequencies but not intervals. |
| D&R, W-050 | siren disk | 3C20.30 | An air jet is directed at a rotating disc with concentric rows of holes. |
| Disc 10-10 | siren disc | 3C20.30 | A disc with concentric ring of equally spaced holes is spun by a motor and a jet of air is blown at each circle of holes. |
| TPT 42(7), 418 | siren | 3C20.35 | Pictures, functions, and characteristics of typical demonstration sirens. |
| PIRA 1000 | Savart's wheel | 3C20.40 | |
| AJP 32(2),xiv | frequency and pitch | 3C20.40 | A set of gears on a single shaft of a variable speed motor have the ratios of 44-47-49-52-55-59-62-66-70-74-78-83-88. |
| F&A, Sc-2 | musical saw | 3C20.40 | A card is held against a dull saw as the speed is varied. |
| Mei, 19-4.3 | tooth ratio scale | 3C20.40 | A set of gears with 44-47-49-52-59-62-66-70-74-83-88 teeth are mounted coaxially on a shaft connected to a variable speed motor. Varying the speed shows intervals are determined by frequency ratios rather than absolute pitch. |
| Sut, S-121 | Savart wheel | 3C20.40 | Hold a stiff cardboard against the rim of a spinning toothed wheel. Use wheels on the same shaft each with different numbers of teeth. |
| Hil, S-3b | Savart's wheels | 3C20.40 | A major chord is produced when a cardboard is held against rotating wheels with tooth ratios of 3:4:5:6. |
| Disc 10-11 | gear and card | 3C20.40 | Hold a card against gears on a common shaft with teeth in ratio of 4:5:6:8. |
| Mei, 19-4.4 | saw blade organ | 3C20.41 | Several saw blades are mounted on the same rotating shaft with sound produced by amplifying the output of a coil pickup. A band of switches selects the active blades, allowing chords to be played. |
| Sut, S-118 | pitch sort of | 3C20.45 | Many examples of sound of poor quality but with some definite pitch. E.g., a thumbnail on a book cover. |
| TPT 36(8), 508 | increasing pitch with decreasing amplitude | 3C20.60 | Euler's disk, buzzing magnets, and glass bottles that are gently struck together demonstrate an increasing audible pitch with the decrease in motion amplitude. |

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| AJP 47(2),199 | sound cart | 3C20.70 | All the instrumentation for a physics of sound course is loaded on one mobile cart. |
| | **Intensity and Attenuation** | **3C30.00** | |
| PIRA 200 | dB meters and horn | 3C30.20 | |
| PIRA 500 - Old | dB meters and horn | 3C30.20 | |
| UMN, 3C30.20 | dB meters and horn | 3C30.20 | Place dB meters in the class at 2 meter intervals, then blow a loud horn. |
| PIRA 1000 | dB meter and horn | 3C30.21 | |
| UMN, 3C30.21 | dB meter and horn | 3C30.21 | An air horn driven by a compressed air tank gives a 120 dB sound at close range. Use a dB meter to measure the intensity at various ranges. |
| F&A, Sc-4 | air horn | 3C30.21 | A railroad horn blown from a tank of compressed air has a nearby intensity of 110 dB. |
| D&R, W-090 | dB meter and horn | 3C30.21 | Students measure air horns and other readily available sound sources. |
| Hil, S-3c | sound level meter | 3C30.22 | A sound level meter is used to measure the instructor speaking, etc. |
| PIRA 1000 | loudness (phones and sones) | 3C30.30 | |
| PIRA 1000 | hearing -3dB | 3C30.35 | |
| UMN, 3C30.35 | hearing -3dB | 3C30.35 | A function generator with a dB meter is used to quickly adjust to half power. |
| Mei, 19-4.15 | 3 dB | 3C30.36 | One and two students pound the table equidistant from an observer. |
| Sut, S-88 | attenuation of materials | 3C30.41 | Place various materials between a sounding board and a tuning fork stuck in a block of wood. |
| Mei, 19-9.2 | modified tuning fork resonance box | 3C30.42 | The tuning fork is removed from a resonance box and a rod, string, and water are interposed. |
| D&R, M-945 | modified tuning fork resonance box | 3C30.42 | Place a tuning fork on different tables or objects to increase the volume. |
| Sut, S-89 | attenuation in CO2 | 3C30.43 | A high pitched tone transmitted through a 10' pipe will be attenuated when filled with CO2. |
| Hil, S-7f | acoustical tiles | 3C30.45 | Show various acoustical tiles. |
| | **Architectual Acoustics** | **3C40.00** | |
| PIRA 500 | reverberation time | 3C40.10 | |
| AJP 48(1),32 | room reverberation time | 3C40.10 | Go around and record pistol shots in various rooms, then determine reverberation time at different frequencies with some equipment in the classroom. |
| Mei, 19-4.14 | reverberation time | 3C40.10 | Students clap hands to generate sound for reverberation time. |
| Mei, 19-4.13 | reverberation time | 3C40.10 | Study the reverberation time of a room. |
| Sut, S-146 | reverberation time | 3C40.10 | Measure reverberation time of the classroom with a dB meter. (-60dB) |
| Sut, S-147 | reverberation tube | 3C40.11 | Measure the time required for sound to die in a tube that can be fitted with caps of various materials. |
| Sut, S-148 | ripple tank acoustics | 3C40.20 | Cross sectional models of various auditoriums are used in a ripple tank to show scattering and reflection. |
| | **Wave Analysis and Synthesis** | **3C50.00** | |
| PIRA 200 - Old | Pasco Fourier synthesizer | 3C50.10 | The Pasco Fourier synthesizer allows one to build an arbitrary waveform with up to nine harmonics. |
| UMN, 3C50.10 | Pasco Fourier synthesizer | 3C50.10 | The Pasco Fourier synthesizer is used to build up a square wave. |
| F&A, Sk-3 | Pasco Fourier synthesizer | 3C50.10 | The Pasco Fourier synthesizer allows one to build an arbitrary waveform out of up to nine harmonics. |
| D&R, W-075 | Pasco Fourier synthesizer | 3C50.10 | A Pasco Fourier synthesizer allow on to build arbitrary waveforms out of nine harmonics. An oscilloscope is attached for viewing. |
| Disc 10-15 | Fourier synthesizer | 3C50.10 | Use the Pasco Fourier synthesizer to demonstrate building square and triangle waves. |
| AJP 43(9),755 | electronic music synthesizer | 3C50.12 | The principles of an electronic music synthesizer and its use in demonstrations. |
| AJP 29(6),372 | electric organ as synthesizer | 3C50.12 | The timbre of a musical note is demonstrated by showing an oscilloscope trace of an electric organ while changing the drawbars. |
| AJP 40(7),937 | electromechanical Fourier synthesize | 3C50.13 | A set of eight mechanically geared potentiometers generate sine/cosine waves and harmonics. |
| Mei, 18-4.4 | mechanical multichannel generator | 3C50.13 | A four channel mechanical signal generator is used to show a fundamental and two harmonics. Picture. Construction details in appendix, p. 626. |
| AJP 43(10),899 | synthesizer | 3C50.14 | The PAiA 2720 Synthesizer used with an oscilloscope for ten demonstrations. |
| AJP 42(9),754 | waveform synthesizer | 3C50.14 | Oscillators tuned to 1, 2, 3, 4, and 5 Khz have variable amplitude and phase. External input and an audio amp are also included. |
| AJP 53(9),874 | waveform synthesizer | 3C50.14 | A waveform synthesizer based on the Intel 8748 microcontroller is described along with some theory and an experiment. |

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| D&R, W-055 | waveform synthesizer | 3C50.14 | Multiple oscillators to make waveforms, or a microphone, drives an audio system with speaker. Connect an oscilloscope to make the waveforms visible. |
| PIRA 1000 | mechanical square wave generator | 3C50.15 | |
| UMN, 3C50.15 | mechanical square wave generator | 3C50.15 | Shadow project a mechanism with a small disc mounted at the edge of a larger disc with 1/3 the diameter geared to rotate 3 times as fast as the larger disc. |
| Mei, 33-2.9 | arbitrary waveform generator | 3C50.18 | Sweep a high freq signal at a low freq on an oscilloscope with a mask cut out to the shape of the wave desired and look at it with a photocell. |
| PIRA 200 - Old | Helmholtz resonators and microphone | 3C50.30 | Hold a small microphone individually to a set of Helmholtz resonators. |
| UMN, 3C50.30 | Helmholtz resonators and microphone | 3C50.30 | |
| Mei, 19-4.6 | Helmholtz resonator | 3C50.31 | Sound from a loudspeaker is directed at a series of Helmholtz resonators with pinwheel detectors at their small apertures. |
| Mei, 19-4.8 | ganged resonance boxes | 3C50.31 | A pistol is fired in front of a set of tuning fork resonance boxes equipped with inductive pickups. Picture. |
| Mei, 19-4.11 | resonance in a box | 3C50.33 | A complex setup to plot the frequency spectrum of a box. Pictures, Diagrams. |
| Sut, S-117 | resonant response of vocal cavities | 3C50.34 | Use a fake larynx to talk without using the vocal cords. |
| PIRA 1000 | resonance tube spectrum | 3C50.35 | |
| UMN, 3C50.35 | resonance tube spectrum | 3C50.35 | Drive a speaker at one end of a tube with the swept frequency output of a spectrum analyzer. |
| AJP 48(1),24 | air column resonance spectra | 3C50.36 | Use a storage scope and two function generators to display the swept spectrum. Interesting additions are end corrections, tone holes, and adding a bell. |
| Sut, S-145 | radiation patterns of horns | 3C50.37 | Feed an oscillator or other sound to any one of four different types of horns to show differences in quality at various frequencies. |
| PIRA 1000 | harmonic tones (vibrating string) | 3C50.40 | |
| AJP 50(6),570 | string resonance spectra on oscilloscope | 3C50.40 | Sweep the source generator and oscilloscope horizontal from a generator. Use a steel wire and guitar pickup. |
| AJP 52(5),470 | resonances in strings | 3C50.40 | Excite a steel string with a linearly swept sinusoidal signal and show the output on a spectrum analyzer or storage oscilloscope. |
| PIRA 1000 | noise (pink and white) | 3C50.50 | |
| PIRA 1000 | distinguishing harmonics with the ear | 3C50.55 | |
| UMN, 3C50.55 | distinguishing harmonics | 3C50.55 | A generator with an adjustable high Q bandpass filter allows one to train the ear to pick out the harmonics of a complex sound. |
| AJP 53(11),1112 | distinguishing harmonics | 3C50.55 | The circuit diagram for the Gronseth device. |
| PIRA 1000 | wave analysis (PASCO filter) | 3C50.70 | |
| PIRA 1000 | spectrum analyzer | 3C50.80 | |
| Mei, 33-3.7 | RLC bank harmonic analyzer | 3C50.81 | A bank of RLC circuits covering to the tenth harmonic of 235 Hz is used as a harmonic analyzer. Diagram. |
| AJP 28(4),405 | LC harmonic analyzer | 3C50.82 | Sweep a square wave generator through a single LC filter and detect maxima at harmonics of the fundamental. |
| AJP 45(1),103 | low cost spectrum analyzer | 3C50.83 | A circuit for a 100 kHz spectrum analyzer using a standard oscilloscope for display. |
| AJP 48(6),451 | spectrum analyzer - Tek 5L4N | 3C50.83 | The Tek 5L4N spectrum analyzer plug-in is used with a camera (instead of a storage scope) to show the spectrum of sustained tones from musical instruments at different pitch and loudness. |
| AJP 52(8),713 | FFT on 6502 | 3C50.94 | A FFT algorithm relocatable to any 6502 is available from the author. |
| AJP 53(11),1107 | microcomputer based analyzer | 3C50.94 | Discusses algorithms for cross correlation and sound intensity analysis. |
| | **Music Perception and the Voice** | **3C55.00** | |
| PIRA 1000 | pitch of complex tones | 3C55.20 | |
| AJP 50(9),855 | pitch of complex tones | 3C55.20 | Use an Apple computer to generate complex tones. Students judge the pitch. |
| PIRA 1000 | missing fundamental | 3C55.25 | |
| AJP 52(5),470 | missing fundamental | 3C55.25 | Microcomputers with built-in tone generators are handy for generating "missing fundamental" demonstrations. |
| AJP 41(8),1010 | sing/whistle - which octave | 3C55.26 | Whistle and sing into a three foot pipe and use the resonances to show your whistling range is much higher than your singing range. |
| PIRA 1000 | difference tones | 3C55.30 | |
| UMN, 3C55.30 | difference tones | 3C55.30 | |

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| AJP 42(7),616 | subjective tones | 3C55.30 | A toy whistle emits tones at 2081, 1896, and 1727 Hz. Subjective difference tones at 169, 185, and 374 Hz are clearly audible. |
| AJP 37(7),730 | combination tones and the ear | 3C55.31 | Explanation of how the nonlinear ear creates difference tones and common examples of the phenomena. Two demonstrations: sweep with a second oscillator to find the difference tone, add 200, 300 and 400 Hz to hear 100 Hz. |
| PIRA 1000 | beats vs. difference tones | 3C55.35 | |
| AJP 49(7),632 | difference tones and beats | 3C55.35 | Two pure tones produce beats or difference tones. Theory and a demonstration that trains our ears to hear and distinguish the two. |
| AJP 3292),xiii | beats on scope, difference tones | 3C55.35 | The usual two oscillators, amplifier, and scope. For difference tones, set one oscillator above the audible range and the difference tone is the only thing the student can hear. |
| Mei, 19-5.4 | beats on scope, difference tones | 3C55.35 | Two audio oscillators drive two speakers. A microphone pickup displays the sum on an oscilloscope. ALSO - difference tone. |
| PIRA 1000 | chords | 3C55.40 | |
| F&A, Sj-5 | chords | 3C55.40 | Using the three string sonometer to study the structure of chords by varying the bridge location of strings tuned in unison. |
| F&A, Sk-2 | circular glockenspiel | 3C55.41 | Mallets can be put in any of twelve holes on a spool to play major, minor, augmented, and diminished cords on a circular glockenspiel. |
| AJP 49(6),579 | consonant musical interals | 3C55.42 | Consonant and dissonant intervals are explained by a relation between the time required to perceive a definite pitch and the period of a complex tone. |
| PIRA 1000 | consonance and dissonance | 3C55.45 | |
| F&A, Sj-4 | harmonious notes | 3C55.45 | Using the sonometer to demonstrate the harmonic content of different interval combinations. |
| PIRA 500 | musical scale | 3C55.50 | |
| AJP 55(3),223 | numerical investigation of scales | 3C55.51 | An investigation of why the 12 note scale is the best equal tempered scale. |
| AJP 42(7),543 | quanitiative investigation of scales | 3C55.51 | A quantitative measurement of how well any tuning succeeds in providing just intonation for any specific piece of music. |
| AJP 35(5),441 | scales and algebraic groups | 3C55.51 | On transposing. |
| AJP 56(4),329 | lucky equal temperaments | 3C55.52 | An analysis of how good the fits of 12, 19, 31, and 53 steps per octave are in equally tempered scales. |
| PIRA 1000 | tuning forks on resonance boxes | 3C55.55 | |
| AJP 47(6),564 | piano tuning | 3C55.55 | On making use of instrumentation to help with piano tuning. |
| AJP 47(5),475 | piano tuning | 3C55.55 | A pianist discusses the finer points of piano tuning. |
| AJP 46(8),792 | piano tuning | 3C55.55 | On "stretching" the equally tempered scale. |
| F&A, Sf-1 | tuning forks with resonators | 3C55.55 | A set of tuning forks mounted on resonance boxes make the musical scale. |
| Hil, S-4d.4 | tuning fork resonance boxes | 3C55.55 | A set of four different tuning forks on resonant boxes. |
| Sprott, 3.7 | tuning forks | 3C55.55 | Using resonance boxes with tuning forks. |
| Disc 11-08 | tuning forks on resonant boxes | 3C55.55 | Two tuning forks, two boxes. Show the box needs to be matched to the fork. |
| F&A, Sk-1 | Johnson intonation trainer | 3C55.60 | A small organ that is switched between fixed and variable tuning to demonstrate even tempered and just intonation. |
| Sut, S-123 | tone quality | 3C55.65 | A series of organ pipes tuned carefully to give the harmonics of a fundamental can be used to show the effect of suppressing various harmonics. |
| PIRA 1000 | tone quality | 3C55.70 | |
| UMN, 3C55.70 | microphone and oscilloscope | 3C55.70 | Show the output of a microphone on an oscilloscope. |
| D&R, W-390 | microphone and oscilloscope | 3C55.70 | Show the output of a microphone on the oscilloscope. Observe patterns of voices, speech, tuning forks, and musical instruments. |
| Sprott, 3.7 | microphone and oscilloscope | 3C55.70 | Use a microphone with an oscilloscope to display waveforms. |
| Sut, S-79 | sound wave on oscilloscope | 3C55.71 | Show a sound wave on the oscilloscope while listening to it. |
| Sut, S-125 | tone quality | 3C55.72 | Using a microphone and oscilloscope, demonstrate that a tuning fork does not produce a pure sine wave but a fork on a resonance box does. |
| AJP 43(8),736 | tone quality of a Boehm flute | 3C55.73 | Harmonic analysis of rich and dull tones from the Boehm flute. |
| PIRA 1000 | keyboard and oscilloscope | 3C55.74 | |
| AJP 44(6),593 | forms of sounds | 3C55.75 | A variant of the circuit produces roulette figures, etc. |
| AJP 43(3),282 | voice display - corridor demo | 3C55.75 | A circuit to advance the horizontal 45 degrees and retard the vertical 45 degrees to give a circular trace when a falsetto "o-o-o" is sung. |
| PIRA 1000 | formants | 3C55.80 | |
| UMN, 3C55.80 | formants | 3C55.80 | Sing formants into a HP analog spectrum analyzer. |
| Disc 10-16 | vocal formants | 3C55.80 | Use an computer based real time spectrum analyzer to display vocal formants. |

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| AJP, 59 (6), 564 | vocal formants | 3C55.80 | A simple demonstration experiment that illustrates the separate functions of the vocal cords and the vocal tract. |
| Sut, S-124 | tone quality | 3C55.82 | Using a phonelescope or oscilloscope, sing the different vowels at the same pitch and the same vowels at different pitches. |
| PIRA 1000 | filtered music and speech | 3C55.85 | |
| UMN, 3C55.85 | filtered music and speech | 3C55.85 | |
| AJP 50(11),1050 | octave-band filters | 3C55.85 | Use an octave-band filter (from an audio store) to demonstrate filtered music and speech. |
| AJP 59(1),94 | Book/CD review - piano acoustics | 3C55.90 | Review of a book "Acoustics of the Piano" that comes with a CD that includes examples used in the lectures. |
| Hil, S-7b | musical sound records | 3C55.90 | The Science of Sound - Bell Labs, Energy and Motion - Zaret and Singer, Experimental Songs - Dorothy Collins, Space Songs - Tom Glazer & Dottie Evans, Physics Songs - State University of Iowa. |
| D&R, W-095 | Science of Sound records or tapes | 3C55.90 | Produced by Bell Labs. Many audio demonstrations and examples. |
| F&A, Si-7 | churchbell guitar | 3C55.99 | Swing a guitar back and forth as it is plucked to mimic a church bell. |
| | **INSTRUMENTS** | **3D00.00** | |
| | **Resonance in Strings** | **3D20.00** | |
| PIRA 200 - Old | sonometer | 3D20.10 | A sounding box with strings, tuning machines, and adjustable bridges. |
| UMN, 3D20.10 | sonometer | 3D20.10 | The standard two wire sonometer. |
| F&A, Sj-1 | sonometer | 3D20.10 | A long spruce box with three strings, tuning machines, and adjustable bridges. |
| Sut, S-131 | sonometer | 3D20.10 | A general discussion of sonometers and the various demonstrations possible. |
| D&R, W-120 | sonometer | 3D20.10 | Commercial 3 wire sonometer. |
| AJP 58(1),93 | vertical sonometer | 3D20.11 | A vertical sonometer allows tension to be applied by simply hanging weights. |
| F&A, Sj-3 | harmonics on a string | 3D20.15 | Pluck a string at different distances from the end or pluck while touching at various nodes. |
| PIRA 1000 | modes of string oscillation on scope | 3D20.20 | |
| F&A, Sj-2 | modes of string oscillation | 3D20.20 | Use voltages generated by magnets placed across steel strings attached to an oscilloscope to view string motion. |
| D&R, B-240, M-916, & W-320 | modes of wire oscillation | 3D20.20 | Display voltages generated by magnets placed across vibrating steel wires on an oscilloscope. |
| Disc 10-02 | sonometer | 3D20.20 | An electromagnetic pickup is used to display the waveform of the sonometer string on an oscilloscope. |
| PIRA 1000 | guitar and scope | 3D20.21 | |
| AJP 77 (2), 144 | electric guitar - modeling the magnetic pickup | 3D20.21 | A model that analyzes and explains the distortion that the pickup generates when converting the motion of a string to an electric signal with good accuracy. |
| AJP, 78 (1), 47 | guitar - fretted string instruments | 3D20.21 | Analyzes the intonation of instruments with frets taking into account the effects of deformation of the strings and inharmonicity due to other string characteristics. |
| Disc 10-01 | guitar and scope | 3D20.21 | Show the output of an electric guitar on an oscilloscope. |
| AJP 44(11),1077 | bowed string | 3D20.30 | An overhead projector is modified for strobe projection and the string is bowed with a motorized "O" ring. |
| Sut, S-132 | sonometer wire motion | 3D20.30 | Demonstrate the motion of a sonometer wire by stroboscopic shadow projection or using a light beam and revolving mirror. |
| Sut, S-133 | string in a projector | 3D20.30 | The motion of a string is shown by placing any portion in a lantern projector limited by a slit. The difference in bowing, plucking, and striking can be demonstrated. |
| AJP 53(12),1195 | optical detection of string motion | 3D20.31 | An optical detection system for showing the position of a vibrating string. |
| AJP 52(2),137 | simulated piano string coupling | 3D20.36 | A classroom device that simulates the coupled motion of piano strings and theory of the device. |
| Sut, S-108 | longitudinal vibrations in strings | 3D20.45 | Stroke a string attached to a diaphragm across the open end of a cylinder. By jerking, you can make it bark like a dog. |
| PIRA 1000 | Aeolian harp | 3D20.50 | |
| Sut, S-141 | aeolian harp | 3D20.52 | Mount strings vertically on a rotating table to give the sound of strings excited by the wind. |
| Sut, S-142 | aeolian scope | 3D20.52 | A sort of aeolian stethoscope. |
| Sut, S-134 | rubber-band harp | 3D20.60 | The pitch of a rubber-band changes only slightly with great increase in length (tension). |
| | **Stringed Instruments** | **3D22.00** | |
| PIRA 1000 | violin | 3D22.10 | |
| UMN, 3D22.10 | violin | 3D22.10 | |

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| PIRA 1000 | cigar box cello | 3D22.20 | |
| UMN, 3D22.20 | cigar box cello | 3D22.20 | A wooden cigar box serves as sounding box for a one string violin. |
| F&A, Sj-6 | cigar box cello | 3D22.20 | A one string violin made with a cigar box body. |
| D&R, W-410, W-415 | coffee can monochord | 3D22.20 | Run a string through a coffee can, stretch taut and pluck or bow. |
| | **Resonance Cavities** | **3D30.00** | |
| PIRA 200 - Old | vertical resonance tube | 3D30.10 | Draw a glass tube out of a water bath while holding a tuning fork over one end. |
| UMN, 3D30.10 | veritcal resonance tube | 3D30.10 | The length of a glass tube is varied by pulling it out of a water reservoir. A tuning fork is used as a frequency source. |
| AJP 36(1),ix | vertical resonance tube modification | 3D30.10 | Design of a clamp to hold the tuning fork and resonance tube, and a bracket for the water reservoir. |
| F&A, Se-1 | vertical resonance tube | 3D30.10 | A glass tube is drawn out of a water bath while holding a tuning fork over one end. |
| Sut, S-80 | vertical resonance tube | 3D30.10 | Use a tuning fork to excite the air column in a vertical tube as it is pulled out of a water bath. |
| D&R, W-255 | vertical resonance tube | 3D30.10 | Draw a piece of electrical conduit out of a water bath while holding a tuning fork over one end. |
| Sut, S-112 | vertical resonance tube | 3D30.11 | Blow across the mouth of bottles or a adjustable air column. |
| Mei, 19-4.9 | vertical resonance tube | 3D30.12 | A vertical tube is mounted over a siren disk. |
| Sut, S-113 | open tube resonance | 3D30.14 | A length of open tube adjusted by a paper extension and excited by a tuning fork. |
| AJP 69(3), 311 | open tube resonance | 3D30.14 | Measure *Q* of an open ended tube being driven by a speaker set some distance away. |
| PIRA 1000 | resonance tube with piston | 3D30.15 | |
| AJP 77 (8), 678 | resonance tube analysis | 3D30.15 | Using holographic interferometry to study standing sounds waves in a resonance tube driven by a small loudspeaker at one end. |
| Disc 11-01 | resonance tube with piston | 3D30.15 | Mount a microphone on a piston that slides in a glass tube and close the other end of the tube with a speaker. |
| PIRA 1000 | horizontal resonance tube | 3D30.16 | |
| UMN, 3D30.16 | horizontal resonance tube | 3D30.16 | A plunger on a rod is used to change the effective length of a horizontal glass tube as a tuning fork supplies the exciting frequency. |
| Sut, S-129 | organ pipe velocity nodes | 3D30.16 | Lower a ring with a membrane and sand into a pipe with a clear side to observe velocity nodes and antinodes. |
| AJP 56(8),702 | modes of a bottle | 3D30.17 | A thorough discussion of modes of various bottles working up to a 3-D model. |
| AJP 77 (10), 882 | modes of cylindrical containers | 3D30.17 | Use a small speaker, a microphone, and a CD container as a ready made acoustical resonant cavity. The angular behavior of resonant modes can be observed in addition to its frequency on an oscilloscope. |
| Sut, S-66 | low frequency generator | 3D30.19 | A special tip for an air jet that produces many frequencies of low intensity useful for exciting enclosed air columns. |
| PIRA 500 | open and closed tubes 256/512 | 3D30.20 | |
| Disc 11-04 | resonance tube 256/512 | 3D30.20 | A tube is cut to length to resonate at 256 Hz when closed and 512 Hz when open. |
| Sut, S-114 | conical pipes | 3D30.21 | Corrections for the effective length of open and closed circular pipes are given. A conical pipe discussion with several interesting demonstrations is listed. |
| PIRA 500 | bloogles - kroogah tubes | 3D30.35 | |
| AJP 42(4),278 | Hummer tube | 3D30.35 | The complete explanation on singing corrugated pipes. |
| F&A, Se-7 | freq tube dash pot | 3D30.35 | A freq tube is attached to coffee can moved up and down in a pail of water. |
| F&A, Se-6 | freq tube | 3D30.35 | Open tubes of corrugated plastic are whirled around. |
| D&R, W-230 | freq tube | 3D30.35 | Open tubes of corrugated plastic of different lengths are whirled around. |
| Sprott, 3.7 | freq tube - corrugaphone | 3D30.35 | Swing a corrugated plastic tube in a circle and observe the wave forms on an oscilloscope. |
| PIRA 1000 | Hemholtz resonators | 3D30.40 | |
| F&A, Se-3 | Helmholtz resonators | 3D30.40 | A set of spherical resonators made of spun brass. |
| Mei, 19-4.5 | Helmholtz resonators | 3D30.40 | A small vane is rotated when placed near the small opening of a resonating Helmholtz cavity. |
| Hil, S-4d.1 | acoustic resonator | 3D30.40 | This picture appears to be of a Helmholtz resonator. |
| AJP 72(8), 1035 | Hemholtz resonators | 3D30.40 | Some Helmholtz resonators are measured for the quality factor *Q* and the results are compared to the computed theoretical values. |
| Sprott, 3.7 | Helmholtz resonators | 3D30.40 | Various objects used as Helmholtz resonators. |
| Disc 11-09 | Helmholtz resonators | 3D30.40 | Two resonators are matched to two tuning forks. |
| F&A, Sd-3 | tuning a resonance box | 3D30.41 | The hole size of a resonance box is adjusted to maximize resonance with a tuning fork. |

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| Sut, S-81 | Fizeau resonance box | 3D30.43 | A toothed wheel is used to produce a high pitched sound and an adjustable resonance box with a sensitive flame detector is used to determine speed of sound. |
| F&A, Se-2 | ploop tubes | 3D30.45 | Stoppers are removed from a set of tubes of varying length. |
| Sut, S-111 | ploop tubes | 3D30.45 | Pull stoppers out of test tubes filled with water to different depths. |
| PIRA 500 | Ruben's tube | 3D30.50 | |
| UMN, 3D30.50 | Ruben's tube | 3D30.50 | The standard Reuben's tube. |
| F&A, Sa-16 | Ruben's tube | 3D30.50 | A gas filled tube with flames from a row of holes along the top and a speaker at one end. |
| Mei, 19-3.5 | Ruben's tube | 3D30.50 | Directions for building a Ruben's tube. Picture, Diagrams. |
| Sut, S-130 | Ruben's tube | 3D30.50 | Drill a line of holes along a downspout and drive one end with a loudspeaker and introduce gas in the other. Flames indicate nodes and antinodes. |
| Hil, S-2h | Ruben's tube | 3D30.50 | A horn driver is used as a sound source. |
| D&R, W-225 | Ruben's tube | 3D30.50 | Directions for building and use of a Ruben's tube with driving speaker. |
| Sprott, 3.6 | Ruben's tube | 3D30.50 | A pipe several meters long, with evenly spaced holes along the top, filled with natural gas and connected to a loud speaker. |
| Bil&Mai, p 212 | Ruben's tube | 3D30.50 | Directions for building and use of a Ruben's tube with driving speaker. Use an electric keyboard to drive the speaker. |
| AJP 54(4),297 | Rubens tube comment | 3D30.55 | A comment on AJP 53,1110 (1985). |
| AJP 51(9),848 | Rubens tube flame structure | 3D30.55 | An examination of the structure of the flames in the normal mode (flame maxima at pressure nodes). |
| AJP 53(11),1110 | Ruben's tube nodes | 3D30.55 | The pressure is measured at each flame hole and the results are that the flames are larger at the pressure antinodes. |
| AJP 54(12),1146 | Ruben's tube nodes | 3D30.55 | A comment on a note that the tube can be operated with flame maxima at either pressure node or pressure antinode. |
| PIRA 200 | Kundt's tube | 3D30.60 | |
| PIRA 1000 - Old | Kundt's tube | 3D30.60 | |
| F&A, Sa-17 | Kundt's tube | 3D30.60 | Sawdust in a tube makes piles when driven by rubbing a rod attached to a disc. |
| Sut, S-82 | Kundt's tube | 3D30.60 | Standard Kundt's tube: glass tube with cork dust, stroke a rod to excite air in tube. |
| Disc 11-03 | Kundt's tube | 3D30.60 | Stroke a rod to excite cork dust in a tube. |
| AJP 30(7),512 | horn driven Kundt tube | 3D30.61 | Investigation of striations in an electrically driven Kundt tube. |
| Hil, S-3f | Kundt's tube | 3D30.61 | The cork dust in Kundt's tube is excited by a horn driver. |
| Sut, S-127 | Kundt's tube | 3D30.62 | A variation of Kundt's tube with an organ pipe made with one side of rubber or cellophane and sprinkled with sand while laid on its side. |
| Mei, 19-3.1 | Kundt's tube on the overhead | 3D30.63 | A Kundt's tube is modified for use on the overhead projector. |
| TPT 3(1),30 | evacuate Kundt's tube | 3D30.64 | Show the effect of pressure variation on the speed of sound by partially evacuating the Kundt's tube. |
| F&A, Sa-18 | hot wire Kundt's tube | 3D30.65 | Cooling of a glowing wire down the center of a tube indicates standing waves. |
| Mei, 19-3.4 | horizontal resonance tube - wire | 3D30.65 | A nichrome wire stretched down the middle of a glass tube and heated electrically will glow to show standing waves. |
| Sut, S-128 | hot wire pipe | 3D30.65 | Blow a whistle at one end of a tube with a hot wire running down the axis to show areas of low and high luminosity. |
| Mei, 19-3.2 | Kundt's tube - impedance measurement | 3D30.66 | Use the oscilloscope to show variation of impedance in the driving coil with changes in tube length. |
| AJP 39(7),811 | pressure distribution in a cavity | 3D30.69 | Liquid deformation on the bottom of an acoustic cavity shows the time-dependent pressure distribution in a standing sound wave. |
| PIRA 200 | hoot tubes | 3D30.70 | A bunsen burner heats a screen in the bottom of a large open vertical tube. |
| UMN, 3D30.70 | hoot tubes | 3D30.70 | Large glass tubes sound when a wire mesh at one end is heated with a Bunsen burner. |
| F&A, Se-5 | hoot tubes | 3D30.70 | A Bunsen burner heats a screen in the bottom of a large open tube. |
| Sut, S-62 | hoot tubes | 3D30.70 | Singing tubes excited by hot gauze. |
| Sut, S-61 | hoot tubes | 3D30.70 | Hints for making a singing tube work with only flame excitation. |
| D&R, W-210 | hoot tubes | 3D30.70 | Singing tubes excited by hot gauze. Turn the tube horizontally to "pour out" the sound. |
| Sprott, 3.7 | hoot tubes | 3D30.70 | A tube lowered over a Bunsen burner or a tube with an internal screen that is heated. |
| Disc 11-07 | singing pipes | 3D30.70 | Two metal tubes and a glass one. |
| Hil, S-4c | hoot tube | 3D30.71 | Insert a fisher burner in a tube. |
| D&R, W-210 | hoot tubes | 3D30.71 | Lower one end of a large pipe onto a Fisher burner until it resonates. |
| Sut, S-64 | hoot tubes | 3D30.72 | The gauze in a hoot tube is held at the bottom of the tube and the flame is lit above it. |

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| AJP 34(4),360 | Rijke Tube - electrical heating | 3D30.73 | Construction of electrically heated Rijke tubes, tuning a T shaped tube. |
| PIRA 1000 | variable hoot tubes | 3D30.74 | |
| UMN, 3D30.74 | variable hoot tube | 3D30.74 | |
| Sut, S-63 | Knipp tubes | 3D30.75 | Knipp tubes are a special form of singing tube made by holding a short length of glass tube in the closed end of a larger tube. Picture. Ref. F.R.Watson, "Sound"p.214. |
| AJP 50(5),398 | hot chocolate effect | 3D30.77 | Tap on a tall cylinder full of water and then repeat with hot water so there are lots of bubbles. The pitch descends three octaves and rises as the bubbles float up. |
| AJP 59(4),296 | hot chocolate effect - comment | 3D30.77 | A few explanations from a physical chemist. |
| AJP 58(11),1033 | hot chocolate effect | 3D30.77 | Tap on the bottom of an empty glass, a full glass (higher pitch), and a glass full of tiny bubbles (pitch raises as glass clears). Methods of generating bubbles with beer and hot water. More. |
| | **Air Column Instruments** | **3D32.00** | |
| PIRA 1000 | organ pipes | 3D32.10 | |
| Mei, 19-3.3 | tin flute | 3D32.10 | Open and close holes on a tin flute to find pressure nodes and antinodes. |
| Disc 11-02 | resonance tubes (three lengths) | 3D32.10 | Blow air out of a flat nozzle across a set of three different length tubes. |
| Sut, S-65 | shrieker | 3D32.13 | Insert a 1/2" dia. tube 12" long into a bottle of water and blow across. |
| Sprott, 3.7 | clarinet - saxaphone with a soap bubble | 3D32.14 | Dip the bell of a wind or brass instrument in soap solution. You can play the instrument without popping the bubble showing that sound is a wave that does not result in a net motion of the air. |
| TPT 28(7), 459 | clarinet - saxaphone | 3D32.14 | How to make a PVC clarinet from a clarinet mouthpiece and PVC pipe. Also some discussion on various scales. |
| PIRA 1000 | slide whistle | 3D32.15 | |
| UMN, 3D32.15 | slide whistle | 3D32.15 | Use a high quality sliding whistle made for band. |
| F&A, Se-10 | variable pitch whistle | 3D32.15 | A whistle with a sliding piston. |
| D&R, W-220, W-360 | whistles | 3D32.15 | A collection of whistles including a train whistle and police whistles |
| Disc 11-06 | slide whistle | 3D32.15 | The variable length organ pipe. |
| Sut, S-59 | bird call | 3D32.16 | Directions for making a bird call. Diagram. |
| TPT 23(9), 566 | soda straw oboe | 3D32.18 | How to make a soda straw oboe. |
| PIRA 1000 | organ pipes with holes | 3D32.20 | |
| Sut, S-126 | organ pipes with holes | 3D32.20 | Show open and closed pipes of various lengths and one with holes bored in the side to give the diatonic scale. |
| PIRA 1000 | open and closed end pipes | 3D32.25 | |
| UMN, 3D30.25 | organ pipes | 3D32.25 | A collection of open, closed, and variable length organ pipes. |
| F&A, Se-9 | organ pipe | 3D32.25 | A set of square wood organ pipes with a removable plug. |
| Sut, S-57 | pipes and whistles | 3D32.25 | A simple discussion listing organ pipes and whistles. |
| Hil, S-4d.3 | open and closed tubes | 3D32.25 | Some very nice adjustable open and closed resonance tubes. |
| Hil, S-7c.1 | organ pipe | 3D32.25 | An organ pipe is connected to the house air. |
| D&R, W-190 | open and closed end pipes | 3D32.25 | Excite the fundamental of an open or closed pipe. Open pipe is one octave higher. |
| D&R, W-215 | organ pipes | 3D32.25 | A collection of open, closed, and variable length organ pipes. |
| Disc 11-05 | open and closed end pipes | 3D32.25 | Three organ pipes, open and closed. |
| TPT 13(9), 557 | harmonica | 3D32.30 | The harmonica as an audio frequency generator. |
| F&A, Se-11 | "C" bazooka | 3D32.35 | A 1.314 m brass tube sounds the note "C" when blown with the lips. |
| AJP 53(12),1130 | hose in the bell | 3D32.36 | With a garden hose in the bell of a trombone (flush with the end), the tones are: 3:5:7:9:11 and without the hose: 2:3:4:5:6. |
| PIRA 1000 | demonstration trumpet | 3D32.40 | |
| AJP 53(5),504 | demonstration trumpet | 3D32.40 | Interchangeable mouthpiece, leadpipe, cylindrical section, and bell allow one to show the function of the various parts of the brass instruments. |
| Sprott, 3.7 | trumpet with a soap bubble | 3D32.41 | Dip the bell of a wind or brass instrument in soap solution. You can play the instrument without popping the bubble showing that sound is a wave that does not result in a net motion of the air. |
| PIRA 1000 | PVC instruments | 3D32.45 | |
| D&R, W-415 | PVC instruments - pan pipes | 3D32.45 | Pan Pipe made from 1/2 inch plastic water pipe. |
| TPT 28(7),459 | PVC instruments, etc. | 3D32.45 | Very good instructions on making various instruments out of PVC. Also using a computer with a synthesizer to study scales. |
| | **Resonance in Plates, Bars, Solids** | **3D40.00** | |
| PIRA 1000 | xylophone | 3D40.10 | |
| UMN, 3D40.10 | xylophone | 3D40.10 | |
| AJP 69(7), 743 | xylophone | 3D40.10 | The basic physics of xylophone and marimba bars. |
| F&A, Sf-5 | glockenspiel | 3D40.10 | A small xylophone can be played to demonstrate the musical scale. |
| Hil, S-7d.2 | xylophone | 3D40.10 | A small xylophone. |

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| D&R, W-130 | xylophone | 3D40.10 | A 2 m long, 1.3 cm diameter aluminum rod is struck in the center to produce transverse standing waves. Use this to discuss location of supports under xylophone pipes. |
| D&R, W-145 | xylophone construction | 3D40.10 | Homemade xylophone made from aluminum conduit. |
| Disc 10-07 | xylophone bars | 3D40.10 | Use a microphone and oscilloscope to display the waveforms of various notes on a xylophone. |
| PIRA 1000 | rectangular bar oscillations | 3D40.11 | |
| Disc 10-05 | rectangular bar oscillations | 3D40.11 | Strike a three foot rectangular bar on different faces and on the end. Listen to the different frequencies. |
| PIRA 1000 | high frequency metal bars | 3D40.12 | |
| Disc 10-06 | high frequency metal bars | 3D40.12 | Hold a metal rod at the midpoint and strike at the end. Two rods an octave apart are shown. |
| PIRA 1000 | musical sticks | 3D40.15 | |
| UMN, 3D40.15 | musical sticks | 3D40.15 | A set of wood sticks play a major scale when dropped on the lecture table. |
| F&A, Sf-6 | musical sticks | 3D40.15 | A set of wood sticks is cut so they sound the musical scale when dropped. |
| Sut, S-119 | musical sticks | 3D40.15 | Directions for making musical sticks. |
| Hil, S-7d.1 | musical sticks | 3D40.15 | A set of sticks give a complete scale when dropped. |
| D&R, W-145 | musical sticks | 3D40.15 | Sticks of different lengths in a xylophone configuration. |
| D&R, W-146 | musical rods - Xylopipes | 3D40.15 | A set of copper pipes, aluminum pipes, or steel electrical conduit, cut to specific lengths will produce notes of the musical scale when rolled off a table onto a hard floor. |
| Bil&Mai, p 216 | musical rods - Xylopipes | 3D40.15 | A set of copper pipes cut to specific lengths will produced notes of the musical scale when dropped onto a hard floor. |
| PIRA 1000 | musical nails | 3D40.16 | |
| TPT 25(2), 98 | musical strips - musical ruler | 3D40.16 | Hold or clamp one end of a meter stick to a table and vibrate the other end. A graph of the frequency vs. the length of the meter stick can be obtained. |
| D&R, M-900 | musical strips - musical ruler | 3D40.18 | Clamp one end of a hacksaw blade to a table and set the other end to vibrating. An audible sound is produced with an increase in frequency with a reduction of the vibrating length. |
| TPT 43(5), 282 | musical strips - musical ruler | 3D40.18 | Drive the hacksaw blade with an electromagnetic coil. |
| Bil&Mai, p 216 | musical strips - musical ruler | 3D40.18 | Hold one end of a wooden meter stick against a table top and set the other end that is extending over the edge of the table to vibrating. Reduce the vibrating length to increase the frequency. |
| TPT 39(5), 310 | thumb piano | 3D40.19 | Description and analysis of a thumb piano also known as a mbira or kalimba. Also pictures and analysis of Marloye's harp. |
| PIRA 200 | singing rod | 3D40.20 | Hold a long aluminum rod at the midpoint and stroke with rosined fingers. |
| UMN, 3D40.20 | singing rod | 3D40.20 | A long aluminum rod will sing when held at the center and stroked with a piece of rosin coated leather. |
| D&R, W-135, W-205 | singing rod | 3D40.20 | Hold a long aluminum rod at the midpoint and stroke with rosined fingers. If rod is of correct diameter and length, coupled oscillations between longitudinal and transverse waves can occur. |
| Sprott, 3.7 | singing rod | 3D40.20 | Stroke or hit the end of a rod to produce loud longitudinal sound modes. Observe the wave forms on an oscilloscope. |
| Bil&Mai, p 219 | singing rod | 3D40.20 | Hold a long aluminum rod at the midpoint and stroke with rosined fingers. Press the end of the rod to a Styrofoam cup to amplify the sound. |
| Disc 10-08 | singing rods | 3D40.20 | Hold a long aluminum rod at the midpoint and stroke with rosined fingers. |
| Mei, 19-3.6 | singing rod | 3D40.21 | Stroke a 1/2" x 72" aluminum rod while holding at nodes to produce different harmonics. |
| Sut, S-136 | bow the vertical rod | 3D40.23 | A long thin rod attached to a short thick rod clamped vertically is bowed and plucked while held at various positions. |
| AJP 38(9),1152 | regenerative feedback in rod | 3D40.24 | A detector at one end, speaker at the other, and an amplifier in between provides a regenerative feedback system for exciting a rod in the fundamental frequency. |
| AJP 41(5),734 | speed of sound in a rod | 3D40.24 | Stroke a loud rod to get a squeal, tune an oscillator and speaker to get rid of beats, and calculate the velocity. |
| AJP 42(12),1117 | speed of sound in a metal wire | 3D40.24 | Wire is stretched tightly and stroked with a wet sponge. |
| Mei, 19-2.2 | velocity of sound in a rod | 3D40.24 | A rod clamped in the middle is excited by a coil at one end tuned until a Lissajous pattern is formed on an oscilloscope with the signal from a microphone placed at the other end. |
| Mei, 18-1.1 | singing rod | 3D40.24 | A rod is excited electromagnetically at one end and the motion is detected in the same manner at the other end for quantitative studies. |
| Mei, 18-1.2 | singing rod | 3D40.27 | Find Young's modulus by finding the sag in a rod and then compare the frequency of the fundamental mode with theory. |

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| PIRA 200 | Chladni plate | 3D40.30 | Strike or bow a horizontal metal plate covered with sand while touching the edge at various nodal points. |
| UMN, 3D40.30 | Chladni plate | 3D40.30 | A brass plate clamped horizontally in the center is bowed while the edges are touched to provide user selected nodes. Banding sand shows patterns of oscillations. |
| F&A, Sb-3 | Chladni plates | 3D40.30 | Bow the Chladni plate while damping at node locations with a finger. |
| Mei, 19-4.2 | Chladni plates | 3D40.30 | Excite the Chladni plates with a cello bow. Picture. |
| Sut, S-137 | Chladni plate | 3D40.30 | A horizontal metal plate covered with sand is struck or bowed while touching the edge at various nodal points. |
| Hil, S-7e | Chladni plates | 3D40.30 | Bow circular and square Chladni plates. |
| D&R, W-165 | Chladni plates | 3D40.30 | A horizontal metal plate covered with sand is bowed while touching the edge at various nodal points. Fluorescent sand and black lights make it more dramatic. |
| Disc 09-30 | Chladni plates | 3D40.30 | A plate is driven by magnetostriction in the 10 to 30 Khz range. |
| AJP, 50 (3), 271 | Chladni plates | 3D40.30 | On Chladni's law for vibrating plates. |
| F&A, Sb-1 | Chladni plates | 3D40.31 | Sprinkled sand shows standing waves on a circular metal plate driven at the center by an oscillator. |
| Sut, S-138 | Chladni plates | 3D40.31 | Drive a Chladni plate from the center. |
| AJP 59(7),665 | Chladni plates on the overhead projector | 3D40.32 | Directions for making a loudspeaker driven Chladni plate for the overhead projector. |
| Mei, 19-4.1 | Chladni plates | 3D40.32 | Chladni plates are driven from above by a loudspeaker. Pictures. |
| PIRA 1000 | thick Chladni plate | 3D40.33 | |
| UMN, 3D40.33 | thick Chladni plate | 3D40.33 | A circular disc of 1/2" aluminum exhibits a single pattern. |
| AJP 73(3), 283 | Chladni plates | 3D40.34 | Additional comments on AJP 72(10), 1345. |
| AJP 72(10), 1345 | Chladni plates | 3D40.34 | Grains of salt and salt dust are used at the same time. The grains collect at the nodal lines while the dust collects at the antinodes. |
| AJP 72(2), 220 | Chladni plates | 3D40.34 | Something about nondegenerate normal-mode doublets in vibrating flat circular plates. |
| AJP 50(3),271 | Chladni plates | 3D40.34 | After some interesting historical and general comments, nonflat plates (cymbals, gongs, etc.) are examined. |
| PIRA 1000 | flaming table | 3D40.35 | |
| UMN, 3D40.35 | flaming table | 3D40.35 | Same as AJP 55(8),733. |
| AJP 55(8),733 | 2-D flame table | 3D40.35 | Two-dimensional rectangular and circular flame tables, extensions of the one-dimensional Rubens tube, are shown in some lower order modes |
| F&A, Sb-2 | flaming birthday cake | 3D40.35 | Flames from a two dimensional array driven by a speaker show many resonant modes. |
| AJP 56(10),913 | 2D flame table analysis | 3D40.36 | An analysis of the two dimensional flame table. |
| PIRA 500 | drum head | 3D40.40 | |
| AJP 51(5),474 | Chladni figures - tympani head | 3D40.40 | Drive a timpani head with a loudspeaker. |
| AJP 35(11),1029 | standing waves on a drum | 3D40.40 | A speaker drives a circular rubber membrane under tension while illuminated with a strobe. |
| Mei, 19-4.12 | standing waves in a drum | 3D40.40 | A circular rubber membrane with a pattern is illuminated with a strobe and driven from below by a 12" loudspeaker. Pictures. |
| Disc 09-29 | drumhead | 3D40.40 | A speaker drives a drumhead. |
| AJP 36(8),669 | vibrations in a circular membrane | 3D40.41 | The eigenfrequencies of (21) agree closely with the theoretical values. Air damping is removed by using a wire mesh driven magnetically. |
| PIRA 1000 | bubble membrane modes | 3D40.45 | |
| UMN, 3D40.45 | bubble membrane modes | 3D40.45 | Use a large right angle PVC fitting. |
| AJP 33(11),xvii | soap film membrane modes | 3D40.45 | Light from a slide projector is reflected off a soap film with a black cloth and speaker behind. |
| AJP 59(4),376 | bubble membrane modes | 3D40.45 | A simple technique to drive bubble membranes of various shapes with a speaker. |
| D&R, W-170 | soap film membrane modes | 3D40.45 | Drive bubble membrane with a speaker on an acrylic tube. Focus reflected light from a slide projector with a large lens. |
| D&R, W-175 | bubble membrane modes | 3D40.45 | Large bubble membranes in large circular and rectangular frames are oscillated by hand. |
| PIRA 1000 | musical goblet | 3D40.50 | |
| F&A, Se-8 | musical goblets | 3D40.50 | Rub the edge of a goblet with a wet finger. |
| Hil, S-7d.3 | glass tumbler | 3D40.50 | Rub a finger dipped in vinegar around the top of a crystal goblet. |
| AJP 73(11), 1045 | musical goblet variation | 3D40.50 | A model to compute the frequency shift of the singing wineglass when water is added. |
| D&R, W-155 | musical goblet | 3D40.50 | Rub the edge of a goblet with a wet finger. |
| D&R, W-160 | musical goblet variation | 3D40.50 | Excite a goblet by rubbing a wet finger around the edge as you vary the water level in the goblet. |
| Mei, 18-5.6 | standing waves in a bowl | 3D40.51 | A 15 l flask is cut in half to form a bowl which is bowed to produce standing waves. Suspended ping pong balls indicate nodes and loops. |

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| Sut, S-139 | bowing the bowl | 3D40.51 | Suspend four pith balls so they touch the edge of a bowl and bow between two of the balls. |
| AJP 53(11),1070 | "whispering" waves in a wineglass | 3D40.52 | A thorough discussion of surface waves in vessels, including ethylene glycol in a trifle dish. |
| AJP 51(8),688 | wineglass acoustics | 3D40.52 | A study of wineglass acoustics. |
| TPT 28(9),582 | wine glass waves, etc. | 3D40.53 | Seven questions about wine glass waves are answered. Pictures of a glass harmonica and a Chinese "water spouting basin". |
| PIRA 200 | shattering goblet | 3D40.55 | |
| PIRA 500 - Old | shattering goblet | 3D40.55 | |
| AJP 47(9),828 | shattering goblet or beaker | 3D40.55 | Laboratory beakers are shattered in a chamber with a small piece of folded paper over the rim serving as a resonance detector. |
| TPT 28(6),418 | shattering goblet | 3D40.55 | Break a lead crystal goblet with amplified sound. |
| Sprott, 3.9 | shattering goblet or beaker | 3D40.55 | A glass beaker exposed to a sufficiently intense sound wave at its natural resonant frequency will shatter. |
| Disc 09-06 | glass breaking with sound | 3D40.55 | Large amplitude sound at the resonant frequency is directed at a beaker. |
| AJP 58(1),82 | wind chimes | 3D40.60 | Directions for making wind chimes. Some discussion of the perception of complex tones. |
| PIRA 1000 | bull roarer | 3D40.65 | |
| Sut, S-143 | aeolian "bull roarer" | 3D40.65 | The Australian "bull-roarer" produces a loud noise due to eddies in the air. |
| AJP 53(6),579 | spherical oscillations movie | 3D40.90 | A description by the author of a computer generated movie of spherical oscillations. |
| | **Tuning Forks** | **3D46.00** | |
| Hil, S-2g | tuning fork sets | 3D46.15 | Various sets of tuning forks. |
| PIRA 1000 | tuning fork | 3D46.16 | |
| Sprott, 3.7 | oscilloscope waveforms - tuning forks | 3D46.16 | An oscilloscope displays the waveforms of various tuning forks. |
| Disc 10-03 | tuning fork | 3D46.16 | Use a microphone and oscilloscope to display the waveforms of 256, 512, and 1024 Hz tuning forks. |
| Sut, S-110 | tuning forks | 3D46.20 | Strike two tuning forks. Hold one against the table and the other in the air. When the first is no longer audible, hold the second on the table. |
| Sut, S-55 | tuning forks | 3D46.21 | Compare losses of tuning forks of steel and alloy, on and off a resonator box. |
| PIRA 1000 | adjustable tuning fork | 3D46.22 | |
| Disc 10-04 | adjustable tuning fork | 3D46.22 | Adjust masses on each tine of a large fork and show the waveform on an oscilloscope. Mistuned forks damp quickly. |
| Mei, 19-9.3 | modulation of sound waves | 3D46.25 | Two tuning forks of slightly different frequencies mounted on resonant boxes couple when the amplitude is varied by an oscillating barrier between them. |
| F&A, Sh-4 | low frequency tuning fork | 3D46.30 | Tuning fork motion can be studied with a large fork. |
| D&R, W-265 | low frequency tuning fork | 3D46.30 | Tuning fork vibrations may be studied with a strobe and a long fork. |
| Bil&Mai, p 216 | low frequency tuning fork | 3D46.30 | Tuning fork vibrations may be studied with a large fork and a bowl of water or a strobe. |
| Sut, S-51 | project a tuning fork | 3D46.31 | Stroboscopically shadow project a vibrating tuning fork on a screen. |
| F&A, Sf-2 | vowel tuning forks | 3D46.40 | A set of tuning forks made to give sounds that sound like the vowels. |
| F&A, Sc-3 | quadrupole nature of a tuning fork | 3D46.45 | Hold a tuning fork close to the ear and rotate it. |
| AJP 68(12), 1139 | quadrupole nature of a tuning fork | 3D46.45 | The sound of a tuning fork rotated close to the ear, and then at arms length, is shown to be that of a linear quadrupole. |
| AJP 28(8),ix | frequency standard tuning forks | 3D46.90 | Driven precision tuning forks of 400 and 100 Hz are used as secondary frequency standards. |
| AJP 28(5),505 | Electronically driven tuning fork | 3D46.90 | A tube circuit for driving a tuning fork. |
| Sut, S-56 | electrically driven fork | 3D46.90 | A vacuum tube circuit for driving tuning forks. |
| | **Electronic Instruments** | **3D50.00** | |
| PIRA 500 | keyboards | 3D50.10 | |
| Sprott, 3.7 | electronic keyboard | 3D50.10 | Display the output of an electronic keyboard on an oscilloscope. |
| | **SOUND REPRODUCTION** | **3E00.00** | |
| | **Audio Systems** | **3E10.00** | |
| PIRA 1000 | audio cart - complete audio system | 3E10.10 | |
| | **Loudspeakers** | **3E20.00** | |
| D&R, W-425 | loudspeakers | 3E20.10 | A simple speaker constructed of a coil wrapped on a dowel rod that is connected to a tape player. Hold the coil next to a magnet. The sound can be made audible by placing the end of the dowel rod on a Styrofoam cup. |

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| Disc 10-12 | cutaway speaker | 3E20.15 | A loudspeaker has been cut in two so that the motion of the cone can be easily observed at low frequencies. |
| AJP, 50 (4), 348 | loudspeaker - resonant frequency | 3E20.15 | Finding the fundamental resonant frequency of a loudspeaker and marking its useful low-frequency limit. |
| PIRA 1000 | crossover network for speakers | 3E20.20 | |
| PIRA Local | crossover network for speakers | 3E20.20 | White noise is played through a speaker that has low, mid-range, and high frequency speaker elements that are controlled by a crossover. Using a microphone connected to an oscilloscope, you can easily show that the high frequencies are coming through the tweeter, and low frequencies are coming through the woofer. |
| TPT, 9, (1), p.47 | crossover network | 3E20.25 | A crossover is connected to a signal generator. As the frequency is adjusted, the speaker is switched between the tweeter and woofer positions in the circuit demonstrating how the crossover works. |
| D&R, W-405 | sound color organ | 3E20.30 | A kit that is basically a low-mid-high crossover with the output of each range connected to a different colored light. In this case, low frequencies to a red light, mid-range frequendies to a green light, and high frequencies to a blue light. |
| | **Microphones** | **3E30.00** | |
| | **Amplifiers** | **3E40.00** | |
| PIRA Local | distortion in an audio amplifier | 3E40.10 | Raising the input signal of an audio amplifier past its linear range creates distortion in the ouput signal. The distortion and additional harmonics can be easily seen on an oscilloscope. |
| Sprott, 3.7 | distortion in an audio amplifier | 3E40.10 | Show effect of distortion due to signal amplification using a transistor radio and oscilloscope. |
| | **Recorders** | **3E60.00** | |
| PIRA Local | harmonic disortion of tape recorders | 3E60.10 | Set up to record a square wave on the tape player. Look at the signal after it passes the preamps of the recorder, and then look at the signal after it has been recorded and played back. |
| | **Digital Systems** | **3E80.00** | |
| PIRA 1000 | CD with holes | 3E80.10 | |
| PIRA Local | CD with holes | 3E80.10 | A CD has small increasing size holes drilled in it. The CD will play over the small holes with no skipping as the disk is coded to override localized damage to the disc. |
| PIRA Local | MP3 compression | 3E80.50 | Play and compare various MP3 compressions of a short musical CD excerpt. Do a spectral analysis of the sound to see how the spectrum is being limited as the bit-rate is reduced. |

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| | **THERMAL PROPERTIES OF MATTER** | **4A00.00** | |
| | **Thermometry** | **4A10.00** | |
| PIRA 500 | various thermometers | 4A10.10 | |
| Sut, H-2 | various thermometers | 4A10.10 | Show many different thermometers. |
| Mei, 25-1 | commercial apparatus | 4A10.12 | A listing of commercial apparatus for measuring temperature. |
| AJP 29(6),368 | demonstration thermometer | 4A10.13 | Review of the large dial Atomic Laboratories thermometer. |
| PIRA 1000 | mercury thermometer | 4A10.15 | |
| F&A, Ha-1 | mercury thermometer | 4A10.15 | Show various liquid thermometers. |
| PIRA 1000 | Galileo's thermometer | 4A10.20 | |
| AJP 59(1),90 | Galileo's thermometer | 4A10.20 | A set of glass spheroid buoys of varying density in a glass cylinder arranged so the lowest floating ball represents the temperature. History and sources. See AJP 57,845-846. |
| Sut, H-96 | low temperature thermometers | 4A10.25 | Measure temperatures with thermocouples or a pentane thermometer. |
| Sut, H-6 | thermocouple | 4A10.30 | The copper-constantan thermocouple and galvanometer as a lecture table thermometer. |
| Sut, H-7 | thermocouples | 4A10.31 | Make a thermocouple and demonstrate it if you are going to use it in thermoelectricity. |
| Mei, 25-2.5 | supersensitive thermometer | 4A10.35 | Directions for making a thermometer from a thermistor and transistor amplifier. |
| Mei, 25-2.3 | temperature sensitive paint | 4A10.40 | Directions for making temperature sensitive paint. |
| AJP 30(4),300 | thermosensitive pigment | 4A10.42 | Double iodide of mercury and silver (HgI2.2AgI) changes from yellow to red on heating. Several demos. |
| TPT 1(5),226 | thermochromic cards | 4A10.45 | Many demonstrations are discussed using thermochromic cards as temperature indicators. |
| Mei, 26-3.5 | Thermicon card | 4A10.45 | Many demonstrations are discussed making use of the Thermicon card. Pictures, Diagrams, Reference. |
| PIRA 1000 | cholesteric liquid crystals | 4A10.50 | |
| AJP 38(4),425 | cholesteric liquid crystals | 4A10.50 | Making liquid crystals for thermal mapping. |
| D&R, H-018 | liquid crystal sheets | 4A10.50 | Gather an assortment of commercially available liquid crystal strips with different temperature ranges. |
| Disc 24-17 | liquid crystal sheets | 4A10.50 | Watch a liquid crystal thermometer change color. |
| Sut, H-8 | pyrometry | 4A10.70 | 1) Show the changes in color and brightness as a iron wire is heated. 2) Place a lamp on the focal plane of a projection lantern and vary the voltage so the filament appears darker and brighter than the background. |
| Sut, H-1 | temperature ranges | 4A10.90 | Prepare a large diagram several meters long ranging from 0 to 6000 K with points of interest indicated. |
| | **Liquid Expansion** | **4A20.00** | |
| PIRA 500 | Torchelli tube | 4A20.10 | |
| UMN, 4A20.10 | Torricelli tube | 4A20.10 | Immerse a Torchelli tube filled with red water in a boiling water bath. The fluid will drop before rising. |
| F&A, Ha-9 | expansion up a tube by heating | 4A20.10 | A flask with a long slender neck is filled with colored water and immersed in a hot water bath. |
| Disc 14-13 | thermal expansion of water | 4A20.10 | Fill a round bottomed flask with water, stick a slender tube in the neck, and heat with a burner. |
| Sut, H-32 | Torricelli tube | 4A20.11 | A small bulb with a capillary full of mercury is immersed in a bath of hot water. The meniscus falls, then rises. |
| Mei, 25-2.1 | Torricelli tube | 4A20.12 | A thermometer inserted in hot water shows a drop in temperature as the glass expands before the liquid warms. |
| Hil, H-2a.7 | water thermometer | 4A20.13 | A bulb with a small bore tube. |
| F&A, Ha-12 | expansion of fluids | 4A20.20 | A manometer is surrounded on one side with ice water and on the other by steam. |
| Sut, H-27 | test tube set | 4A20.25 | A number of test tubes filled with various liquids are immersed in a hot water bath. Expansion is magnified by small bore tubes. |
| PIRA 1000 | maximum density of water | 4A20.30 | |
| Sut, H-28 | maximum density of water | 4A20.30 | A flask with a narrow stem shows volume changes and a thermocouple shows temperature changes when water is allowed to warm from 0 C. |
| Sut, H-29 | maximum density of water | 4A20.30 | Refinements to H-28. Use a 100 ml quartz flask and 1 mm bore capillary tube for a meniscus drop of 5 to 6 mm. |
| Disc 14-14 | negative expansion coefficient of water | 4A20.30 | Immerse a water thermometer in an ice bath |
| F&A, Ha-13 | water at 4 C | 4A20.35 | Water at the bottom of a cylinder remains at 4 C when surrounded by ice at the middle. |

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| Sut, H-31 | maxium density of water | 4A20.35 | The familiar Hope apparatus. A tall cylinder of water with a collar of salt/ice around the middle will freeze at the top and remain at 4 C at the bottom. |
| Sut, H-30 | maximum density of water | 4A20.35 | In a jar of water 35 cm high with 15 cm of ice floating on top, the temperature at the bottom does not fall below 4 C. |
| TPT 2(7),338 | coefficient of expansion of oil | 4A20.40 | A hydrometer is used to measure the density of olive oil as it cools. |
| | **Solid Expansion** | **4A30.00** | |
| PIRA 200 | bimetal strip | 4A30.10 | Strips of dissimilar metals bonded together bend when heated. |
| UMN, 4A30.10 | bimetal strip | 4A30.10 | A bimetal strip of brass and steel is heated in a Bunsen burner flame. |
| F&A, Ha-5 | bimetal strip | 4A30.10 | Strips of dissimilar metals bonded together bend when heated. |
| Mei, 25-2.2 | bimetallic strip | 4A30.10 | A pointer is mounted on the end of a bimetallic strip. Picture. |
| Sut, H-21 | bimetal strip | 4A30.10 | Two 25 cm strips of brass and invar steel are welded together for use as a bimetal strip. |
| Hil, H-2a.5 | bimetallic strip | 4A30.10 | Just a picture. |
| D&R, H-110 | bimetalic strip | 4A30.10 | Heat a bimetallic strip and observe bending. |
| Disc 14-08 | bimetallic strip | 4A30.10 | Heat the commercial bimetallic strip in a flame. |
| PIRA 1000 | thermostat model | 4A30.11 | |
| F&A, Ha-6 | thermostat | 4A30.11 | A small bimetal strip acts as a switch in a thermostat. |
| Sut, H-22 | bimetallic strip thermostat | 4A30.11 | Set up a bimetallic strip thermostat to ring bells or flash lights. |
| D&R, H-044 | bimetallic strip thermostat | 4A30.11 | A bimetallic strip thermostat will turn lights on and off. |
| Disc 14-09 | thermostat model | 4A30.11 | A bimetallic strip bends away from an electrical contact when heated turning off a light. |
| AJP 55(10),954 | turn signal oscillator | 4A30.12 | Two types of turn signal oscillators that use bimetal strips are discussed. |
| PIRA 1000 | wire coil thermostat - Zigmund Peacock, University of Utah | 4A30.15 | Two thermostat coils made from flat spring steel with pointer rods added to the outer end. One flat, and one stretched into the shape of a cone. Both work the same. Shows that most thermostats are just coils of spring steel and not bimetal strip. |
| PIRA 200 | balls and ring | 4A30.20 | A ring with a set of two balls, one over and one under size. Heat the ring and slip over both. |
| UMN, 4A30.20 | balls and ring | 4A30.20 | |
| F&A, Ha-7 | ball and ring | 4A30.21 | A ball passes through a ring only when it is heated. |
| Sut, H-15 | ball and ring | 4A30.21 | A ball passes through a snugly fitting ring when both are at the same temperature. |
| Hil, H-2a.4 | ball and ring | 4A30.21 | Just a picture. |
| D&R, H-114 | ball and ring | 4A30.21 | The ball will pass through a ring only after the ring has been heated. |
| Disc 14-11 | thermal expansion | 4A30.22 | A brass plate with a hole is heated until it fits over a ball. |
| Sut, H-16 | shrink fit | 4A30.23 | Heat a brass ring and slip it onto a slightly tapered steel bar and pass around the class. |
| PIRA 500 | break the bolt | 4A30.30 | |
| UMN, 4A30.30 | break the bolt | 4A30.30 | Heat a iron bar, then tighten it in a yoke so it breaks a cast iron bar when the bar cools. |
| F&A, Ha-10 | forces caused by change of length | 4A30.30 | A heavy iron bar heated and placed in a yoke breaks a cast iron bolt as it cools. |
| Sut, H-17 | break the bolt | 4A30.30 | A heated bar is tightened in a yoke against a cast iron peg which breaks as the bar cools. |
| Disc 14-10 | pin breaker | 4A30.30 | Heat a rod to break a 1/8" diameter pin by expansion. |
| Sut, H-18 | break the bolt | 4A30.31 | A drill rod clamped between a inner steel rod and an outer brass tube breaks when the brass tube is heated. Diagram. |
| PIRA 1000 | hopping discs | 4A30.40 | |
| F&A, Ha-11 | hopping discs | 4A30.40 | Bimetal discs hop on guide wires between hot and cold plates. |
| D&R, H-122 | hopping discs | 4A30.40 | Warm bimetal disks will jump in the air when cooled. |
| Sut, H-13 | bending glass by expansion | 4A30.45 | One edge of a strip of plate glass is heated with a Bunsen burner causing the glass to bend toward the cooler side. |
| Sut, H-24 | Trevelyan rocker | 4A30.46 | A brass or copper rocker heated and placed on a lead support will rock due to expansion of the lead. Diagram. |
| PIRA 1000 | expansion of quartz and glass | 4A30.50 | |
| UMN, 4A30.50 | expansion of quartz and glass | 4A30.50 | |
| F&A, Hd-8 | expansion of quartz | 4A30.50 | Quartz and glass tubes are both heated with a torch and plunged into water. |
| Sut, H-25 | expansion of quartz and glass | 4A30.50 | Heat a piece of quartz tube and quench it in water. Try the same thing with Pyrex and soft glass. |
| F&A, Ha-8 | expansion of a tube | 4A30.55 | Steam is passed through an aluminum tube and a dial indicator shows the change in length. |
| Sut, H-12 | expansion tube | 4A30.55 | One end of a tube rests on a needle attached to a pointer that moves as the tube is heated. |

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| D&R, H-040 | expansion rod | 4A30.55 | One end of a rod rests on a needle attached to a pointer with attached mirror. The pointer will move as the rod is heated. Shine a laser at the mirror to observe minute expansion. |
| Bil&Mai, p 228 | expansion rod | 4A30.55 | One end of a rod rests on a needle attached to a pointer with attached mirror. The pointer will move as the rod is heated. Shine a laser at the mirror to observe the expansion. |
| PIRA 500 | sagging wire | 4A30.60 | |
| UMN, 4A30.60 | sagging wire | 4A30.60 | |
| Sut, H-9 | sagging wire | 4A30.60 | Heat a length of nichrome wire electrically and watch it sag. ALSO - Recalescence temperature of iron (800 C). |
| Hil, H-2b | linear expansion of a wire | 4A30.60 | A wire is heated electrically and a pointer indicates change of length. Also recalescence of iron. |
| Disc 14-07 | thermal expansion of wire | 4A30.60 | A long iron wire with a small weight hanging at the midpoint is heated electrically. |
| Sut, H-10 | expanding wire | 4A30.61 | One end of a heated wire is passed over a pulley to a weight. The pulley has a pointer attached. |
| Sut, H-14 | bridge expansion | 4A30.65 | Either the wire or the roadway can be heated in this model of a suspension bridge. |
| Sut, H-23 | gridiron pendulum | 4A30.69 | A gridiron pendulum of constant effective length when heated is made of tubes of brass and zinc. |
| PIRA 1000 | heat rubber bands | 4A30.80 | |
| UMN, 4A30.80 | heat rubber bands | 4A30.80 | |
| AJP 31(5),397 | heat rubber bands | 4A30.80 | 1) Pass out rubber bands, have the students stretch them while holding against lips, then wait and reverse for cooling. 2) Hang a 1 kg mass from four rubber bands so it touches the table, heat 20 sec with a heat lamp and the mass will lift 1 cm. |
| F&A, Hm-4 | thermal properties of rubber | 4A30.80 | Rubber tubing inside a copper shield contracts as it is heated. |
| Sut, H-19 | heat rubber | 4A30.80 | Hang a 100 g weight from a rubber band and heat with a radiant heater. Or, enclose a rubber tube in a brass cylinder and heat with a Bunsen burner. |
| Sut, H-173 | rubber band on lips | 4A30.80 | Pass out rubber bands for the students to put on their lips to feel the change in temperature as they stretch and unstretch. |
| D&R, H-054 | heat rubber bands | 4A30.80 | Hang 1 kg from a rubber band and heat. Observe contraction. |
| D&R, H-340 | rubber band on lips | 4A30.80 | Touch a rubber band to upper lip, stretch and unstretch. Temperature will go up when stretched and down when unstretched. |
| Sut, H-20 | heat rubber | 4A30.82 | A complex apparatus that oscillates as a rubber band is heated and cooled. |
| | **Properties of Materials at Low Temperatures** | **4A40.00** | |
| PIRA 200 - Old | lead bell, solder spring | 4A40.10 | Ring a lead bell after it is frozen in liquid nitrogen, cool a coil of solder to make a spring. |
| UMN, 4A40.10 | lead bell | 4A40.10 | Ring a lead bell at room temperature and after it has been cooled in liquid nitrogen. |
| F&A, Hk-9 | lead bell | 4A40.10 | A lead bell frozen in liquid nitrogen gives a tone. |
| Sut, H-100 | lead bell, solder spring | 4A40.10 | A lead bell rings at low temp, a solder spring supports a weight. |
| AJP 77 (10), 917 | lead bell | 4A40.10 | Picture of two different types of lead bells. |
| PIRA 500 | solder spring | 4A40.15 | |
| UMN, 4A40.15 | solder spring | 4A40.15 | Cool a solder spring in liquid nitrogen and hang a mass from it. |
| Disc 08-09 | elasticity of low temperature | 4A40.15 | Liquid nitrogen and a solder spring, rubber hose, etc. |
| PIRA 1000 | mercury hammer | 4A40.20 | |
| F&A, Hk-8 | mercury hammer | 4A40.20 | Mercury is frozen in the shape of a hammer head and used to pound a nail. |
| Sut, H-101 | mercury hammer | 4A40.20 | Cast a mercury hammer and freeze with liquid nitrogen. |
| PIRA 200 | smashing rose and tube | 4A40.30 | Cool a rose, urffer tube, or handball in a clear dewar of liquid nitrogen and smash it. |
| UMN, 4A40.30 | smashing rose and tube | 4A40.30 | Cool a rose in a clear dewar of liquid nitrogen and smash it. |
| F&A, Hk-7 | rubber at low temperature | 4A40.30 | A rubber hose is dipped in liquid nitrogen and smashed. |
| D&R, H-078 | smashing flower and balls | 4A40.30 | Cool flowers and cheap rubber balls in liquid nitrogen and smash. Also try bananas and balloons. |
| Sprott, 2.9 | smashing flower and balls | 4A40.30 | Objects placed in liquid nitrogen change their physical properties. |
| TPT 28(8),544 | low temp behavior | 4A40.32 | A discussion of a heat of vaporization of liquid nitrogen lab and a listing of the usual demonstrations. |
| Sut, H-99 | low temp behavior | 4A40.32 | Smash a wiener, sheet metal, flower, hollow rubber ball, saw a sponge, alcohol is viscous, a pencil won't mark. |
| TPT 28(5),321 | cyrogenics day in a high school | 4A40.33 | Description of the annual cryogenics day at F. D. Roosevelt High School listing many demonstrations. |

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| PIRA 1000 | cool rubber band | 4A40.35 | |
| PIRA 1000 | viscous alcohol | 4A40.40 | |
| F&A, Hk-10 | viscous alcohol | 4A40.40 | Ethyl alcohol becomes very viscous at liquid nitrogen temperatures. |
| Disc 14-05 | viscosity of alcohol at low temp | 4A40.40 | Cool alcohol with liquid nitrogen and pour through a cloth screen. |
| Sut, H-114 | liquid air fountain | 4A40.50 | A fountain is made using evaporating liquid air as a pressure source. |
| Sut, H-116 | absorption of gases | 4A40.60 | A test tube filled with charcoal is attached to a bent 80 cm tube dipped in a beaker of mercury. When the charcoal is cooled, the mercury rises. |
| Sut, H-117 | absorption of gases | 4A40.60 | A discharge tube filled with charcoal passes through all the stages to vacuum when cooled in liquid air. |
| Sut, H-121 | burning in liquid oxygen | 4A40.70 | Steel wool is burned after being immersed in liquid oxygen. |
| Sut, H-118 | burning in liquid oxygen | 4A40.71 | Old cigars (and other things) burn well when saturated with liquid oxygen. |
| Sut, H-120 | burning in liquid oxygen | 4A40.72 | While smoking a cigarette the lecturer puts liquid oxygen in the mouth and blows out. |
| Sut, H-119 | chemical reaction rates in liquid oxygen | 4A40.75 | Drop a piece of potassium cooled in liquid oxygen into water. |
| Sut, H-107 | filtering liquid air | 4A40.80 | Crystals of ice and carbon dioxide are retained in a filter. |
| Sut, H-108 | density of liquid air | 4A40.85 | Pour liquid air into water. As the nitrogen evaporates, the liquid air sinks and oscillates with convection currents. |
| AJP 55(6),565 | low temperature lattice models | 4A40.90 | Arrays of magnetic quadrapoles in square and triangular lattices simulate orientational ordering of diatomec molecule at low temperatures. |
| | **Liquid Helium** | **4A50.00** | |
| Mei, 28-1 | basic low temperature apparatus | 4A50.10 | The basic apparatus for working with liquid helium is reviewed. Details in appendix, p.1305. |
| AJP 34(8),692 | low temp apparatus | 4A50.11 | Pictures of many devices for use in lecture demonstration and laboratory. |
| AJP 43(12),1105 | superconduction in lead | 4A50.20 | A superconducting ammeter allows direct observation of the current. |
| Mei, 28-2.1 | superconduction in lead | 4A50.20 | Lead in liquid helium is superconducting and floats a magnet. Picture. |
| Mei, 28-2.2 | the persistent current | 4A50.30 | A niobium coil remains superconducting at 4.2 K for up to 5 amps. Picture, Diagram. |
| Mei, 28-2.3 | lambda-point transition | 4A50.40 | The transition between helium I and II. |
| Mei, 28-2.4 | superleak | 4A50.50 | Leakage through a fritted disk happens with helium I but not II. |
| Mei, 28-2.5 | the fountain effect | 4A50.60 | The fountain effect. Pictures. |
| Mei, 28-2.6 | rolling creeping film | 4A50.70 | A film of helium II creeps out of a dish. Picture. |
| Mei, 28-2.7 | resistance vs. temperature | 4A50.80 | A circuit shown can be used to demonstrate superconductivity in lecture. Diagram. |
| | **HEAT AND THE FIRST LAW** | **4B00.00** | |
| | **Heat Capacity and Specific Heat** | **4B10.00** | |
| AJP 52(9),856 | specific heat of liquids problem | 4B10.05 | A note on the inexplicably high specific heat of liquids. |
| PIRA 500 | water and aluminum on a hot plate | 4B10.10 | |
| UMN, 4B10.10 | water and aluminum on the hot plate | 4B10.10 | One liter of water in a beaker, water and aluminum of 1 Kg total mass in another beaker, are heated on the same hot plate. Display temperatures of both. |
| F&A, Hb-2 | heat capacity | 4B10.10 | Two beakers, one with 1 Kg water and the other with .5 Kg water and .5 Kg lead are heated at the same rate. |
| Disc 14-17 | specific heat | 4B10.10 | Heat lead, aluminum, and steel to 100 C and then warm cool water. Show temp on LED bar graph. |
| PIRA 1000 | water and oil on a hot plate | 4B10.15 | |
| UMN, 4B10.15 | water and oil | 4B10.15 | Heat two beakers on a single hot plate, each contains the same mass of either water or oil. |
| Sut, H-35 | iron and water | 4B10.16 | Iron and a vessel of water with the same mass and area are heated on identical Bunsen burners. Dip your hand in the water and sprinkle it on the iron plate where it will sizzle. |
| Sut, H-39 | mixing water | 4B10.20 | Different masses of hot and cold water are mixed in a large beaker and the final temp is compared to the calculated value. |
| F&A, Hb-1 | calorimeter | 4B10.26 | A calorimeter is used to measure the specific heat of lead. |
| Sut, H-40 | hot lead into water | 4B10.26 | Known masses of lead and copper are heated and poured into calorimeters with a known mass of water. Specific heats are computed from initial and final temperatures. |
| Sut, H-38 | ice calorimeter | 4B10.27 | Several different metals on the same mass are heated to the same temp and lowered into a line of crushed ice filled funnels. The melted water is collected in graduates. |
| Sut, H-37 | metals in water | 4B10.28 | Heat metals of the same mass and lower them into beakers containing the same amount of water at room temperature. |

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| PIRA 1000 | melting wax | 4B10.30 | |
| UMN, 4B10.30 | melting wax | 4B10.30 | Five metals of the same mass are heated in boiling water and placed on a thin sheet of paraffin. |
| Sut, H-36 | melting wax | 4B10.30 | Several cylinders of the same metals with the same mass and diameter are heated in paraffin and transferred to a paraffin disc. |
| D&R, H-210 | melting wax | 4B10.30 | Balls of steel, aluminum, and lead with same diameter are heated in boiling water and then dropped onto a thin sheet of wax. |
| Disc 14-18 | specific heat with rods and wax | 4B10.30 | Heat equal mass cylinders of aluminum, steel, and lead and let them melt a path through honeycomb. |
| Mei, 26-2.1 | specific heat at low temperatures | 4B10.35 | Cylinders of the same size of aluminum and lead heat up at the same rate after being cooled in liquid nitrogen. |
| Sut, H-41 | differential thermoscope | 4B10.40 | The jacket areas of two unsilvered unevacuated dewar flasks are connected to a U tube and equal masses of water and mercury at 100 C are poured in. The U tube shows the difference in heat capacities. |
| Sut, H-42 | heat of combustion | 4B10.50 | A bomb or continuous flow calorimeter is used to show heating value of foods and fuel. |
| AJP 33(1),18 | specific heat of a gas | 4B10.55 | Heat a gas in a flask by discharging a capacitor through a thin constantan wire and measure the momentary increase in pressure on an attached water manometer. |
| PIRA 1000 | Clement's and Desormes' experiment | 4B10.60 | |
| UMN, 4B10.60 | Clement's and Desormes' experiment | 4B10.60 | A 10 L flask fitted with a mercury manometer is over pressured and then the valve is quickly opened and shut. The ratio of pressures is related to the specific heats. |
| F&A, Hg-3 | Clement's and Desormes' experiment | 4B10.60 | A large flask with an attached mercury manometer is overpressured and momentarily opened to the atmosphere. |
| AJP 35(9),892 | comment on Cp/Cv with manometer | 4B10.61 | Recommendation of an alternative statement of the problem and results. |
| AJP 35(4),xvi | Cp/Cv with water manometer | 4B10.61 | Replace the mercury in the oscillating column method with water provided the confined air is a large volume. |
| UMN, 4B10.65 | elastic properties of gases | 4B10.65 | A steel ball in a precision tube oscillates as gas escapes from a slightly overpressured flask. |
| F&A, Hg-4 | elastic properties of gases | 4B10.65 | Gas escapes from a flask through a precision tube with a precision ball oscillator. |
| PIRA 1000 | elastic properties of gases | 4B10.70 | |
| AJP 32(1),xiii | Ruchhardt's method for gamma | 4B10.70 | An ordinary glass tube is selected with a slight taper wider at the top. A throttle valve controls the inlet pressure and the oscillations of the ball in the tube are timed. |
| Mei, 27-6.5 | Ruchhardt's method for gamma | 4B10.70 | A ball oscillates in the neck of a flask filled with gas. The pressure is measured indirectly as the ball oscillates. |
| AJP 32(4),xvi | Ruchhardt's method - add mass | 4B10.72 | Add additional mass to the oscillating ball and plot period as a function of mass. |
| Mei, 27-6.6 | Ruchhardt's method for gamma | 4B10.72 | Ruchhardt's apparatus is driven by a slow flow of gas and the ball is loaded with additional mass. |
| AJP 53(7),696 | syringe Ruchhardt's experiment | 4B10.73 | A glass syringe replaces the precision ball in a precision tube and an accelerometer mounted on the syringe allows the oscillations to be displayed on an oscilloscope. |
| F&A, Hg-5 | Ruchhardt's experiment | 4B10.75 | Measure the temperature in the flask with the oscillating balls. |
| AJP 68(3), 265 | Ruchhardt's experiment | 4B10.75 | Ruchhardt's experiment is used to measure the bulk moduli and ratio of specific heats for eighteen gases with atomicity ranging from 1 to 12. |
| AJP 69(3), 387 | Ruchhardt's experiment | 4B10.75 | Ruchhardt's experiment is used to measure the ratio of specific heats for air using computer data acquisition sensors. |
| AJP 69(11), 1205 | Ruchhardt's experiment | 4B10.75 | Ruchhardt's experiment is used to measure the ratio of specific heats for air using a graphic calculator, interface, and sensors. |
| | **Convection** | **4B20.00** | |
| PIRA 200 | convection tube | 4B20.10 | Heat one side of a glass tube loop filled with water and insert some ink. |
| UMN, 4B20.10 | convection tube | 4B20.10 | Heat one side of a glass tube loop filled with water and insert some ink. |
| F&A, Hc-2 | convection of liquids | 4B20.10 | One side of a square tube filled with water is heated while ink is inserted to show the flow. |
| Sut, H-143 | heating system model | 4B20.10 | Heat water in a loop of glass tubing. |
| D&R, H-160 | convection of liquids | 4B20.10 | Food coloring or ink is added to a water filled square tube. Heat one side of the tube and observe the flow pattern. |
| Sut, H-144 | convection tube | 4B20.11 | A rectangular glass tube filled with water is heated on one side. Permanganate crystals show flow. |
| Sut, H-145 | heating system | 4B20.13 | A model of a heating system with an expansion chamber and radiator. Diagram. |

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| PIRA 500 | convection flasks | 4B20.15 | |
| PIRA 1000 | two chimney convection box | 4B20.20 | |
| UMN, 4B20.20 | two chimney convection box | 4B20.20 | |
| F&A, Hc-1 | two chimney convection box | 4B20.20 | A candle burns under one chimney in a double chimney convection box. |
| Sut, H-139 | two chimney convection box | 4B20.20 | A container has two lamp chimneys, a candle is placed under one of them. |
| Hil, H-3a.2 | two chimney convection box | 4B20.20 | Smoke is used to indicate convection in the two chimney box. |
| D&R, H-160 | two chimney convection box | 4B20.20 | A candle burns under one chimney in a double chimney convection box. Smoke paper in the box will enhance viewing. |
| PIRA 1000 | convection chimney with vane | 4B20.25 | |
| UMN, 4B20.25 | convection chimney with vane | 4B20.25 | |
| Sut, H-140 | convection chimney | 4B20.25 | A candle in a chimney burns as long as there is a metal vane dividing the chimney into two parts. |
| Sprott, 2.13 | convection chimney with vane | 4B20.25 | A candle extinguishes when a glass cylinder is placed over it unless a T-shaped piece of metal is lowered into the cylinder. |
| PIRA 1000 | convection chimney with confetti | 4B20.30 | |
| TPT 26(7), 468 | convection of a gas - heat turbine | 4B20.38 | How to make a small turbine rotator that will turn when placed above a heat source. |
| PIRA 1000 | convection currents projected | 4B20.40 | |
| Sut, H-142 | convection projection cell | 4B20.40 | Electrically heat the water at the bottom of a projection cell. Diagram. |
| Disc 14-27 | convection currents | 4B20.40 | An electric element heats water in the bottom of a projection cell. |
| Sut, H-138 | convection box | 4B20.41 | Shadow project convection in a 1 foot square box with hot and cold sinks on the sides. |
| Sut, H-141 | projection cell | 4B20.42 | Introduce hot water at the bottom of cold or cold water at the top of warm in a projection cell. |
| PIRA 500 | burn your hand | 4B20.45 | |
| UMN, 4B20.45 | burn your hand | 4B20.45 | Shadow project a Bunsen burner flame on a screen and hold your hand in the hot gas. |
| Sut, H-137 | burn your hand | 4B20.45 | Shadow project convection currents from a Bunsen burner, hot pipe, dry ice, or ice water. |
| PIRA 1000 | Barnard cell | 4B20.50 | |
| UMN, 4B20.50 | Barnard cell | 4B20.50 | A thin layer of paraffin with reflective flakes is heated until Barnard cells form. |
| F&A, Fp-3 | Barnard cell | 4B20.50 | Paraffin with aluminum dust is heated in a small brass dish until convection cells are formed. |
| UMN, 4B20.55 | Jupiter's red spot | 4B20.55 | Show time lapse video of Jupiter's red spot. Astronomy video disc frame 32888. |
| | **Conduction** | **4B30.00** | |
| PIRA 500 | conduction - dropping balls | 4B30.10 | |
| UMN, 4B30.10 | conduction - dropping balls | 4B30.10 | Waxed balls drop off various metal rods connected to a heat source as the heat is conducted. |
| F&A, Hd-1 | conduction of heat | 4B30.10 | Waxed balls drop at different times from rods attached to a common heat source. |
| D&R, H-140 | conduction - dropping tacks | 4B30.10 | Waxed tacks drop off various metal rods as the center of the apparatus is heated. |
| Hil, H-3a.1 | conduction - dropping balls | 4B30.11 | The center of a star configuration of five different metal bars is heated to melt wax at the far ends, dropping balls. |
| PIRA 1000 | conduction - melting wax | 4B30.12 | |
| Disc 14-21 | thermal conductivity | 4B30.12 | Dip rods in wax, then watch as the wax melts off. Time Lapse. |
| PIRA 500 | melting paraffin - sliding pointer | 4B30.15 | |
| Sut, H-124 | sliding pointers | 4B30.15 | Vertical rods of different metals are soldered onto the bottom of a vessel filled with boiling water. Pointers held by some paraffin slide down as the rods heat. Diagram. |
| PIRA 1000 | painted rods | 4B30.20 | |
| F&A, Hd-2 | conduction of heat | 4B30.20 | Rods of different material are coated with heat sensitive paint and attached to a common heat source. |
| Mei, 26-3.3 | painted rods | 4B30.20 | Steam is passed through a manifold with heat sensitive paint coated rods of different materials. |
| D&R, H-140 | conductometer | 4B30.20 | Rods of different materials are coated with heat sensitive paint and connected to a heat source. |
| PIRA 200 | conduction bars | 4B30.21 | |
| Sut, H-122 | conduction bars | 4B30.21 | Relative conductivities of bars of metals in a common copper block are indicated by match head ignition or temperature indicating paint. |
| Mei, 26-3.8 | iron and copper strips | 4B30.22 | Iron and copper strips are coated with "thermal color" and heated at one end. |
| PIRA 1000 | four rods - heat conduction | 4B30.25 | |

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| UMN, 4B30.25 | four rods - heat conduction | 4B30.25 | |
| PIRA 1000 | copper and stainless tubes | 4B30.30 | |
| UMN, 4B30.30 | copper and stainless tubes | 4B30.30 | A contest is held between people holding copper and stainless tubes in twin acetylene torch flames. |
| F&A, Hd-5 | poor thermal conductivity of stainless steel | 4B30.31 | Heat a stainless tube with a blow torch until it is white hot and hold close to the hot spot. |
| Mei, 26-3.4 | stainless rod | 4B30.31 | Heat one end of a stainless steel rod white hot while holding the other end. |
| Mei, 26-3.2 | iron and aluminum rods | 4B30.32 | A student holds iron and aluminum rods in a burner flame. |
| PIRA 1000 | toilet seats | 4B30.35 | |
| UMN, 4B30.35 | toilet seats | 4B30.35 | |
| Sut, H-129 | wood and metal rod | 4B30.40 | Wrap a paper around a rod made of alternating sections of wood and metal and hold in a flame. |
| Sut, H-130 | high conductivity of copper | 4B30.41 | Hold a burning cigarette on a handkerchief placed over a coin. |
| Mei, 26-3.1 | matches on hot plates | 4B30.42 | Matches are placed on plates of two different metals over burners. |
| PIRA 1000 | heat propagation in a copper rod | 4B30.50 | |
| UMN, 4B30.50 | heat propagation in a copper rod | 4B30.50 | |
| Mei, 26-3.7 | propagation in a copper rod | 4B30.50 | Solder a copper-constantan thermocouple into a copper rod and thrust the end into a flame. |
| Mei, 26-3.10 | spreading heatwave | 4B30.51 | An aluminum bar has a series of small mirrors mounted on small bimetallic strips to allow projection of the curve of the temperature in the bar as it is heated. Construction details in appendix, p.1287. |
| Sut, H-123 | dropping ten penny nails | 4B30.52 | Ten penny nails attached with wax will progressively drop off a bar as a Bunsen burner heats one end. Pennies or lead shot can also be used. |
| AJP 41(2),281 | liquid crystal indicator | 4B30.53 | Liquid crystal indicator from Edmund Sci. was bonded to a strip and a plate of metal and the resulting color change compared well with a computer generated model. |
| Sut, H-125 | temperature indicating paper | 4B30.53 | A copper bar is placed on temperature indicating paper and one end is heated. |
| F&A, Hd-6 | heat transfer | 4B30.54 | A solid copper rod has holes bored to pass steam and cold water from the same end. Thermometers along the rod measure the heat transfer into the water. |
| Sut, H-128 | anisotropic conduction | 4B30.56 | Conductivity is greater along the grain in wood and crystals. Heat the center of a thin board covered with a layer of paraffin and watch the melting pattern. |
| Mei, 26-3.9 | thermal vs. electrical conduction | 4B30.58 | A rod is fabricated with end sections of copper and a center section of constantan. Temperatures along the rod when heated differentially are compared with voltages along it while a potential is applied. |
| AJP 36(2),120 | electrical analog of heat flow | 4B30.59 | A circuit that gives the electrical analog of heat conduction. |
| Sut, H-131 | heat conductivity of water | 4B30.60 | Boil water in the top of a test tube while ice is held at the bottom. |
| Sut, H-132 | heat conductivity of water | 4B30.61 | The bulb of a hot air thermometer is placed in water and a layer of inflammable liquid is poured on top and burned. |
| TPT, 36(9), 546 | demonstrating that air is a bad conductor of heat | 4B30.63 | Placed on a flat heat source and with both half-filled with H2O, a flat bottom Al can and a soda can are heated together, with the resulting temp change in each can analyzed over time. |
| Sut, H-133 | heat conduction in gases | 4B30.65 | Small double walled flasks are filled with ether, the jackets contain different gases. When placed in boiling water, the height of ether flames varies. |
| AJP 29(8),549 | heat conductivity of CO2 | 4B30.66 | Author tried using dry ice to cool break the bolt. Nothing happened. |
| Sut, A-61 | conduction of heat in a lamp | 4B30.71 | A carbon filament lamp is filled with different gases at various pressures and the brightness of the filament observed. |
| Mei, 27-5.1 | glowing tubes | 4B30.72 | Filaments in Pyrex tubes containing air, flowing hydrogen, and hydrogen at reduced pressure glow with different intensities. Picture. |
| Mei, 27-5.2 | double glow tube | 4B30.73 | A single length of Nichrome wire runs through two chambers allowing comparison of thermal conductivity of two gases and variation of pressure. |
| | **Radiation** | **4B40.00** | |
| PIRA 200 | light the match | 4B40.10 | Light a match at the focus of one parabolic reflector with a heating element at the focus of another reflector. |
| UMN, 4B40.10 | light the match | 4B40.10 | Two parabolic reflectors are aligned across the table, a heat source at the focus of one reflector and a match at the focus of the other. |
| TPT 28(1),56 | light the match | 4B40.10 | Use a homemade nichrome wire coil for the light the match demonstration. |
| F&A, Hf-5 | transmission of radiant heat | 4B40.10 | A match at the focus of one parabolic reflector is lit by a heating element placed at the focus of another reflector. |
| Sut, H-150 | light the match | 4B40.10 | Two parabolic mirrors are used to transmit radiation to light matches, etc. |

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| Sprott, 2.14 | light the match | 4B40.10 | A match at the focal point of a parabolic reflector is lit by the radiation of a heating element at the focus of another reflector. |
| Disc 22-04 | heat focusing | 4B40.10 | Light a match using a heater and concave reflectors. Animation. |
| Mei, 38-5.9 | reflection of radiation | 4B40.11 | A beam from a heated metal ball in the focus of a parabolic mirror reflects off another parabolic or flat mirror to a thermopile. |
| Hil, H-3c | radiation reflector | 4B40.11 | A heat source at the focal point of one concave reflector directs heat at a radiometer at the focus of a second concave reflector. |
| Mei, 38-5.10 | beakers of water at a distance | 4B40.12 | A thermopile mounted the at focus of a parabolic mirror detects radiation differences from different colored beakers of water at 20'. |
| Sut, H-149 | reflection of radiation | 4B40.13 | Polished sheet metal is used to reflect radiation onto a thermopile. A plate glass mirror is less effective due to IR absorption. |
| PIRA 500 | IR focusing | 4B40.20 | |
| Mei, 38-5.7 | light the match | 4B40.20 | Focus an arc lamp on a match with and without filters, using CS2 and iodine in a round flask for a lens. |
| Sut, H-151 | focusing IR radiation | 4B40.20 | A opaque flask of a solution of iodine in carbon disulfide serves as a lens to focus IR radiation. |
| Sut, L-113 | infrared | 4B40.20 | Iodine dissolved in alcohol gives a filter transmitting in the IR but absorbing in the visible. Ignite a match in the focus of an arc lamp. |
| Sut, H-152 | ice lens | 4B40.21 | Form an ice lens between two watch glasses. Focus the light from an arc lamp on a match head. |
| PIRA 1000 | Leslie's cube | 4B40.30 | |
| F&A, Hf-1 | radiation from a black box | 4B40.30 | Radiation from Leslie's cube is measured with a thermopile. |
| Sut, H-156 | Leslie cube | 4B40.30 | Relative radiation from various surfaces at the same temperature is shown with a Leslie cube and thermopile. |
| Disc 14-25 | radiation cube | 4B40.30 | Fill a Leslie cube with hot water and use a thermopile to detect the radiation. |
| UMN, 4B40.32 | Leslie's cube | 4B40.32 | |
| Mei, 38-5.8 | Leslie's cube | 4B40.32 | Rotate the cube to demonstrate Lambert's law, move the thermopile away to demonstrate the inverse square law, measure at several temperatures to demonstrate the fourth power law. |
| Sut, H-163 | radiation and absorption | 4B40.33 | Two Leslie cubes form a differential thermoscope with a third between. Orient faces shiny to black. |
| PIRA 1000 | two can radiation | 4B40.40 | |
| AJP 58(3)244 | cooling cans | 4B40.40 | Cooling rates of shiny unpainted, black painted, and white painted cans. |
| Disc 14-24 | two can radiation | 4B40.40 | Shiny and flat black cans filled with cool water warm up, cool off when filled with boiling water. |
| F&A, Hf-4 | radiation from a shiny and black surface | 4B40.45 | A paper held close to a stove element is not scorched where the element is painted white. |
| Mei, 38-5.3 | stove element | 4B40.45 | A sheet of paper is held near a stove heating element painted half white and half black. |
| D&R, H-180 | radiation on black and white surfaces | 4B40.45 | A card painted half black and half white has drops of wax applied. Wax on the black side melts first when heated with a heat lamp. Can also be done with a black and a white ball on some ice. When warmed with a heat lamp the black ball melt into the ice faster. |
| Mei, 38-5.6 | hot wire in a tube | 4B40.48 | A platinum wire is heated inside of a quartz tube showing transparent objects radiate less. |
| PIRA 1000 | selective absorption and transmission | 4B40.50 | |
| UMN, 4B40.50 | selective absorption and transmission | 4B40.50 | |
| Sut, H-155 | selective absorption | 4B40.50 | Various screens (black bakelite, Corex red-purple, glass, water, quartz, etc.) are placed between a heat source and a thermopile detector. |
| Hil, H-3b.2 | absorption and transmission | 4B40.50 | Clear heat absorbing and opaque heat transmission glass filters are inserted between a heat lamp and a radiometer detector. |
| Sut, H-162 | absorption of radiation | 4B40.51 | A white card with letters in India ink is exposed lettered side to a hot source charring it locally where the letters are. |
| Hil, H-3b.1 | Leybold radiation screen | 4B40.52 | One side of a polished metal plate has a black letter, the other is covered with thermochrome paint. |
| PIRA 1000 | black and white thermometers | 4B40.60 | |
| Mei, 38-5.2 | two thermoscopes | 4B40.60 | One thermoscope is painted white, the other black, and both are illuminated by a lamp. |
| Sut, H-159 | surface absorption | 4B40.60 | A radiant heater is placed midway between two junctions of a demonstration thermocouple and the junctions are covered with black or white caps. |
| Sut, H-154 | selective absorption | 4B40.60 | Focus a large light on a blackened match head, the clear glass bulb of a thermoscope, and the bulb covered with black paper. |

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| Sut, H-161 | surface absorption | 4B40.61 | A Leslie cube with opposite faces blackened is placed between two bulbs of a differential thermoscope. Blacken one bulb. |
| Sut, H-160 | surface absorption | 4B40.62 | Make a special thermocouple of a sheet of copper with constantan wires attached opposite blackened and whitened areas. Shine a light and expose to a hot water container to show different response at different wavelengths. |
| Hil, H-3a.3 | radiation thermometers | 4B40.64 | A heat lamp directed at two thermometers will cause different temperature rises. One thermometer is in a chamber - (?). |
| AJP 58(7),697 | soot and flour - nonlinear absorption | 4B40.70 | Add different amounts of carbon to flour and measure the reflectivity. |
| | **Heat Transfer Applications** | **4B50.00** | |
| PIRA 500 | four thermos bottles | 4B50.10 | |
| UMN, 4B50.10 | four thermos bottles | 4B50.10 | Monitor the temperatures of water in four thermos bottles with different combinations of vacuum and silvering. |
| F&A, Hd-3 | thermal properties of dewars | 4B50.10 | Temperatures are recorded for cooling of four thermos bottles of different construction. |
| AJP 71(7), 678 | heat flow in a thermos | 4B50.10 | Measurements and modeling of the temperature change in a thermos full of ice cold water as a function of both time and position in the thermos. |
| Disc 14-26 | insulation (dewar flasks) | 4B50.10 | Hot water is placed in the four thermos bottles. |
| Sut, H-167 | bad dewar | 4B50.11 | Evacuate a unsilvered dewar, pour in liquid air, let air into the space, see frost form. |
| Sut, H-166 | four thermos bottles - LN2 | 4B50.15 | Pour liquid air into four thermos bottles to sort out conduction, convection and radiation. |
| F&A, Hd-4 | insulation with asbestos | 4B50.17 | Fight asbestos abatement. Two identical cans of water, one wrapped with asbestos, cool. |
| Mei, 38-5.1 | radiation from different surfaces | 4B50.17 | Three cans, black, asbestos covered, and shiny, are filled with boiling water and left to cool. |
| Sut, H-157 | surface radiation | 4B50.17 | An asbestos paper covered can cools faster than a shiny can. |
| PIRA 200 - Old | boiling water in a paper cup | 4B50.20 | Burn one paper cup, boil water in another. |
| UMN, 4B50.20 | boil water in a paper cup | 4B50.20 | Fill a KFC bucket 1/8 full of water, boil the water with a Bunsen burner, and burn away the top part of the bucket with a propane torch. |
| Sut, H-147 | boil water in a paper cup | 4B50.20 | Boil water in a paper container. |
| Disc 14-19 | boiling water in a paper cup | 4B50.20 | Burn one paper cup, boil water in another. |
| PIRA 200 | water balloon and matches | 4B50.25 | |
| PIRA 1000 - Old | water balloon and matches | 4B50.25 | |
| UMN, 4B50.25 | balloon and matches | 4B50.25 | |
| D&R, H-144 | balloons and matches | 4B50.25 | A match is brought up to an air or water filled balloons. Only the air balloon will burst. |
| Bil&Mai, p 230 | water balloon and matches | 4B50.25 | Fill one balloon with air and one with water. Light a candle and hold the flame against each balloon. Only the air balloon will burst. |
| Disc 14-20 | water balloon heat capacity | 4B50.25 | Pop a balloon with a flame, then heat water in another balloon. |
| PIRA 1000 | Leidenfrost effect | 4B50.30 | |
| Disc 14-22 | Leidenfrost phenomenom | 4B50.30 | Drop water on a hot plate, liquid nitrogen on the lecture table. |
| Sut, H-136 | spheroidal state | 4B50.31 | A nugget of silver heated red and plunged into water does not cause immediate boiling. |
| Sut, H-134 | spheroidal state | 4B50.32 | A drop of water suspended from a glass tube above a hot plate is stable until the plate cools. |
| Sut, H-105 | Leidenfrost effect | 4B50.32 | Pour liquid air on your hand or roll it about on the top of your tongue. |
| Sprott, 2.10 | Leidenfrost effect | 4B50.32 | Liquid nitrogen poured over the hand causes no harm. |
| AJP 46(8),825 | Leidenfrost phenomenom | 4B50.33 | Four demonstrations: floating liquid drops on their own vapor, delayed quenching, Boutigny bomb, and stick your finger in boiling oil. |
| PIRA 1000 | finger in hot oil | 4B50.35 | |
| UMN, 4B50.35 | finger in oil | 4B50.35 | Heat oil in a beaker, cut a potato and cook a french fry, then wet you finger in a beaker of water and stick it in the hot oil. |
| Sut, H-135 | spheroidal state | 4B50.35 | A wet finger can be dipped into molten lead. |
| PIRA 1000 | reverse Leidenfrost | 4B50.40 | |
| UMN, 4B50.40 | reverse Leidenfrost | 4B50.40 | |
| Sut, H-106 | reverse Leidenfrost effect | 4B50.40 | Place a brass ball into liquid air in a clear dewar and observe the initial leidenfrost effect. When the ball is cold, place it in a flame and observe the reverse leidenfrost effect as frost forms on the ball while it is in the flame. |
| Sut, H-127 | insulators | 4B50.50 | Show commercial insulating materials. Heat a penny red hot on your hand protected by 1/2" rock wool. |
| PIRA 1000 | greenhouse effect | 4B50.60 | |
| Sut, H-153 | greenhouse effect | 4B50.60 | The temperature of a closed bottle in direct sunlight is compared to the ambient temperature. |

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| AJP 41(3),443 | greenhouse effect chamber | 4B50.61 | A chamber with interchangeable windows and provisions to introduce CO2. |
| AJP, 78 (5), 536 | greenhouse effect | 4B50.61 | Shows how the wrong result can be achieved when using CO2 due to the suppression of convective mixing with the ambient air. |
| F&A, Hd-7 | Davy lamp | 4B50.70 | A Bunsen burner will burn on top and bottom of two copper screens a few inches apart. |
| Sut, H-126 | Davy safety lamp | 4B50.70 | Show that a Bunsen burner flame will not strike through to the other side of fine copper wire gauze. Direct a stream of gas at a lit Davy safety lamp. |
| Sut, H-146 | conduction and convection - Pirani | 4B50.80 | The basic principles of the Pirani vacuum gauge. Heat a platinum wire in a flask until it glows dull red, then evacuate the flask and the wire will glow more brightly at the same voltage. |
| TPT 28(6),420 | forced air calorimeter | 4B50.90 | Fans on either side of a 48 quart styrofoam cooler create a forced air calorimeter used in this example to measure the heat produced by a candle. |
| | **Mechanical Equivalent of Heat** | **4B60.00** | |
| PIRA 200 | dropping lead shot | 4B60.10 | Drop a bag of lead shot is dropped several times and measure the temperature rise. |
| UMN, 4B60.10 | dropping lead shot | 4B60.10 | A bag of lead shot is dropped several times and the temperature rise is measured. |
| F&A, He-1 | work into heat | 4B60.10 | Drop lead shot in a bag several times and compare the temperature before and after. |
| Mei, 26-4.2 | dropping lead shot | 4B60.10 | The temperature of a bag of lead shot is taken before and after being dropped repeatedly. A diagram of a projection thermometer is given. |
| PIRA 1000 | invert tube of lead | 4B60.11 | |
| Sut, H-176 | dropping lead shot | 4B60.11 | One or two Kg of lead shot in a mailing tube are inverted 100 times and the temperature rise is measured. |
| D&R, H-405 | dropping lead shot | 4B60.11 | Invert a mailing tube containing several hundred grams of lead shot several hundred times and measure the temperature rise. |
| Bil&Mai, p 226 | dropping lead shot | 4B60.11 | Measure the temperature of lead shot in a long tube. Rotate the tube 100 times allowing the lead shot to fall the full length of the tube each time. Measure and record the final temperature. |
| Disc 15-02 | mechanical equivalent of heat | 4B60.11 | Flip a one meter tube containing lead shot ten times. A thermistor embedded in one end measures the temperature. |
| Sut, H-174 | heating mercury by shaking | 4B60.12 | A nichrome - iron wire thermojunction is inserted into a bottle of mercury which is shaken vigorously. |
| PIRA 1000 | hammer on lead | 4B60.15 | |
| UMN, 4B60.15 | hammer on lead | 4B60.15 | Hammer on a piece of lead that has an embedded thermocouple. |
| Mei, 26-4.7 | hammer on lead | 4B60.15 | Hammer on a piece of lead to heat it. A simple air thermoscope is shown. |
| Sut, H-175 | heating lead by smashing | 4B60.15 | Hit a 250 g lead block with a heavy hammer and show the temperature rise. |
| Bil&Mai, p 226 | hammer on wood | 4B60.15 | Hammer on a piece of wood. Use heat sensitive liquid crystal film to see the increase in temperature where the hammer struck the wood. |
| D&R, H-395 | hammer on wood | 4B60.15 | Hammer on a piece of wood and show temperature rise in struck area with a liquid crystal sheet. |
| Mei, 26-4.3 | drop ball on thermocouples | 4B60.16 | A steel ball is dropped onto an anvil holding a set of thermocouples embedded in solder beads. |
| PIRA 1000 | copper barrel crank | 4B60.20 | |
| UMN, 4B60.20 | copper barrel crank | 4B60.20 | Crank a copper barrel that has copper webbing wrapped around it while under tension and measure the temperature rise of the water inside the barrel. |
| F&A, He-3 | mechanical equivalent of heat | 4B60.20 | The temperature of a copper barrel filled with water with a copper braid under tension wrapped around it is measured before and after cranking. |
| AJP 28(9),793 | motorized mechanical equivalent of heat | 4B60.22 | Continuous flow apparatus with counter rotating turbines powered by an electric motor. |
| Sut, H-177 | Searle's apparatus | 4B60.23 | Searle's apparatus is used to obtain a numerical value of Joule's equivalent. Picture. |
| Sut, H-178 | mechanical equivalent of heat | 4B60.24 | Picture of an elaborate apparatus to measure the mechanical equivalent of heat. Derivation. |
| Sut, H-172 | heating by bending | 4B60.41 | Pass around a No. 14 iron wire for the students to bend. |
| PIRA 1000 | bow and stick | 4B60.50 | |
| Sut, H-171 | bow & stick | 4B60.50 | How to make a fire with a bow and stick. |
| PIRA 500 | boy scout fire maker | 4B60.55 | |
| UMN, 4B60.55 | boy scout fire maker | 4B60.55 | |
| F&A, He-2 | fire maker | 4B60.55 | A motor shaft extended with a hardwood dowel is held against a wood block. |

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| Sprott, 2.15 | drill and dowel | 4B60.55 | Chuck up a dowel in an electric drill and make smoke by drilling a board. |
| Disc 15-01 | drill and dowel | 4B60.55 | Chuck up a dowel in an electric drill and make smoke by drilling a board. |
| Sut, H-170 | flint and steel | 4B60.60 | Sparks from flint and steel or a grindstone show heat from work. |
| PIRA 1000 | cork popper | 4B60.70 | |
| Sut, H-169 | friction cannon | 4B60.70 | Pour ether, alcohol, or water into a tube, cork, and spin by a motor until the frictional heat causes enough vapor pressure to blow the cork. |
| Hil, H-5a.3 | ether friction gun | 4B60.70 | Heat ether by a motor driven friction device until a cork blows. |
| Disc 15-08 | cork popper | 4B60.70 | Water is heated in a stoppered tube by a motorized friction device until the cork blows. |
| Hil, H-5a.2 | steam gun | 4B60.75 | Heat a tube until the cork pops off. |
| | **Adiabatic Processes** | **4B70.00** | |
| PIRA 500 | fire syringe | 4B70.10 | |
| UMN, 4B70.10 | light the cotton | 4B70.10 | Put a small piece of cotton in a glass tube and push down on the piston to light it. |
| Sut, H-179 | light the cotton | 4B70.10 | A piece of cotton in a glass tube will ignite when a plunger is used to quickly compress the air. |
| Hil, H-5c | fire syringe | 4B70.10 | Three fire syringes are shown. |
| Disc 15-05 | fire syringe | 4B70.10 | Compress air in a glass tube to light a tuft of cotton. Slow motion photography. |
| F&A, He-5 | match lighter | 4B70.11 | A match head placed in a cylinder lights when a tight fitting piston is quickly compressed. |
| Mei, 27-6.1 | light a match head | 4B70.11 | Push down hard on a piston in a close fitting tube to light a match head at the bottom. |
| PIRA 200 | expansion cloud chamber | 4B70.20 | |
| PIRA 500 - Old | expansion cloud chamber | 4B70.20 | |
| UMN, 4B70.20 | expansion cloud chamber | 4B70.20 | Pressurize a jug of saturated water vapor with and without smoke particles. |
| F&A, Hl-8 | expansion chamber | 4B70.20 | A 1 L flask is fitted with a rubber bulb and an inlet for smoke. |
| Sut, H-89 | expansion cloud chamber | 4B70.20 | Introduce smoke into a flask attached to a squeeze bulb through a pitchcock. |
| D&R, H-360 | expansion cloud chamber | 4B70.20 | Pressurize a jug of saturated water vapor with and without smoke particles. Smoke provides nucleation sites giving better fog formation when stopper pops out. |
| Bil&Mai, p 235 | expansion cloud chamber | 4B70.20 | Flush a plastic soft drink bottle with salt water and then pressurize with a Fizzkeeper. Release the pressure suddenly and a cloud will be produced in the bottle. |
| Sut, H-88 | expansion cloud chamber | 4B70.21 | Put some smoke and alcohol in a stoppered flask and shake. When the stopper is released a fog forms. |
| D&R, H-230 | cloud formation by cooling | 4B70.23 | Place warm water in a clear container. Close with Saran wrap and place ice cubes on top of the wrap. Condensation will collect on the underside of the wrap, and over time a cloud will form in the container. |
| PIRA 1000 | pop the cork cooling | 4B70.25 | |
| UMN, 4B70.25 | big expansion cloud chamber | 4B70.25 | |
| Hil, M-22b.2 | cloud chambers | 4B70.25 | Pump a one gallon jug with a bicycle pump until the cork pops out. |
| Disc 15-04 | adiabatic cooling | 4B70.25 | Pressurize a one gallon jar with a bicycle pump until the cork blows. Measure the temperature with a thermistor and computer. |
| AJP 58(11),1112 | adiabatic decompression | 4B70.26 | A laser beam is temporarily scattered when an air filled chamber is pumped down with a vacuum pump. |
| F&A, He-6 | adiabatic heating and cooling | 4B70.30 | An air cylinder moves a piston back and forth and a thermocouple measures the temperature. |
| Sut, H-180 | adiabatic compression | 4B70.31 | A thermopile is constructed and put in the bottom of a tube in which air is compressed by a plunger. Instructions. |
| Bil&Mai, p 235 | adiabatic compression | 4B70.31 | Place a liquid crystal thermometer into a plastic soft drink bottle. Pressurize the bottle with a Fizzkeeper while observing the temperature. Release the pressure and observe the temperature decrease. |
| Sut, H-181 | expansion chamber | 4B70.35 | Directions for making a temperature detector to insert into a flask that will be warmed and cooled by compression and expansion. |
| Mei, 27-6.2 | measuring adiabatic compression | 4B70.36 | Temperatures of fixed amounts of gases undergoing adiabatic compression are measured. Diagram, Picture, construction hints. |
| Bil&Mai, p 233 | measuring adiabatic compression | 4B70.36 | A large syringe which has a thermocouple inserted near the tip is filled with butane gas. Compress the syringe and see droplets of liquid form near the bottom. Release and observe the droplets disappear. Monitor the temperature during these operations. |
| Mei, 27-6.3 | adiabatic cycles | 4B70.37 | A thermocouple connected to a lecture galvanometer shows temperature cycles as air in a test tube is compressed and expanded. |

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| Mei, 27-6.4 | Joule-Kelvin coefficients | 4B70.40 | A thermocouple measures the temperature change as N2 cools on expansion and H2 heats on expansion. |
| | **CHANGE OF STATE** | **4C00.00** | |
| | **PVT Surfaces** | **4C10.00** | |
| PIRA 500 | PVT surfaces | 4C10.10 | |
| UMN, 4C10.10 | PVT surfaces | 4C10.10 | Three dimensional models of PVT curves are shown for different substances. |
| Hil, H-5f | thermodynamic surfaces | 4C10.10 | Models of two thermodynamical surfaces. |
| D&R, H-320 | PVT surfaces | 4C10.10 | Three dimensional model of PVT curve for water is shown. |
| AJP 30(12),870 | thermodynamic surfaces | 4C10.11 | Pictures of p-v-T,f-p-T, and delta F-S-r surfaces in a heavy duty article. |
| F&A, Hg-2 | model of P-V-T surface | 4C10.20 | A large P-V-T surface made with bent wires. |
| Sut, H-94 | PVT surfaces | 4C10.30 | Use various charts and models. |
| | **Phase Changes: Liquid-Solid** | **4C20.00** | |
| PIRA 1000 | supercooled water | 4C20.10 | |
| UMN, 4C20.10 | supercooled water | 4C20.10 | A small test tube of water is cooled in a peltier device and the temperature is followed with a thermocouple. |
| Sut, H-71 | supercooling water | 4C20.11 | Water in a small test tube is cooled to - 4 C by placing in a dry ice/alcohol bath. Shake to freeze and the temperature will rise to 0 C. |
| AJP 39(10),1125 | drop freezer | 4C20.12 | 1971 Apparatus Competition Winner. Drops are placed on a copper plate with a tail in dry ice. A thermometer is placed in the copper plate and a mirror at 45 degrees allows easy observation of the drops. |
| Mei, 26-5.15 | supercooling in four substances | 4C20.15 | Four methods are given for supercooling various substances. |
| PIRA 500 | ice bomb in liquid nitrogen | 4C20.20 | |
| UMN, 4C20.20 | ice bomb in liquid nitrogen | 4C20.20 | An ice bomb is placed in a beaker of liquid nitrogen in a Plexiglas cage. |
| F&A, Hk-5 | ice bomb | 4C20.20 | An ice bomb is filled with water and placed in a salt water bath. |
| Sut, H-56 | ice bomb | 4C20.20 | The ice bomb takes half an hour to break when placed in a freezing mixture of ice and salt. |
| Hil, H-2a.1 | ice bomb | 4C20.20 | Just a picture. |
| Disc 15-15 | ice bomb | 4C20.20 | An ice bomb is placed in a liquid nitrogen bath. |
| AJP 44(9),893 | ice bomb - galvanized pipe | 4C20.21 | Use a galvanized coupling and plugs for a bomb and liquid nitrogen for a fast freeze. |
| Sut, H-55 | expansion of freezing bismuth | 4C20.22 | A hummock rises on the surface of bismuth as it freezes in a tube. |
| Hil, M-20a.5 | contraction of paraffin | 4C20.23 | Let a beaker of liquid paraffin freeze. |
| PIRA 500 | regelation | 4C20.30 | |
| UMN, 4C20.30 | regelation | 4C20.30 | Cut through a block of ice with a wire loop that has a heavy mass hanging from it. |
| F&A, Hk-4 | regelation | 4C20.30 | A copper wire under tension cuts through a block of ice. |
| D&R, H-304 | regelation | 4C20.30 | Cut through a block of ice with a wire loop that has 4 kg hanging from each end. |
| Disc 15-16 | regelation | 4C20.30 | A mass hanging from a loop of thin stainless steel wire cuts through a block of ice. |
| TPT 3(7),301 | regelation explained completely | 4C20.31 | The complexity of regelation is examined by Mark Zemansky. |
| TPT 3(4),186 | regelation | 4C20.31 | Explanation of regelation. Copper cuts through faster than iron or thread. |
| Sut, H-57 | regelation | 4C20.32 | Substances that expand on freezing show a lowering melting point under pressure. Two blocks of ice, held together by hand, will freeze. Also complete directions for the standard demo. |
| Sut, H-58 | crushed ice squeeze | 4C20.32 | Crushed ice squeezed in a thick walled cylinder forms a solid block. |
| D&R, H-304 | ice cube squeeze | 4C20.32 | Ice cubes that are pressed together will become a single frozen block. |
| TPT 28(5),260 | pressure and freezing point | 4C20.33 | A letter disputing TPT 25,523 pointing out the difficulty in obtaining a uniform 0 C temperature in an ice bath. |
| PIRA 500 | liquefying CO2 | 4C20.35 | |
| UMN, 4C20.35 | liquefying CO2 | 4C20.35 | Press down on a piston on dry ice in a clear tube until at 5 atmospheres liquefication occurs. |
| Sut, H-59 | liquefying CO2 | 4C20.35 | A strong bulb with a 1 cm square neck area is filled with dry ice and a 5 kg mass is added. The melting point of CO2 is about 5 atmospheres. Lift the weight slightly to freeze. |
| AJP 47(3),287 | CO2 syringe | 4C20.36 | Put some CO2 in a small transparent syringe and squeeze to liquefy. Can be shown on the overhead projector. |
| PIRA 500 | freezing liquid nitrogen | 4C20.40 | |
| UMN, 4C20.40 | freezing liquid nitrogen | 4C20.40 | Put some liquid nitrogen in a clear dewar and pump until it freezes. |
| AJP 35(6),540 | freezing liquid nitrogen | 4C20.40 | In addition to the standard freezing by evaporation in a clear dewar - pop off the cork when the nitrogen is solid and it will instantly turn to liquid while the temperature remains below its boiling point. |
| Sut, H-109 | freezing liquid nitrogen | 4C20.40 | Pumping on liquid air will produce solid nitrogen at -210 C. Air passed slowly over the outside of the flask will condense out liquid air at atmosphere pressure. |

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| Sprott, 2.7 | freezing liquid nitrogen | 4C20.40 | Put some liquid nitrogen in a flask and pump until it freezes. |
| AJP 36(9),919 | freezing nitrogen modification | 4C20.42 | The dewar has a smaller cross section in the lower part to prevent the frozen plug from rising to the pumping port. |
| PIRA 500 | CO2 expansion cooling - fire extinguisher | 4C20.45 | |
| UMN, 4C20.45 | CO2 expansion cooling - fire extinguisher | 4C20.45 | Shoot off a CO2 fire extinguisher. |
| Disc 15-03 | CO2 expansion cooling | 4C20.45 | Shoot off a fire extinguisher at a test tube of water, freezing the water. |
| Sut, H-65 | CO2 cylinder | 4C20.46 | Liquid CO2 from cylinder is released into a heavy bag, freezing the central stream by evaporative cooling. |
| UMN, 4C20.50 | heat of fusion of water | 4C20.50 | Melt ice in a beaker of water and measure the temperature. |
| Sut, H-54 | heat of fusion of ice | 4C20.51 | Melt some ice in a calorimeter with a known amount of water. |
| Mei, 26-5.2 | freezing lead | 4C20.52 | Insert thermocouple into molten lead and plot the temperature on an x-y recorder as it freezes. |
| Sut, H-46 | freezing tin | 4C20.53 | Tin is heated to 360 C and temperature readings taken every 30 seconds until the temperature reaches 160 C. Half the time the temperature remains at 230 C. |
| Mei, 26-5.1 | heat of fusion of water | 4C20.54 | Place a thermocouple cooled in liquid nitrogen in warm water. Plot temperature as ice forms and then melts. |
| PIRA 1000 | heat of solution | 4C20.55 | |
| Mei, 26-5.6 | heat of solution | 4C20.55 | A manometer shows cooling when hypo or ammonium chloride are added to water, heating when sulfuric acid is used. ALSO - equal weights of water and ammonium nitrate will lead to freezing. |
| Sut, H-50 | heat of solution | 4C20.56 | Heat is generated if sulfuric acid is dissolved in water. Cooling results if hypo or ammonium nitrate is dissolved. |
| Mei, 26-5.3 | latent heat heating | 4C20.59 | Two experiments that use the latent heat from one substance freezing to heat another. |
| PIRA 1000 | heat of crystallization | 4C20.60 | |
| Sut, H-48 | heat of crystallization | 4C20.60 | Prepare a supersaturated solution of sodium acetate or sodium sulfate and drop in a crystal to trigger crystallization. A thermocouple will show the change in temperature. |
| AJP 76 (6), 547 | heat of crystallization | 4C20.60 | How the flexing of a metal disk can trigger the crystallization of a sodium acetate solution. |
| Sut, H-49 | heat of crystallization | 4C20.61 | A manometer hooked into the jacket of a double walled flask is used to detect the change in temperature of a sodium thiosulfate solution as it crystallizes. |
| Mei, 26-5.4 | heat of crystallization | 4C20.62 | A manometer indicates heating when a flask of supercooled hypo solution crystallizes. |
| Sut, H-44 | project crystallization | 4C20.70 | Project while crystallization occurs in a thin film of melted sulfur or saturated solution of ammonium chloride. |
| Sut, H-45 | crystallization | 4C20.71 | Crystallization from a conc. solution of sodium acetate or sodium hyposulfate. See also E-195 (lead tree) and L-122 (polarization). |
| Mei, 26-5.12 | water crystals in soap film | 4C20.72 | A ring with a soap film is cooled in a chamber surrounded by dry ice on the overhead projector. Water crystals form. |
| Mei, 26-5.13 | crystal growth on the overhead | 4C20.73 | Various organic compounds are used to show crystal growth between crossed Polaroids on the overhead projector. |
| Mei, 26-5.14 | crystal growth on the overhead | 4C20.73 | Tartaric acid and benzoic acid are melted together and the crystal growth on cooling is observed between crossed Polaroids on the overhead projector. |
| Mei, 26-5.17 | observing crystallization | 4C20.74 | Directions for building a microprojector useful for showing crystallization phenomena. |
| AJP 45(4),395 | hard sphere model | 4C20.90 | A two dimensional hard sphere model of a fluid shows propagating holes or flow if 4% of the spheres are removed. |
| AJP 46(1),80 | Metglas 2826 | 4C20.98 | Metglas 2826 is a metal that has been quenched from liquid to solid without crystallization. The mechanical, electrical, and magnetic properties are demonstrated. |
| Sut, H-47 | Wood's metal | 4C20.99 | The recipe for Wood's metal (melting point 65.5 C). |
| | **Phase Changes: Liquid-Gas** | **4C30.00** | |
| PIRA 200 | boiling by cooling | 4C30.10 | Cool a stoppered flask filled with warm water with ice until boiling starts. |
| UMN, 4C30.10 | boiling by cooling | 4C30.10 | Same as Hj-4. |
| F&A, Hj-4 | boiling by cooling | 4C30.10 | A flask with warm water is cooled with ice until boiling starts. |
| Sut, H-75 | boiling by cooling | 4C30.10 | Boil water vigorously in a flask, stopper and remove from heat, cool with ice or water to show boiling at reduced pressure. A thermometer or thermocouple can be added to show temperature. |
| Hil, H-5d | boiling cold water | 4C30.10 | Heat water to boiling in a round bottom flask, stopper, invert, pour cold water over to maintain boiling. |

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| D&R, H-260 | boil water at reduced pressure | 4C30.10 | Heat boiling water in a round bottom flask, stopper, invert, apply cold towels or ice to the flask. |
| Sprott, 2.8 | boiling by cooling | 4C30.10 | Holding ice against a sealed flask contain hot water and steam causes the water to boil. |
| Disc 15-10 | boil water under reduced pressure | 4C30.10 | Boil water in a round bottom flask with a dimple in the bottom, remove from heat, stopper, invert and add ice to the dimple. |
| PIRA 1000 | boiling at reduced pressure | 4C30.15 | |
| TPT 2(4),178 | boiling point depression | 4C30.15 | Boil at reduced pressure using an aspirator. |
| F&A, Hj-3 | boiling at reduced pressure | 4C30.15 | A thermometer measures the boiling point as a vacuum pump is used to reduce the pressure in a flask of water. |
| Mei, 27-3.6 | boiling by reduced pressure | 4C30.15 | Boil water at room temperature by evacuating. |
| Sut, H-76 | boiling at reduced pressure | 4C30.15 | Pump on a flask of warm water with aspirator or vacuum pump until boiling starts. |
| Mei, 26-5.16 | superheating liquids | 4C30.20 | Water is superheated in a very clean flask free of flaws. A similar flask with boiling water is nearby. Add chalk dust to the superheated water and boiling starts explosively. |
| AJP, 75 (6), 496 | superheated water | 4C30.20 | A simple experiment to verify the theory of water vaporization and measure the bubble radius under superheating conditions. |
| Sut, H-83 | bumping | 4C30.21 | When an open tube (H-82) containing water is heated the temp will rise above 100 C before a vapor bubble suddenly forms. |
| PIRA 1000 | geyser | 4C30.25 | |
| F&A, Hj-5 | geyser | 4C30.25 | A long tapered tank is used to form a geyser. |
| Sut, H-79 | geyser | 4C30.25 | A conical tube 12 cm at the bottom and 4 cm at the top, 2 m long, and heated at the bottom, models a geyser. |
| Sut, H-80 | geyser | 4C30.25 | A .5" brass tube 6' long soldered to a 4" tube 10"long filled with water and heated gives a 3 ft. geyser. |
| Hil, H-5e | geyser | 4C30.25 | Picture of a geyser demonstrator. |
| D&R, H-264 | geyser | 4C30.25 | A funnel placed mouth-down in a beaker of boiling water will display geyser like action. Place a coin under one edge of funnel to allow water to get underneath. |
| Sprott, 2.6 | geyser | 4C30.25 | A long tapered tube is heated from below and erupts periodically. |
| Sut, H-78 | steam bomb | 4C30.27 | Heat a corked test tube or make a bomb by sealing off some water in a glass tube and heating it. Flying glass hazard. |
| PIRA 1000 | helium and CO2 balloons in liquid N2 | 4C30.30 | |
| F&A, Hk-3 | change of volume with change of state | 4C30.30 | Balloons of CO2 and He are immersed in liquid nitrogen. |
| Disc 15-17 | helium and CO2 balloons in liquid N2 | 4C30.30 | Helium and CO2 balloons are immersed in liquid nitrogen. Cut open the CO2 balloon to show solid carbon dioxide. |
| Sut, H-102 | ice stove | 4C30.33 | Boil away liquid air in a teakettle on a cake of ice. |
| PIRA 1000 | liquid nitrogen in a balloon | 4C30.35 | |
| UMN, 4C30.35 | liquid nitrogen in a balloon | 4C30.35 | |
| Sut, H-112 | burst a balloon | 4C30.35 | A small amount of liquid air in a test tube blows up a balloon until it bursts. (800:1 volume ratio). |
| Disc 15-09 | liquid nitrogen in balloon | 4C30.35 | Pour some liquid nitrogen in a small flask and cap with a balloon. |
| Mei, 27-10.2 | gas and vapor under compression | 4C30.36 | A mercury piston applies equal pressure to air and sulfur dioxide until the SO2 collapses into liquid at 2 1/2 atmospheres. |
| UMN, 4C30.40 | heat of vaporization of water | 4C30.40 | Boil water in a beaker while measuring the temperature. |
| Mei, 26-5.11 | bromine cryophorous | 4C30.50 | One end of an L-shaped evacuated tube containing bromine is immersed in a dry ice/alcohol mixture. |
| Sut, H-60 | bromine condensation | 4C30.50 | The color of bromine gas in one end of a tube is reduced when the other end is cooled. |
| Sut, H-61 | steam into calorimeter | 4C30.60 | Pass steam into a calorimeter to determine the heat of condensation. |
| Mei, 27-10.1 | making liquid oxygen | 4C30.80 | Liquid oxygen will drip from the outer surface of a thin copper cone filled with liquid nitrogen. |
| Mei, 27-10.3 | heat exchanger oxygen liquifier | 4C30.81 | A heat exchanger is used to liquefy oxygen from a high pressure tank. Picture, Construction details in appendix, p. 1297. |
| Sut, H-110 | liquification of air under pressure | 4C30.82 | A bicycle pump is used to put a test tube immersed in liquid air under pressure. Liquification will continue as long as the tube is operated. |
| Sprott, 2.12 | liquid nitrogen cloud | 4C30.90 | liquid nitrogen induced to vaporize cools the air and creates a dense cloud. |
| | **Cooling by Evaporation** | **4C31.00** | |
| PIRA 500 | cryophorous | 4C31.10 | |
| UMN, 4C31.10 | cryophorous | 4C31.10 | One end of an evacuated glass tube with bulbs at each end is put in liquid nitrogen, water in the other end will freeze. |
| F&A, Hj-8 | cryophorous | 4C31.10 | One end of a tube is stuck in a cold trap and water in the other end freezes. |

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| Sut, H-67 | cryophorous | 4C31.10 | Water in one end of an evacuated J tube will freeze when the other is placed in a ice-salt mixture, alcohol-dry ice mixture, or liquid air. |
| Disc 15-14 | cryophorus | 4C31.10 | Place a cryophorus in liquid nitrogen. |
| Sut, H-68 | cryophorous | 4C31.11 | Water in an evacuated sealed flask with a concave bottom freezes when it is inverted and a dry ice/alcohol mixture is placed in the concavity. |
| Mei, 26-5.10 | cryophorous | 4C31.12 | A Lucite assembly for the overhead projector with an evacuated chamber holding water and an area for a dry ice/acetone mixture. |
| PIRA 1000 | freezing by evaporation | 4C31.20 | |
| AJP 32(11),xxii | freezing by evaporation | 4C31.20 | Evacuate a chamber with water on the overheard between crossed Polaroids. |
| AJP 35(9),x | freezing by evaporation | 4C31.20 | For the overhead projector: make a hole for a small thermometer in the bottom of a small test tube and pump on a small amount of water. |
| Mei, 26-5.9 | freezing by evaporation | 4C31.20 | Pump down some distilled water in a chamber on an overhead projector until the water freezes. Crossed Polaroids make the effect more visible. |
| Disc 15-13 | freezing by boiling | 4C31.20 | Evacuate a chamber containing a small amount of water. |
| Sut, H-70 | freezing by evaporation | 4C31.21 | Freeze water in a watch glass over a dish of sulfuric acid in a bell jar. |
| D&R, H-280 | freezing by evaporation | 4C31.21 | Freeze water in a watch glass over a dish of sulfuric acid in a bell jar. Also observe boiling before water freezes. |
| Sut, H-69 | freezing by evaporation | 4C31.22 | Freeze water in a flask by pumping through a sulfuric acid trap. Supercooling up to 10 C is possible. |
| Sprott, 2.7 | freezing by evaporation | 4C31.22 | Water at room temperature boils vigorously and then turns into ice when the pressure is reduced. |
| PIRA 200 | drinking bird | 4C31.30 | Cooling causes vapor to condense, raising the center of gravity until the bird tips, lowering the center of gravity. |
| UMN, 4C31.30 | drinking bird | 4C31.30 | The drinking bird has a wet head which evaporates drawing liquid up his neck and tipping him over. |
| F&A, Hj-7 | drinking bird | 4C31.30 | Cooling causes vapor to condense raising the center of gravity until the bird tips. |
| D&R, H-240 | drinking bird | 4C31.30 | Dip head of bird in water. Cooling by evaporation causes liquid to draw up into the bird until it tips because of the raised center of gravity. |
| AJP 74(8), 677 | drinking bird | 4C31.30 | The motion and temperature of the drinking bird are monitored to determine the quantitative history of its motion over time and to determine the thermodynamic and mechanical constraints on its performance. |
| AJP 72(6), 782 | drinking bird | 4C31.30 | A drinking bird system that obtains energy from the evaporation of water, but is not a heat engine. |
| AJP 71(12), 1264 | drinking bird | 4C31.30 | Measurements on the drinking bird system which has the body heated instead of the head being cooled by evaporation. |
| AJP 71(12), 1257 | drinking bird | 4C31.30 | Measurements and modeling of the drinking bird system with the head being cooled by evaporation. The effect of humidity is also shown. |
| Bil&Mai, p 231 | drinking bird | 4C31.30 | Dip the head of the bird in water. Cooling by evaporation causes liquid to draw up into the bird until it tips because of the raised center of gravity. |
| Disc 15-12 | drinking bird | 4C31.30 | Standard drinking bird. Includes animation. |
| Sut, H-66 | CO2 cartridge cools | 4C31.31 | Puncture a CO2 cartridge and the steel bulb will cool enough to form frost but there is not enough gas to produce snow. |
| Sut, H-64 | evaporating carbon disulfide | 4C31.32 | Evaporating carbon disulfide (highly inflammable and poisonous) is used to form frost. |
| Sut, H-63 | evaporating ether | 4C31.33 | Evaporating ether in a watch glass freezes a drop of water between the bottom of the glass and a cork. A method for burning off the ether is shown. Diagram. |
| Sut, H-62 | evaporating ethyl chloride | 4C31.34 | Ethyl chloride is used to freeze water in a small dish or cool a thermometer. |
| Mei, 26-5.5 | cooling by evaporation | 4C31.35 | An attached manometer shows cooling when several drops of ether are placed in a flask. |
| Sut, H-73 | pulse-glass engine | 4C31.37 | A pulse glass will oscillate when mounted in a stirrup so one side and then the other can contact a cool pad. |
| D&R, H-500 | pulse glass engine | 4C31.37 | A pulse glass will oscillate when mounted on a pivot so that one side and then the other can come near a heat lamp. |
| | **Dew Point and Humidity** | **4C32.00** | |
| PIRA 1000 | sling psychrometer | 4C32.10 | |
| UMN, 4C32.10 | sling psychrometer | 4C32.10 | Use a commercial sling psychrometer to determine relative humidity. |
| F&A, Hl-2 | sling psychrometer | 4C32.10 | Two thermometers, one with a wet wick, are mounted on a device swung around the head. |
| Hil, M-22a.1 | sling psychrometer | 4C32.10 | Two thermometers, one with a wet wick on the bulb, are rotated. |
| F&A, Hl-1 | wet and dry bulb thermometers | 4C32.11 | Identical thermometers are mounted on a panel, one with a wet wick. |
| Sut, H-92 | humidity | 4C32.11 | Wet and Dry bulb readings. |

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| Hil, M-22a.2 | wet and dry bulb | 4C32.11 | Wet and dry bulb thermometers are mounted on a frame with a humidity graph. |
| Hil, M-22a.3 | dial hygrometer | 4C32.15 | A dial type hygrometer is pictured. |
| F&A, Hl-3 | demonstration hair hygrometer | 4C32.16 | A hair is connected to a pivot. |
| F&A, Hl-4 | dew point measurement | 4C32.20 | Evaporating alcohol cools a shiny surface until dew forms. |
| F&A, Hl-5 | dew point | 4C32.21 | Evaporating ether cools a gold band until dew forms. |
| Sut, H-93 | dew point | 4C32.22 | Reflect a light beam off two bright plates, one cooled by ether. |
| Mei, 27-3.10 | dew point with evaporating ether | 4C32.23 | When the dew point is reached in a test tube of evaporating ether, water drops on the outside complete an electrical circuit, lighting a neon lamp. |
| F&A, Hl-9 | condensation and coalescence | 4C32.24 | Watch the shiny surface of a Frigister (thermoelectric cooler) as small water drops grow and coalesce. |
| PIRA 1000 | condensation nuclei | 4C32.40 | |
| F&A, Hl-6 | condensation nuclei | 4C32.40 | Cigar smoke is introduced into a steam jet. |
| F&A, Hl-7 | condensation nuclei | 4C32.41 | An extinguished match is held in the steam from a tea kettle. |
| Mei, 27-3.11 | fog in a bell jar | 4C32.50 | Place moistened cotton in a bell jar and evacuate until fog forms. After cleaning the air of dust, ions are introduced and a thick fog forms. |
| | **Vapor Pressure** | **4C33.00** | |
| PIRA 1000 | vapor pressure in barometer | 4C33.10 | |
| UMN, 4C33.10 | vapor pressure in barometer | 4C33.10 | Insert water or alcohol in a mercury barometer. |
| F&A, Hj-1 | vapor pressure of liquids | 4C33.10 | Set up a series of mercury barometers and insert a small amount of volatile liquid in each one. |
| Sut, H-81 | vapor pressure in barometer | 4C33.10 | Place four mercury barometers in a line and introduce different liquids into three to show vapor pressure. |
| Mei, 27-3.7 | vapor pressure with a manometer | 4C33.11 | Three flasks containing water, alcohol, and ether are connected by stopcocks to the evacuated side of a mercury manometer. |
| D&R, H-244 | vapor pressure with a manometer | 4C33.11 | A small bottle containing 1/2 ml of methanol is connected to a water manometer. |
| F&A, Hl-10 | vapor pressure of water | 4C33.12 | A barometer is sealed off with liquid over the mercury. |
| Sut, H-86 | comparison of vapor and gas | 4C33.13 | Barometer tubes are moved up and down in a deep well of mercury. One contains air, the other alcohol vapor. The mercury level remains the same in the tube with alcohol vapor. |
| Sut, H-82 | vapor pressure tube | 4C33.13 | Separate tubes are made up with a liquid sealed over mercury and with an evacuated tube extending out of the mercury to show the vapor pressure. |
| PIRA 1000 | addition of vapor pressures | 4C33.20 | |
| UMN, 4C33.20 | addition of vapor pressures | 4C33.20 | Add water and then alcohol to a mercury barometer |
| F&A, Hj-2 | addition of partial pressures | 4C33.21 | Measure the pressure change with a manometer when a vial of ether is broken in a flask of air. |
| Mei, 27-3.1 | soda pop pressure | 4C33.25 | Attach a pressure gauge to a soda pop bottle and measure the buildup of pressure. |
| PIRA 1000 | vapor pressure curve for water | 4C33.30 | |
| AJP 29(10),xiii | vapor curve of water | 4C33.30 | Boil water in a flask attached to one side of a mercury manometer, remove the heat and seal off the flask from the atmosphere, take readings of the temp and pressure difference as the system cools. |
| Mei, 27-3.8 | vapor pressure curve for water | 4C33.30 | A flask of boiling water is stoppered with a thermometer and mercury manometer. Readings are taken as the water cools. |
| Mei, 27-3.5 | vapor pressure of water vs temperature | 4C33.31 | Add a thermometer and pressure gauge to a pressure cooker the demonstrate the effect of temperature on partial pressure of water. |
| Sut, H-74 | vapor pressure of water at boiling | 4C33.32 | Insert a mercury filled J tube with water at the closed end into a boiling water bath and the mercury comes to the same level on both sides of the tube. |
| TPT 2(4),178 | vacuum by freezing | 4C33.33 | A table of vapor pressure values for water at standard bath temperatures down to -90 C. Some demo suggestions are included. |
| AJP 43(10),925 | vapor pressure curve for CCl4 | 4C33.35 | Modification of a flexible tube manometer to measure the vapor pressure curve of CCl4. |
| PIRA 500 | pulse glass | 4C33.50 | |
| Sut, H-72 | pulse glass | 4C33.50 | A tube with a small bulb on each end partially filled with a volatile liquid is held by one bulb in the palm forcing the liquid into the other bulb. |
| Hil, H-2a.2 | pulse glass | 4C33.50 | Just a picture. |
| Sut, H-85 | vapor pressure fountain | 4C33.55 | Ether is introduced into a stoppered flask half full of water with a nozzle extending to near the bottom of the flask. The vapor pressure forces the water out the nozzle. Diagram. |
| Mei, 27-3.9 | addition of vapor pressure with ether | 4C33.56 | An apparatus is constructed of glass tubing to allow one to add ether to entrapped air at atmospheric pressure and measure the increased pressure. Reference: AJP 13(1),50. |

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| Mei, 27-3.4 | flask inverted over ether | 4C33.57 | When a flask is inverted over ether, bubbles form due to the partial pressure of ether. |
| Sut, H-84 | retarded evaporation | 4C33.58 | Introduce a volatile liquid into two flasks connected to mercury manometers, one evacuated and the other full of air. The final pressure is the same but the time to get there differs. |
| Mei, 27-3.3 | beakers in a bell jar | 4C33.60 | Beakers of water and brine are placed in a bell jar and left for weeks. The brine gains water. |
| F&A, Hj-6 | lowering of vapor pressure by dissolved salt | 4C33.61 | A manometer separates water and a salt solution in a closed system. |
| Sut, H-87 | vapor pressure of solutions | 4C33.62 | Aqueous solutions of salt or sugar have a higher boiling point than water. |
| | **Sublimation** | **4C40.00** | |
| PIRA 500 | sublimation of carbon dioxide | 4C40.10 | |
| UMN, 4C40.10 | carbon dioxide | 4C40.10 | Watch carbon dioxide sublimate. |
| Sut, H-51 | carbon dioxide | 4C40.10 | Evaporation of "dry ice". |
| Disc 15-18 | sublimation of CO2 | 4C40.10 | Small solid carbon dioxide flakes are generated by cooling a CO2 balloon in liquid nitrogen. |
| Sut, H-95 | carbon dioxide | 4C40.11 | Show chattering due to formation and escape of vapor. |
| D&R, H-220 | carbon dioxide - make dry ice | 4C40.11 | Show the formation of dry ice by the rapid cooling of the gas upon expansion using a carbon dioxide fire extinquisher. |
| Sut, H-52 | carbon dioxide rocker | 4C40.12 | Detect the evaporation of gas by the high pitched rocking motion of one end of an iron rod placed on "dry ice". |
| PIRA 1000 | blow up balloon with CO2 | 4C40.15 | |
| Sut, H-97 | blow up a balloon with CO2 | 4C40.15 | Attach a balloon to a test tube with dry ice and when the balloon is inflated immerse the tube in liquid air. |
| F&A, Hk-1 | change of volume with change of state | 4C40.16 | Dry ice blows up a balloon. |
| Mei, 26-5.8 | iodine | 4C40.20 | Place melted iodine crystals in a partially evacuated tube and heat. |
| Mei, 26-5.7 | ammonium chloride | 4C40.30 | Heat ammonium chloride in a test tube and it evaporates without melting, coating the cool sides of the tube. ALSO- solidify CO2. |
| Sut, H-53 | camphor | 4C40.40 | Heat camphor in one end of a tube and the vapors will condense on the cooler end. Project. |
| TPT 3(7),322 | sublimation of ice and snow | 4C40.50 | Freeze water in a large dish, then cover portions with rectangles of aluminum foil. After three weeks, the uncovered areas have sublimed about a half inch. |
| | **Phase Changes: Solid-Solid** | **4C45.00** | |
| PIRA 1000 | phase change in iron | 4C45.10 | |
| UMN, 4C45.10 | phase change in iron | 4C45.10 | |
| F&A, Es-7 | phase change in iron | 4C45.10 | A long iron wire heated to 1000 K will sag as it goes through a phase change. |
| TPT 30(1), 42 | nitinol wire | 4C45.15 | A nitinol wire returns to a preformed shape when it undergoes a phase transition from the low temperature martensite phase to the high temperature austenite phase. |
| AJP 72(5), 599 | nitinol wire | 4C45.15 | The ability of nitinol wire to remember its annealed shape is used to model a three dimensional folding structure. Useful when looking at protein folding and DNA of RNA hybridization, geometry, topology, and commutativity. |
| AJP 43(7),650 | solid-solid phase projection | 4C45.20 | The salt ammonium nitrate exhibits five phase transitions between 169 C and -16C. Heat the salt on a microscope slide with an electrically conducting coating on one side. |
| PIRA 1000 | polymorphism | 4C45.30 | |
| Mei, 26-5.18 | polymorphism | 4C45.31 | Mercury iodide changes from red to yellow at 126 C. Ammonium nitrate has five solid phases at transformation temperatures of -16, 35, 83, 125 C. Best demonstrated between crossed Polaroids on the overhead projector. |
| AJP 59(3),260 | phase transitions - magnetic model | 4C45.35 | A magnetic model demonstrates phase transitions and excitations in molecular crystals. Construction details and hints included along with theory. |
| | **Critical Point** | **4C50.00** | |
| PIRA 500 | critical point of CO2 | 4C50.10 | |
| UMN, 4C50.10 | critical point of CO2 | 4C50.10 | The meniscus in a tube containing liquid CO2 at high pressure disappears when warmed. |
| F&A, Hk-6 | critical point of carbon dioxide | 4C50.10 | Gently heat a glass tube containing liquid CO2. The critical point is 73 atmospheres and 31.6 C. |
| Sut, H-90 | critical point of CO2 | 4C50.10 | Liquid CO2 in a heavy wall glass tube is heated to show disappearance of the meniscus. |

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| Disc 15-11 | CO2 critical point | 4C50.10 | Warm a tube containing liquid CO2. The critical point is 73 atmospheres at 31.6 C. |
| Mei, 27-2.9 | critical point of CO2 | 4C50.11 | Tubes filled with liquid CO2 at, above, and below the critical point are prepared to demonstrate behavior of a non-ideal gas. Tube preparation instructions. |
| AJP 34(1),68 | citical state analog | 4C50.15 | Use the critical solution of aniline and cyclohexane as an analog of the critical state. |
| PIRA 1000 | critical opalescence | 4C50.20 | |
| UMN, 4C50.20 | critical opalscence | 4C50.20 | A sealed chamber containing freon is heated to the critical point. |
| Sut, H-91 | critical temperature of ethyl chloride | 4C50.30 | Directions for making an ethyl chloride apparatus (187.2 C, 52 atmos). |
| PIRA 1000 | triple point of water cell | 4C50.40 | |
| AJP 29(8),iii | triple point of water cell | 4C50.40 | A real triple point of water cell designed for use as a temperature reference. |
| | **KINETIC THEORY** | **4D00.00** | |
| | **Brownian Motion** | **4D10.00** | |
| PIRA 200 | Brownian motion cell | 4D10.10 | View a smoke cell under a microscope. |
| UMN, 4D10.10 | Brownian motion smoke cell on TV | 4D10.10 | Look through a microscope at a small illuminated cell filled with smoke. |
| F&A, Hh-3 | Brownian motion | 4D10.10 | Observe the motion of particles in a smoke cell through a microscope. |
| Sut, A-48 | Brownian motion smoke cell | 4D10.10 | Observe the Brownian motion smoke cell through a low powered microscope. |
| Hil, M-22j | Brownian motion cell | 4D10.10 | Observe a small smoke cell through a microscope. |
| Hil, A-1b | Brownian motion cell | 4D10.10 | View a smoke cell under a microscope. |
| AJP 78 (12), 1278 | Brownian motion | 4D10.10 | A look at Robert Brown's original observations and some of his misinterpretations. |
| Disc 16-07 | brownian motion | 4D10.10 | A smoke cell is viewed under 100X magnification. |
| Sut, A-51 | Brownian motion - virtual image | 4D10.11 | The optical setup for viewing Brownian motion by enlarged virtual image. |
| AJP 44(2),188 | Brownian motion | 4D10.12 | Use a laser beam to illuminate a smoke cell under a microscope viewed with TV |
| Mei, 27-8.1 | smoke cell | 4D10.12 | Project the Brownian motion smoke cell with TV. Picture. |
| TPT, 36(6), 342 | Brownian motion using a laser pointer | 4D10.12 | Demonstration of Brownian motion using a microvideo camera connected to the eyepiece of a microscope, and with a laser illuminating the smoke cell. |
| AJP 41(2),278 | smoke cell for TV | 4D10.13 | Modifications to the standard Welch smoke tube for use with television projection. |
| AJP 40(5),761 | Brownian motion - macroscopic cell | 4D10.15 | Ball bearings hit a piece of stressed Plexiglas. Crossed Polaroids render the balls invisible. |
| PIRA 1000 | Brownian motion simulator | 4D10.20 | |
| UMN, 4D10.20 | Brownian motion simulation | 4D10.20 | Place many small and a few large balls on a vibrating plate on an overhead projector. |
| Disc 16-08 | Brownian motion simulation | 4D10.20 | A large disc is placed in with small ball bearings in the shaker frame on the overhead projector. |
| Mei, 27-7.6 | Brownian motion simulation | 4D10.21 | A Brownian motion shaker for the overhead projector. Includes the original references to Brown and Einstein. |
| AJP 47(9),827 | Brownian motion simulation | 4D10.25 | The Cenco kinetic theory apparatus is modified by mounting a baffle in the center of the tube to reduce the spinning of the particles, and suspending a 1 cm bead in one half of the chamber. |
| AJP 31(12),922 | Brownian motion of a galvanometer | 4D10.28 | An optical-lever amplifier for studying the Brownian motion of a galvanometer. |
| PIRA 1000 | colloidal suspension | 4D10.30 | |
| Sut, A-49 | Brownian motion - colloidal | 4D10.30 | Place a colloidal metal suspension made by sparking electrodes under water on a microscope slide. |
| Mei, 27-8.5 | formation of lead carbonate crystals | 4D10.31 | Project the formation of flat-sided crystals of lead carbonate in a glass cell on a screen. See Sutton, A-50. |
| Sut, A-50 | rotary Brownian motion | 4D10.31 | Observe a dilute suspension of flat lead carbonate crystals under low magnification. |
| Mei, 27-8.2 | Brownian motion in TiO2 suspension | 4D10.33 | A TV camera looks through a microscope at a water suspension of TiO2. |
| AJP 32(7),vi | Brownian motion corridor demonstration | 4D10.34 | Dow latex spheres in water through a 1900 power projection microscope, mechanical analog with a 2" puck and 1/4" ball bearings. |
| Mei, 27-8.4 | Brownian motion corridor demonstration | 4D10.34 | A corridor demonstration of Brownian motion of Dow latex spheres using a projection 1900 power microscope. |
| PIRA 1000 | Dow spheres suspension | 4D10.40 | |
| AJP 37(9),853 | Brownian motion - light scattering | 4D10.40 | Pass a laser beam through a cell with a suspension of polystyrene spheres. Hold a card up and show the fluctuations of the scattered light. |

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| AJP 71(6), 568 | Brownian motion - video microscopy | 4D10.40 | Measuring Boltzmann's constant using video microscopy of Brownian motion of polystyrene spheres in water. |
| AJP 55(10),955 | Brownian motion on TV | 4D10.40 | Polystyrene microspheres are used in place of the smoke cell, the eyepiece of the microscope is removed and the image is formed on the shielded TV tube. |
| AJP, 75 (2), 111 | Brownian motion with microspheres | 4D10.40 | Using a CCD camera to study the dependence of the Brownian motion of microspheres on their radius, the time, the viscosity of the suspension liquid, or temperature. |
| Mei, 27-8.3 | Brownian motion with Dow spheres | 4D10.40 | Small polystyrene spheres made by Dow are suspended in water for illustrating Brownian motion. |
| | **Mean Free Path** | **4D20.00** | |
| PIRA 200 | Crookes' radiometer | 4D20.10 | The fake radiometer is evacuated until the mean free path is about the dimension of the system. |
| UMN, 4D20.10 | Crookes' radiometer | 4D20.10 | The radiometer spins in the wrong direction. |
| F&A, Hh-6 | radiometer | 4D20.10 | The fake radiometer is evacuated so the mean free path is about the dimension of the system. |
| D&R, H-188 | radiometer | 4D20.10 | A radiometer heated with a lamp or cooled in a freezer. |
| Sprott, 1.13 | Crooke's radiometer | 4D20.10 | A difference in kinetic energy of molecules leads to unequal forces and resultant rotation. |
| Disc 14-23 | radiometer | 4D20.10 | The radiometer and a lamp. |
| AJP 45(5),447 | radiometer analysis | 4D20.11 | An "elementary" model for the radiometer at the sophomore level. |
| Sut, H-164 | Crookes' radiometer | 4D20.11 | When the pressure of the Crookes' radiometer is about 1 mm it works well. Place it near dry ice and it will run backwards. |
| AJP 53(11),1105 | Crookes' radiometer backwards | 4D20.12 | Put your radiometer in the refrigerator, also try an interesting liquid N2 demo. |
| AJP 54(9),776 | Crookes' radiometer backwards | 4D20.12 | Use liquid N2 or freon to cool the radiometer so it will run backwards. |
| AJP 54(6),490 | Crookes' radiometer backwards | 4D20.12 | A letter calling attention to the Woodruff (TPT,6,358) article. |
| AJP 51(7),584 | heating the radiometer | 4D20.13 | Heat the glass of the radiometer until it is motionless and as it cools it will run backwards. |
| Sut, H-165 | radiation and convection | 4D20.14 | Put a hot metal object in a smoke filled projection cell and a clear space will appear around the metal object caused by the radiometric repulsion of the smoke particles. Convection will cause the clear space to extend upward. |
| AJP 72(6), 843 | acoustic radiometer | 4D20.14 | Construction of a simple acoustic radiometer that DOES rotate by radiation pressure. |
| AJP 35(12),1120 | calorotor | 4D20.15 | Vanes rotate in a tube filled with 20 mTorr helium warmed on one end. |
| PIRA 1000 | mean free path and pressure | 4D20.20 | |
| F&A, Hh-7 | mean free path and pressure | 4D20.20 | Aluminum evaporated in high vacuum forms a shadow of a Maltese cross on the side of the bell jar. |
| Mei, 27-8.7 | Maltese Cross | 4D20.20 | Evaporating aluminum atoms plate a bell jar except in the shadow of a Maltese Cross. |
| PIRA 1000 | mean free path pin board | 4D20.30 | |
| Mei, 27-8.6 | mean free path pinboard | 4D20.30 | Steel balls are rolled down a pinboard and the number of collisions is compared with theory. |
| Mei, 10-3.1 | velocity distribution and path length | 4D20.31 | Take pictures of air table pucks and plot velocity distribution and path length. |
| AJP 34(12),1143 | Boltzmann distribution model | 4D20.40 | A set of cusps is formed in a curve with height representing energy levels. The assembly is driven by a shaker. |
| AJP 52(1),54 | computer Maxwell-Boltzmann | 4D20.45 | A FORTRAN program available from the author that shows the evolution of speed distributions. |
| AJP 58(11),1073 | computer many particle systems | 4D20.46 | Computer simulations with a billiard table model and a particle moving in a regular array of hard discs. |
| | **Kinetic Motion** | **4D30.00** | |
| TPT 28(7),441 | on the meaning of temperature | 4D30.05 | Many comments on the TPT 28(2),94 article on temperature. |
| PIRA 500 | Cenco kinetic theory apparatus | 4D30.10 | |
| UMN, 4D30.10 | Cenco kinetic theory apparatus | 4D30.10 | The Cenco apparatus with lead shot in a piston. |
| F&A, Hh-5 | mechanical model of kinetic motion | 4D30.10 | The Cenco molecular motion simulator with lead shot in a piston. |
| Mei, 27-7.7 | Cenco kinetic theory apparatus | 4D30.10 | A discussion of the Cenco kinetic theory apparatus. |
| PIRA 1000 | big kinetic motion apparatus | 4D30.11 | |
| UMN, 4D30.11 | big kinetic motion apparatus | 4D30.11 | Scale up the balls in a piston using a 16" diameter tube and 1/2" diameter balls. |
| Hil, M-22b.1 | mechanical gas model | 4D30.12 | The details are not clear from this picture of a mechanical gas model. |
| Sut, A-42 | kinetic theory models | 4D30.13 | Drive small steel balls in a small chamber with a tuning fork. |
| PIRA 200 | molecular motion simulator | 4D30.20 | |
| PIRA 500 - Old | molecular motion simulator | 4D30.20 | |

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| UMN, 4D30.20 | molecular motion simulator | 4D30.20 | Ball bearings on a vibrating plate on the overhead projector. |
| TPT 2(2),81 | kinetic theory demonstrator | 4D30.20 | A 2-D ball shaker for the overhead projector. |
| F&A, Hh-4 | two dimensional kinetic motion | 4D30.20 | Balls on a vibrating plate are used with the overhead projector for many molecular simulations. |
| D&R, H-440 | molecular motion simulator | 4D30.20 | Ball bearings on a vibrating plate on the overhead. Commercial model. |
| Sprott, 2.15 | molecular motion simulator | 4D30.20 | Drive small steel balls in a small chamber with a mechanical oscillator. |
| PIRA 1000 | equipartition of energy simulator | 4D30.21 | |
| Mei, 27-7.8 | simple equipartition model | 4D30.21 | Jostle two different sized marbles by hand in a large tray to show different velocities. |
| Sut, A-46 | kinetic theory models | 4D30.21 | A large and small version of balls on a horizontal surface agitated by a hand frame. |
| Disc 16-05 | equipartition of energy simulation | 4D30.21 | Use different size balls in the shaker frame on the overhead. |
| PIRA 1000 | pressure vs. volume simulator | 4D30.22 | |
| Disc 16-04 | pressure vs. volume simulation | 4D30.22 | Change the size of the entrained area of the shaker frame on the overhead projector. |
| PIRA 1000 | free expansion simulation | 4D30.23 | |
| Disc 16-13 | free expansion simulation | 4D30.23 | Balls are initially constrained to one half of the shaker frame and then the bar is lifted. |
| PIRA 1000 | temperature increase simulation | 4D30.24 | |
| Disc 16-03 | temperature increase simulation | 4D30.24 | A shaker frame on the overhead projector is shown with different shaking rates. |
| Mei, 27-7.3 | mechanical shaker | 4D30.25 | Determine the distribution of velocities produced by an overhead projector shaker. Picture, Diagrams, Construction details in appendix, p.1294. |
| AJP 45(11),1030 | roller randomizer | 4D30.26 | Cylindrical rollers in a pentagon configuration produce random motion. |
| Mei, 27-7.5 | driven steel cage | 4D30.27 | A motor driven steel cage can be used horizontally or vertically to perform several models of kinetic motion. Pictures, Construction details in appendix, p.1295. |
| Mei, 27-7.1 | hard sphere model | 4D30.30 | A bouncing plate with balls. The free space ratio is varied giving models of gas through crystal behavior. Pictures, Construction details in appendix, p 1292. |
| AJP 52(1),68 | speaker shaker | 4D30.31 | Steel balls in a container on a speaker show both fluid and solid state phenomena. |
| AJP 41(4),582 | shaking velcro balls | 4D30.32 | Attach velcro to spheres and shake. "Bonding" will vary with the vigor of agitation. |
| AJP 38(12),1478 | air table molecules | 4D30.32 | Four magnets placed on the Plexiglas discs provide the attraction for many demonstrations of molecular kinetics. |
| Mei, 27-7.2 | drop formation shaker | 4D30.34 | A motorized shaker frame in a magnetic field causes steel balls to act like molecules forming drops. |
| Sut, A-41 | kinetic theory models | 4D30.37 | A fan propels several hundred small steel balls in a container. Also shows Brownian motion. |
| Sut, A-43 | kinetic theory models | 4D30.38 | Compressed air drives ping pong balls in a large container. |
| PIRA 1000 | glass beads | 4D30.40 | |
| F&A, Hh-1 | model for kinetic theory of gases | 4D30.40 | An evacuated tube containing mercury and some glass chips is heated over a Bunsen burner. |
| Sut, A-44 | kinetic theory models | 4D30.40 | Mercury heated in a evacuated glass tube causes glass beads to fly about. |
| Hil, M-22i | glass beads | 4D30.40 | Heat an evacuated tube with some mercury and glass chips. An optical projection system is shown. |
| Disc 16-06 | mercury kinetic theory | 4D30.40 | Glass chips float on a pool of mercury in an evacuated tube. Heat the mercury and the chips dance in the mercury vapor. |
| Sut, A-45 | kinetic theory model | 4D30.41 | Mercury is heated in a large evacuated tube causing pith balls to jump about. |
| F&A, Hh-2 | model of kinetic pressure | 4D30.50 | Balls drop from a funnel onto a pan balance. |
| Sut, M-117 | dropping shot | 4D30.51 | Pour lead shot onto the apex of a cone attached to a float. Vary the number and velocity of shot. |
| AJP 28(7),666 | stream of dropping balls | 4D30.55 | Apparatus Drawings Project No. 9: Drop 1/2" balls at a rate of 5/sec 25' onto a massive damped balance and compare deflection with static loading and theory. |
| PIRA 1000 | flame tube viscosity | 4D30.60 | |
| F&A, Hh-9 | dependence of viscosity on temperature | 4D30.60 | See Fm-4. |
| F&A, Fm-4 | dependence of viscosity on temperature | 4D30.60 | As the tube on one side of a twin burner is heated, the flame becomes smaller. |
| Mei, 27-4.1 | flame tube viscosity | 4D30.60 | One leg of a "T" tube is heated resulting in increased viscosity and a smaller flame of illuminating gas. |

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| Disc 14-04 | gas viscosity change with temperature | 4D30.60 | Heat the gas flowing to one of two identical burners and the flame decreases. |
| F&A, Fm-3 | viscosity of gas independent of pressure | 4D30.71 | The velocity of a precision ball falling in a precision tube is independent of pressure as the tube is partially evacuated. |
| F&A, Hh-8 | viscosity independent of pressure | 4D30.71 | See Fm-3. |
| Sut, A-58 | viscosity and pressure | 4D30.72 | Oscillations in the quartz fiber radiation pressure apparatus change frequency as it is evacuated. |
| Mei, 27-4.2 | viscosity independent of pressure | 4D30.75 | A viscosity damped oscillator is placed into a bell jar and evacuated to various pressures to show viscosity independent of pressure. Pictures, Construction details in appendix, p. 1290. |
| | **Molecular Dimensions** | **4D40.00** | |
| PIRA 1000 | steric and oleic acid films | 4D40.10 | |
| Sut, A-53 | stearic and oleic acid films | 4D40.10 | Films from drops of stearic or oleic acid are measured. |
| Sut, M-221 | alcohol slick | 4D40.12 | Place a drop of alcohol at the center of a petri dish containing a thin layer of water. |
| F&A, Fi-15 | determination of drop size | 4D40.13 | A ring proportional to drop size forms when dropped on filter paper. |
| TPT 2(2),81 | Avogadro's number | 4D40.15 | Use a BB's to model a drop spreading on the surface of water, then use oleic acid and do the real thing. |
| Mei, 16-5.10 | monomolecular layer | 4D40.15 | A "BB" model and the Oleic acid monomolecular layer. Pictures. |
| Sut, A-52 | films | 4D40.20 | Measure gold leaf thickness and show the black of a soap film. |
| | **Diffusion and Osmosis** | **4D50.00** | |
| PIRA 500 | fragrant vapor - ethyl ketone | 4D50.10 | |
| Mei, 27-7.4 | diffusion model on the overhead | 4D50.15 | Balls of two different colors are initially separated by a Lucite bar on a vibrating table. Picture, Construction details in appendix, p.1295. |
| PIRA 1000 | diffusion through porcelain | 4D50.20 | |
| Sut, A-54 | diffusion through porcelain | 4D50.20 | Different gases are directed around an unglazed porcelain cup. A "J" tube manometer shows pressure. Diagram. |
| Disc 16-09 | diffusion | 4D50.20 | Methane and helium are diffused through a porous clay jar. A glass tube extending down into a jar of water bubbles as an indicator. |
| F&A, Hi-2 | diffusion of $CO_2$ | 4D50.21 | When the porcelain cup is surrounded by $CO_2$, water is sucked up the tube. |
| F&A, Hi-1 | diffusion and hydrogen | 4D50.22 | When hydrogen is trapped around a unglazed porcelain cup attached to a tube leading to a beaker of water, it bubbles out; when the trap is removed, water is sucked up the tube. |
| AJP 35(11),1026 | diffusion in a discharge tube | 4D50.30 | Mercury is collected in the refrigerated end of a discharge tube containing neon. When the cold end is warmed and ac is applied, the diffusion of mercury can be followed by the spectral change. Also works with a germicidal lamp. |
| Sut, A-56 | diffusion and pressure | 4D50.40 | Two 1 L round flasks are joined by a small tube. One is attached to a vacuum pump while the crystals are heated in the other. |
| F&A, Hi-3 | diffusion of gases | 4D50.42 | Hydrogen is allowed to diffuse down in a cylinder into air to form an explosive mixture. |
| PIRA 1000 | bromine diffusion | 4D50.45 | |
| F&A, Hi-4 | diffusion of bromine | 4D50.45 | Bromine diffuses out of a cylinder into air. |
| Disc 16-11 | bromine diffusion | 4D50.45 | Glass tubes containing bromine and bromine/air are cooled in liquid nitrogen and allowed to warm back up to show diffusion. |
| Sut, A-55 | bromine diffusion | 4D50.46 | A few drops of bromine are placed in cylinders containing hydrogen and air. |
| Mei, 27-9.1 | bromine diffusion | 4D50.47 | Break bromine ampules in air filled and evacuated tubes. |
| PIRA 1000 | bromine cryophorus | 4D50.50 | |
| UMN, 4D50.50 | bromine cryophorus | 4D50.50 | Three different bromine tubes: with air, partial vacuum, and vacuum, are cooled in liquid nitrogen and allowed to warm. |
| F&A, Hj-9 | bromine cryophorous | 4D50.50 | Tubes with bromine and air at different pressures are immersed in a cold trap to show different diffusion rates. |
| Mei, 27-9.2 | ether vapor before diffusion | 4D50.55 | Pour ether vapor from a wide mouth bottle into a large beaker suspended from a scale. Shadow projection shows an interface before diffusion starts. Picture. |
| PIRA 1000 | diffusion in liquids - $CuSO_4$ | 4D50.60 | |
| F&A, Hi-5 | diffusion of liquids - CuSo4 | 4D50.60 | Concentrated $CuSO_4$ and water diffuse in a cylinder. |
| Sut, M-262 | diffusion of liquids | 4D50.60 | A graduate 1/3 full of a saturated solution of copper sulfate and topped with water will show diffusion over time. |
| Sut, M-263 | diffusion of liquids | 4D50.60 | A tube 2m long with saturated copper sulfate at the bottom can be displayed for decades. |
| Mei, 17-6.2 | potassium permanganate in water | 4D50.62 | Drop potassium permanganate in a dish of water on the overhead projector. |

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| Mei, 17-6.1 | dissolving crystals | 4D50.63 | How to introduce crystals of potassium chromate or copper sulfate to the bottom of a long tube of water. |
| Mei, 17-6.3 | diffusion pressure in a bottle | 4D50.65 | Carbon tetrachloride or lemon oil diffuses out of polystyrene bottles. |
| PIRA 500 | permeable membrane | 4D50.70 | |
| UMN, 4D50.70 | permeable membrane | 4D50.70 | Place a permeable membrane bag attached to a vertical tube and filled with a sugar solution in water. |
| Sut, M-265 | permeable membrane | 4D50.70 | Place a saturated solution of salt or sugar in a thistle tube capped with a permeable membrane and insert into water. |
| F&A, Hi-6 | osmotic pressure | 4D50.71 | Immerse a semipermeable membrane over a thistle tube in a CuSO4 solution. |
| AJP, 75 (11), 997 | osmotic pressure | 4D50.71 | A discussion of osmosis which follows the discussion in Fermi's book on thermodynamics. The discussion is limited to verifying the equation for the ideal osmotic pressure. |
| Sut, M-264 | osmosis | 4D50.72 | Stick a glass tube into a carrot or beet and put the veggie in water. Water will rise in the tube over several days. |
| Sut, M-266 | optical osmometer | 4D50.73 | An optical lever shows bowing of a permeable membrane over the course of a lecture. |
| F&A, Hi-8 | measurement of osmotic pressure | 4D50.74 | Immerse a solution sealed in a semipermeable porcelain cup in pure water and read the pressure with a manometer. |
| F&A, Hi-7 | preparation of semi-permeably membrane | 4D50.75 | On forming a copper ferricynide precipitate permeable to water but not dissolved substances. |
| PIRA 1000 | osmosis simulator | 4D50.80 | |
| UMN, 4D50.80 | osmosis simulator | 4D50.80 | A vibrating plate on an overhead has a barrier sized so only one of two diameter ball bearings will pass. |
| Disc 16-10 | diffusion simulation | 4D50.80 | A bar across the shaker frame on the overhead projector has a small hole that allows small but not larger balls to pass. |
| | **GAS LAW** | **4E00.00** | |
| | **Constant Pressure** | **4E10.00** | |
| PIRA 500 | hot air thermometer | 4E10.10 | |
| UMN, 4E10.10 | hot air thermometer | 4E10.10 | A large round flask is hooked to a manometer. |
| PIRA 1000 | thermal expansion of air | 4E10.11 | |
| Sut, H-3 | Galileo's thermometer | 4E10.11 | An inverted flask with a long slender stem is set in water. As the air in the flask cools, the water in the tube rises. |
| D&R, H-018 | Galileo's thermometer | 4E10.11 | A small diameter glass tube with a blackened bulb on one end is inverted into a beaker of water. Warm bulb to draw some liquid into the tube. Cooling or heating the bulb will raise or lower the liquid level in the tube. |
| Disc 14-12 | thermal expansion of air | 4E10.11 | Hold the inverted flask of Galileo's thermometer with the hands to heat the entrained air and force the water in the tube down. |
| Mei, 25-2.8 | capillary tube thermometer | 4E10.12 | A capillary tube with a bead of mercury is sealed at one end. |
| Sut, H-4 | horizontal thermometer | 4E10.12 | An air filled flask fitted with a long slender tube is held horizontally and a small globule of mercury moves in the tube as the air in the flask changes temperature. |
| Mei, 25-2.4 | gas thermometer | 4E10.13 | A gas thermometer operated at reduced pressure. |
| Hil, H-2a.3 | air thermometer | 4E10.14 | Just an unclear picture - might be a balloon on a flask. |
| F&A, Hk-2 | change of volume with change of temperature | 4E10.15 | A flask with a balloon fitted on the neck is heated with hot water and immersed in dry ice/alcohol. |
| Mei, 27-2.7 | balloon on a flask | 4E10.15 | A balloon on the neck of a large flask changes volume when the flask is placed into hot water or dry ice/alcohol. |
| Sut, H-34 | expansion of gases | 4E10.16 | Two identical constant pressure gas thermometers are filled with different gases and immersed in a water bath to show the same volume increase. |
| Sut, H-33 | expansion of gases | 4E10.16 | Two bulbs connected by a "U" tube manometer are filled with different gases and heated the same amount by immersing in a water bath to show pressure increase is the same on both sides. |
| PIRA 200 | balloons in liquid nitrogen | 4E10.20 | Pour liquid nitrogen over an air filled balloon until it collapses and then let it warm up again. |
| UMN, 4E10.20 | balloon in liquid nitrogen | 4E10.20 | Pour liquid nitrogen over an air filled balloon and then let it warm up again. |
| AJP 78 (12), 1312 | balloons in liquid nitrogen | 4E10.20 | The radius of a balloon is measured as it is cooled with liquid nitrogen. The volume decreases linearly with time. |
| Sprott, 2.9 | balloon in liquid nitrogen | 4E10.20 | A balloon shrinks when placed in liquid nitrogen. Liquid air can be seen inside the collapsed balloon. Try this when the balloon is filled with helium and see the balloon rise to the ceiling when it warms up. |
| Mei, 27-2.8 | balloon in liquid nitrogen | 4E10.21 | A balloon partially inflated on the end of a glass rod is immersed in liquid nitrogen. |
| AJP 39(7),844 | balloons in liquid nitrogen | 4E10.22 | Cool balloons filled with carbon dioxide, argon, helium, pass them around the class. |

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| Sut, H-98 | air pressure at low temperature | 4E10.30 | Immerse the bulb of a small thermoscope in liquid air. |
| | **Constant Temperature** | **4E20.00** | |
| PIRA 500 | square inch syringe | 4E20.10 | |
| UMN, 4E20.10 | square inch syringe | 4E20.10 | A 50cc syringe has an area of .923 square inches. When lightly oiled, the volume will decrease to half when 13 lbs. are applied. |
| AJP 29(10),706 | Boyle's law syringe | 4E20.10 | A glass syringe is mounted vertically with a weight holder attached to the plunger. |
| F&A, Hg-1 | gas law with hypodermic syringe | 4E20.10 | A hypodermic syringe mounted vertically shows PV relations. |
| Mei, 27-2.1 | Boyle's law | 4E20.11 | Stack weights on a piston and read the volume off a scale. Picture. |
| PIRA 1000 | syringe and pressure gauge | 4E20.15 | |
| Disc 16-01 | pressure vs. volume | 4E20.15 | A pressure gauge is mounted on a glass syringe. |
| PIRA 500 | Boyle's law apparatus | 4E20.20 | |
| UMN, 4E20.20 | Boyle's law apparatus | 4E20.20 | A mercury barometer attached with a heavy walled tube to an adjustable glass tube. |
| Sut, M-319 | Boyle's law apparatus | 4E20.20 | A flexible tube of mercury is used to apply pressure to a chamber of air. From Am.Jour.Sci. 32,329,1911. |
| Mei, 27-2.3 | Boyle's law | 4E20.21 | A large Boyle's law apparatus. Diagram and construction hints. |
| Mei, 27-2.6 | Boyle's law apparatus | 4E20.22 | A curved tube with air trapped in the shorter closed end by mercury is tipped to change the pressure from the mercury column. |
| Mei, 27-2.4 | Boyle's law apparatus | 4E20.25 | A projection Boyle's law apparatus is shown. Includes a projection pressure meter. |
| Mei, 27-2.5 | Boyle's law apparatus | 4E20.26 | A projection Boyle's law apparatus using a mercury plug in a capillary as an indicator. |
| PIRA 1000 | Boyle's law with tap pressure | 4E20.30 | |
| AJP 44(5),493 | Boyle's law with tap pressure | 4E20.30 | Eliminate mercury with this tap water pressure apparatus. |
| Mei, 27-2.2 | Boyle's law | 4E20.31 | "Lab-gas" units are a convenient source of low-pressure gas for Boyle's law demonstrations. |
| PIRA 1000 | balloon in a vacuum | 4E20.40 | |
| UMN, 4E20.40 | balloon in a vacuum | 4E20.40 | Place a partially filled balloon in a bell jar and evacuate. Also try a fresh marshmallow. |
| D&R, F-040 | marshmallow, shaving cream in a vacuum | 4E20.40 | Place a fresh marshmallow or shaving cream in a bell jar and evacuate. |
| Sprott, 2.3 | marshmallow, shaving cream in a vacuum | 4E20.40 | Baloons, marshmallows, and shaving cream that are placed in a bell jar expand when air is evacuated and contract when it's readmitted. Water and carbonated beverages will appear to boil when put in a vacuum. |
| AJP 40(9),1342 | Boyle's law - air track model | 4E20.50 | An air track cart represents a one-molecule gas. The frequency of the collisions with the ends increases if the track is made shorter. |
| | **Constant Volume** | **4E30.00** | |
| PIRA 200 | constant volume bulb | 4E30.10 | Immerse a bulb with an absolute pressure gauge in boiling water, ice water, and liquid nitrogen. |
| UMN, 4E30.10 | constant volume bulb | 4E30.10 | A bulb with an absolute pressure gauge is immersed in boiling water, ice water, and liquid nitrogen. |
| F&A, Ha-4 | constant volume thermometer | 4E30.10 | Immerse a tank bulb with an attached pressure gauge in various temperature water baths. |
| Mei, 25-2.7 | constant volume bulb - He | 4E30.10 | A Bourdon pressure gauge is attached to a toilet-tank bulb filled with helium and immersed in boiling water, dry ice, and liquid nitrogen. |
| Disc 16-02 | pressure vs. temperature | 4E30.10 | A constant volume sphere with a pressure gauge is shown at room temperature and immersed in ice water and boiling water baths. |
| F&A, Ha-2 | gas thermometer | 4E30.11 | A bulb is connected to a mercury manometer. |
| Mei, 25-2.6 | constant volume bulb | 4E30.12 | Capillary tubes containing mercury pistons are attached to toilet-tank bulbs filled with different gases. |
| PIRA 1000 | constant volume thermometer | 4E30.20 | |
| F&A, Ha-3 | constant volume thermometer | 4E30.20 | A bulb is connected to a mercury manometer that can be raised or lowered to keep the mercury on the bulb side at the same place. |
| Sut, H-5 | constant volume air thermometer | 4E30.21 | Looks like the Boyle's law apparatus except the enclosed end has a small flask suitable for immersing in a cold water bath. Adjustments are used to keep the volume constant. |
| Mei, 16-2.9 | light bulb pressure | 4E30.30 | Heat a light bulb locally and the glass is pushed in, then heat it while on and the glass is pushed out. |
| Sut, E-54 | heat generated by spark | 4E30.40 | The increased pressure of air in an enclosed container heated by sparking is measured with a manometer. |
| | **ENTROPY & THE SECOND LAW** | **4F00.00** | |
| | **Entropy** | **4F10.00** | |
| PIRA 500 | time reversal | 4F10.10 | |

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| UMN, 4F10.10 | time reversal | 4F10.10 | An ink column in glycerine between two concentric rotating cylinders appears to mix and unmix. |
| AJP 28(4),348 | unmixing demonstration | 4F10.10 | The area between coaxial cylinders is filled with a Newtonian fluid and a suitable tracer. When the inner cylinder is rotated, the tracer appears to be mixed but is distributed in a fine one armed spiral sheet. Reversing the direction of inner cylinder rotation will cause the original tracer pattern to reappear. |
| F&A, Hm-2 | order and disorder | 4F10.10 | Ink seems to be mixed in glycerine but can be unmixed. |
| D&R, S-270 | unmixing demonstration | 4F10.10 | A dye column in glycerine between to concentric rotating cylinders appears to mix and unmix. |
| Disc 13-08 | un-mixing | 4F10.10 | Glycerine between two concentric cylinders. Animation. |
| AJP 54(8),742 | capacitor charging entropy change | 4F10.11 | A simple demonstration-experiment that measures the difference in change of temperature due to charging a capacitor in many steps or one step. |
| PIRA 1000 | balls in a pan | 4F10.20 | |
| UMN, 4F10.20 | balls in a pan | 4F10.20 | Three red balls and three yellow balls are mixed in a pan. |
| AJP 41(11),1284 | communication time and entropy | 4F10.25 | Demonstrate entropy with the time it takes a student to communicate the structure of ordered and disordered playing cards, and a salt crystal model, etc. |
| Bil&Mai, p 236 | entropy - playing cards | 4F10.25 | Playing cards and a Maxwell's Demon model are used to enhance discussions of entropy. |
| PIRA 500 | Hilsch tube | 4F10.30 | |
| UMN, 4F10.30 | Hilsch tube | 4F10.30 | |
| F&A, Hm-3 | Hilsch tube | 4F10.30 | The Hilsch tube is a sort of double vortex that separates hot and cold air. |
| PIRA 500 | dust explosion | 4F10.40 | |
| UMN, 4F10.40 | dust explosion | 4F10.40 | |
| F&A, Hm-1 | dust explosions | 4F10.40 | Disperse dust in a can with a squeeze bulb and use a spark to set off the explosion. |
| Mei, 26-4.5 | dust explosion | 4F10.40 | Blow a teaspoon of lycopodium powder into a covered can that contains a lighted candle inside. |
| Disc 14-15 | dust explosion | 4F10.40 | Blow lycopodium powder into a can containing a candle. |
| TPT 46(8), 477 | cornstarch / coffee creamer explosion | 4F10.42 | Powdered coffee creamer or cornstarch is placed in a cup inside a 1 gallon can. A lit candle is also placed inside the can. Blow air into the cup and a cloud of dust rises which is then ignited by the candle. |
| Mei, 26-4.6 | gas explosion | 4F10.45 | Fill a can that has a hole on top and bottom with illuminating gas and light the top hole. The flame burns low and then the can explodes. |
| D&R, H-090 | gas explosion | 4F10.45 | Fill a can that has a hole on top and bottom with Natural gas and light the top hole. The flame burns low and then the can explodes. DO NOT USE PROPANE. |
| Sprott, 2.20 | exploding balloons | 4F10.50 | Helium and Hydrogen-filled balloons burst when touched by a lighted match. |
| Sprott, 2.21 | exploding soap bubbles | 4F10.55 | Soap bubbles blown with natural gas or hydrogen are ignited. |
| | **Heat Cycles** | **4F30.00** | |
| ref. | Hero's engine | 4F30.01 | see 1Q40.80 |
| ref. | drinking bird | 4F30.01 | see 4C31.30 |
| PIRA 200 | Stirling engine | 4F30.10 | Show both a working Stirling engine and a cutaway model. |
| UMN, 4F30.10 | Stirling engine | 4F30.10 | Show both a working Stirling engine and a cutaway model. |
| F&A, Hn-4 | Stirling hot air engine | 4F30.10 | A Stirling hot air engine. |
| Mei, 26-6.1 | hot air engine | 4F30.10 | Pictures and diagram of a hot air engine that can be run as a hot or cold engine or driven both ways. |
| Disc 15-06 | Stirling engine | 4F30.10 | Shows the standard Stirling engine, includes good animation. |
| TPT 28(4),252 | the Stirling engine explained | 4F30.11 | An explanation of how the Stirling engine works. Good diagrams. (We had to machine off the top half of one to convince the faculty) |
| PIRA 500 | steam engine | 4F30.20 | |
| F&A, Hn-3 | steam engine | 4F30.20 | A small steam engine runs from a small alcohol lamp. |
| Hil, H-5b.3 | steam engine | 4F30.20 | A small steam engine powers a small electric generator. |
| AJP 41(5),726 | room temperature steam engine | 4F30.22 | Place an inflated balloon on the end of a capped copper tube and immerse the tube in liquid N2. Place a weight on the collapsed balloon and it will rise when the balloon warms up. |
| F&A, Hn-2 | Liquid nitrogen engine | 4F30.25 | Convert a small steam engine to run on liquid nitrogen. |
| Sut, H-113 | liquid air steam engine | 4F30.25 | Run a model steam engine by connecting a test tube of liquid air to the boiler. |
| Hil, H-5b.1 | model steam engine | 4F30.31 | Picture of a model steam engine. |
| F&A, Hn-1 | compressed air engine | 4F30.35 | The parts of a steam engine that runs on compressed air. |
| PIRA 1000 | refrigerator | 4F30.40 | |
| Sut, H-182 | engine models | 4F30.50 | Models of different engines are shown. |
| Hil, H-5b.2 | model gasoline engine | 4F30.52 | A picture of a model gasoline engine. |

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| AJP 52(8),721 | air/ocean uniform temperature engine | 4F30.55 | An experimental engine that shows that it is possible to extract heat from a nonhomogeneous uniform temperature reservoir. The humidity must be less than 100% as evaporative cooling is used. |
| Mei, 26-6.2 | ratchet and pawl model | 4F30.56 | Use of a ratchet and pawl model to discuss the second law. Diagram, Construction details in appendix, p.1287. |
| PIRA 1000 | Nitinol engine | 4F30.60 | |
| UMN, 4F30.60 | Nitinol engine | 4F30.60 | |
| AJP 52(12),1144 | Nitinol engine | 4F30.60 | Short thermodynamic discussion of the Nitinol engine. |
| AJP 54(8),745 | Nitinol engine comments | 4F30.60 | Comments on AJP 52(12),1144 taking issue with several points. |
| PIRA 1000 | rubber band engine | 4F30.70 | |
| F&A, Hm-5 | rubber band motor | 4F30.70 | A wheel with rubber band spokes turns when heated locally with a spotlight. |
| Mei, 26-4.1 | rubber band motor | 4F30.70 | The spokes of a bicycle wheel are replaced with rubber bands and a heat lamp is focused on one area causing the bands to contract at that point. Pictures. |
| D&R, H-340 | rubber band engine | 4F30.70 | An acrylic wheel with rubber band spokes turns when heated locally with a heat lamp. |
| AJP 43(4),349 | rubber band motor thermodynamics | 4F30.71 | An analysis of the thermodynamics of a simple rubber band heat engine. |
| AJP 46(11),1107 | optimizing the rubber-band engine | 4F30.76 | An appropriate choice of dimensions maximizes the torque of an Archibald rubber-band heat engine. Plenty of analysis. |
| AJP 57(4),379 | Buchner diagram extensions | 4F30.90 | Comments extending the Buchner diagram to irreversible systems. |
| AJP 54(9),850 | Bucher diagrams | 4F30.91 | A new diagram of the Carnot cycle to replace the pipeline diagram. |
| AJP 34(10),979 | Carnot cycle diagrams | 4F30.95 | A set of thirty different Carnot cycle diagrams. |
| TPT 21(7), 463 | Carnot cycle diagrams | 4F30.95 | A dynamical model of a Carnot cycle. |
| AJP 70(1), 42 | Carnot cycle | 4F30.96 | Sadi Carnot on Carnot's theorem. |
| AJP 76 (1), 21 | Carnot cycle | 4F30.96 | A look at Sadi Carnot's contribution to the second law of thermodynamics. Discusses the first 12 pages of Carnot's own publication "Reflections on the Motive Power of Heat and the Machines Fitted to Develop that Power". |
| AJP 43(1), 22 | Carnot engine | 4F30.97 | The efficiency of a Carnot engine at maximum power output. |
| AJP 70(11), 1143 | Carnot Engine | 4F30.97 | The efficiency of nonideal Carnot engines with friction and heat losses. |

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| | **ELECTROSTATICS** | **5A00.00** | |
| | **Producing Static Charge** | **5A10.00** | |
| ref. | piezoelectricity | 5A10.01 | see 5E60.20 |
| PIRA 200 | rods, fur, and silk | 5A10.10 | PVC rod and felt, acrylic rod and cellophane, with the Braun electroscope as a charge indicator |
| UMN, 5A10.10 | rods, fur, silk | 5A10.10 | PVC rod and felt, acrylic rod and cellophane, Braun electroscope, electrophorus. |
| F&A, Ea-1 | electrostatic charges | 5A10.10 | Rods, fur, etc. |
| D&R, E-015 | electrostatic rods | 5A10.10 | Common materials to use as rods and charging sheets. |
| Bil&Mai, p 240 | electrostatic charges | 5A10.10 | An acrylic rod, hair, wool cloth and balloons are used to produce like and opposite charges. |
| Disc 16-21 | electrostatic rods | 5A10.10 | Rub acrylic and rubber rods with wool and place on a pivot. Graphic overlays show charges. |
| Sut, E-18 | separating charge | 5A10.11 | Several common ways to separate charges. Scuff a rug and then discharge through a neon bulb. |
| Sut, E-16 | charge the student | 5A10.12 | Strike a student sitting on an insulated stool on the back with a fur. If the student holds a key, sparks may be drawn without discomfort. |
| PIRA 1000 | triboelectric series | 5A10.15 | |
| TPT 28(9),612 | triboelectric series, halos | 5A10.15 | A triboelectric series including modern polymers is listed to help in finding a way to charge yourself so you can levitate a thin metalized plastic hoop as a halo. |
| Sut, E-17 | triboelectric series | 5A10.15 | A list of items sorted according to polarity of charge produced by rubbing. |
| D&R, E-010 | triboelectric series | 5A10.15 | Two series. One of common materials, one of not-so-common materials. |
| Sprott, 4.3 | triboelectric series | 5A10.15 | A list of items sorted according to polarity of charge produced by rubbing. |
| Sut, E-24 | identifying charges | 5A10.16 | Use an electroscope charged with known sign to test other charged objects. |
| AJP 35(6),535 | electrification by rubbing | 5A10.17 | Some electrification by rubbing results that are not easily explained by the close contact theory. |
| PIRA 500 | electrophorus | 5A10.20 | |
| UMN, 5A10.20 | electrophorus | 5A10.20 | Use a metal plate on a handle to transfer charge from a large charged surface. |
| F&A, Ea-19 | electrophorus | 5A10.20 | Obtain charge by induction from an electrophorus. |
| Hil, E-1b | electrophorus, etc | 5A10.20 | An electrophorus is pictured along with a conducting sphere, an ellipsoidal conductor, a hollow cylinder, and a dissectible condenser. |
| D&R, E-140 | electrophorus | 5A10.20 | An aluminum disk is used to transfer charge from a charged phonograph record. |
| Sprott, 4.3 | electrophorus | 5A10.20 | A static electric charge on a large insulator surface can repeatedly induce a charge in a conducting plate. |
| Disc 17-03 | electrophorus | 5A10.20 | Repeat charging a metal plate many times. Animation sequence shows movement of charges. |
| Mei, 29-1.12 | electrophorus, etc. | 5A10.21 | Describes using Lucite or polystyrene as the electrophorus sole and a cylindrical electrophorus with a built in neon lamp. Diagram. ALSO - newer rod and fur material, a shielding demo. |
| Sut, E-10 | electrophorus | 5A10.21 | Directions for making an electrophorus from sealing wax. Use a neon discharge tube to show a flash by holding one end on the electrophorus and then touching the other end. |
| TPT 2(1),32 | electrophorus, etc | 5A10.22 | Four demos: one illustrating the action of an electrophorus, another showing the reaction of a charged balloon to a paddle charged positive, negative, or neutral, and more. |
| AJP 28(8),724 | cylindrical electrophorous | 5A10.23 | A copper tube on a handle fits over a 1" polystyrene cylinder mounted vertically. Some discussion about how electricity is transferred on rubbing that contradicts standard approaches. |
| AJP 30(1),69 | electrophorus - neon wand | 5A10.24 | A neon wand flashes as polystyrene/metal electrophorus is opened and closed. |
| PIRA 1000 | electret | 5A10.30 | |
| Sut, E-12 | electret | 5A10.30 | Directions for making an electret. Used the same as an electrophorus except it is permanently charged. References. |
| PIRA 1000 | equal and opposite charges | 5A10.35 | |
| Mei, 29-1.14 | equal and opposite charge | 5A10.35 | Two electroscopes are charged equal and opposite, then the charge is transferred from one to the other. If tape is pulled off an electroscope plate, charge will result and the tape will also charge a second electroscope with the opposite charge. Picture. |

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| Bil&Mai, p 243 | equal and opposite charges - tape | 5A10.35 | Take a 10 cm long piece of tape and rub it against the surface of a table. Peal if off and hold it next to an electroscope to determine its relative charge. Repeat the demonstration with other tape-surface combinations. |
| Sut, E-14 | equality of charges | 5A10.36 | Rub a rubber rod against a similar rod covered with wool in a Faraday ice pail. The electroscope shows no charge unless either of the rods is removed. Or, rub them together outside the pail and insert them separately and together. |
| AJP, 75 (9), 861 | equality of charge - charge conservation | 5A10.36 | A quantitative demonstration of charge conservation intended for lecture room audiences that addresses some pedagogical difficulties. |
| PIRA 1000 | electrostatic rod and cloth | 5A10.37 | |
| Disc 16-22 | electrostatic rod and cloth | 5A10.37 | Rub a rod with a cloth, place on a pivot, show attraction between rod and cloth. |
| PIRA 1000 | mercury-glass charging wand | 5A10.40 | |
| AJP 42(5),424 | shake mercury in a bottle | 5A10.40 | Put some mercury in a plastic bottle with a conducting rod sticking through a stopper. Shake the mercury and invert to charge the rod for a positive charge, invert a second time for negative. |
| Sut, E-21 | mercury-glass charging wand | 5A10.40 | A glass tube containing some mercury is covered with tin foil on one end. Either positive or negative charge may be produced. |
| Sut, E-20 | mercury tube | 5A10.43 | Directions for making a mercury tube that emits light when shaken. Optionally neon is introduced to produce more light. |
| PIRA 1000 | cyrogenic pyroelectricity | 5A10.50 | |
| TPT 28(7),482 | cyrogenic pyroelectricity | 5A10.50 | The polarization of some pyroelectric crystals increases dramatically at low temperatures. |
| PIRA 1000 | heating and cooling tourmaline | 5A10.55 | |
| Sut, E-189 | heating and cooling tourmaline | 5A10.55 | Heat a long thin crystal of tourmaline over a flame and when it cools opposite charges develop on the ends large enough to deflect an electroscope. |
| Sut, E-190 | cooling and heating tourmaline | 5A10.55 | A long thin crystal of tourmaline that has been immersed in liquid air will form opposite charges on the ends upon warming. |
| Sut, E-22 | charge by freezing sulfur | 5A10.56 | Allow molten sulfur to solidify on a glass rod, check with an electroscope. |
| Sut, E-19 | stretched rubber band | 5A10.76 | A stretched rubber band becomes charged positively. Any amount of charge can be removed by sliding along the band. |
| AJP 52(1),86 | electrostatics in a hot box | 5A10.90 | Perform electrostatics demonstrations in a heated box to decrease the relative humidity. |
| | **Coulomb's Law** | **5A20.00** | |
| PIRA 200 | rods and pivot | 5A20.10 | With one charged rod on a pivot, use another of the same or opposite charge to show attraction or repulsion. |
| UMN, 5A20.10 | rods and pivot | 5A20.10 | With one charged rod on a pivot, use another of the same or opposite charge to show attraction or repulsion. |
| Sut, E-1 | rods and pivot | 5A20.10 | Show attraction or repulsion with rods on a pivot or hung by a thread. |
| PIRA 200 - Old | pith balls | 5A20.20 | Suspend two small pith balls and show either attraction or repulsion. |
| UMN, 5A20.20 | Coulomb's law with pith balls | 5A20.20 | |
| AJP 46(11),1131 | Coulomb's law with pith balls | 5A20.20 | Charge two pith balls with an electrostatic generator, project on the wall and measure, discharge one ball, and remeasure the separation. Accuracy is typically 2%. |
| F&A, Ea-5 | pith balls | 5A20.20 | Suspend two small pith balls from a common support. |
| Sut, E-7 | pith balls | 5A20.20 | Charge pith balls. |
| Mei, 29-1.20 | Coulomb's law on the overhead | 5A20.21 | Demonstrate Coulomb's law on the overhead with two ping-pong balls. |
| Mei, 29-1.4 | pith balls on overhead | 5A20.21 | Suspend two pith balls coated with Aquadag in a clear framework on the overhead projector. |
| TPT 28(9),607 | hollow aluminum foil balls | 5A20.22 | Hollow aluminum foil balls are charged with a Van de Graaff generator. |
| Mei, 29-1.8 | hollow aluminum balls | 5A20.22 | Wrap aluminum foil around a marble or ping-pong ball and then remove the ball to make a replacement for a light pith ball. |
| Sut, E-2 | pith balls & variations | 5A20.22 | Metal painted ping pong balls, gas filled balloons, pith balls are used as charge indicators. |
| D&R, E-040 | pith ball variations | 5A20.22 | Coat ping pong balls with aluminum paint and hang on monofilament fishing line. |
| Bil&Mai, p 240 | pith ball variations | 5A20.22 | 8 inch balloons are hung on 1 meter threads and used as pith balls. |
| Mei, 29-1.21 | repelling balls | 5A20.23 | A small charged pith ball is repelled from a large charged sphere. |
| Sut, E-56 | electric potential | 5A20.23 | Bring a charged pith ball close to a like charged conductor and note the repulsive force. |
| PIRA 1000 | ping pong ball electroscope | 5A20.25 | |
| AJP 35(7),iii | ping pong balls | 5A20.25 | Paint a ping pong ball with silver printer circuit paint. |
| F&A, Ea-6 | ping pong pith balls | 5A20.25 | Two silver coated ping pong balls are suspended from separate supports. |
| Mei, 29-1.2 | ping-pong ball electroscope | 5A20.25 | Repulsion of two charged ping-pong balls hung from nylon cord. |

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| Mei, 29-1.3 | ping-pong ball electroscope | 5A20.25 | Hang an electroscope made from aluminized ping-pong balls from aluminum welding rod. Picture. |
| Disc 16-23 | electrostatic ping-pong deflection | 5A20.25 | Attraction and repulsion between charged conductive ping pong balls. |
| AJP 30(12),926 | ping pong ball electroscope | 5A20.26 | Details of an electroscope made with ping pong balls on the ends of hanging rods. |
| AJP 31(9),xi | image charge | 5A20.27 | A large metalized styrofoam ball is mounted on a rod with a counterweight and air bearing at the midpoint. Bring a second ball and then a highly charged metal plate near. |
| TPT 1(5),225 | counterweighted balls | 5A20.27 | Polystyrene spheres (3" dia.) are mounted on counterweighted Lucite rods. |
| Mei, 29-1.11 | counterweighted balls | 5A20.27 | Pith balls are replaced by balls pivoting on counterweighted rods. |
| PIRA 1000 | beer can pith balls | 5A20.28 | |
| UMN, 5A20.28 | beer can pith balls | 5A20.28 | Aluminum beer cans are used instead of pith balls to show repulsion of like charges. |
| PIRA 1000 | mylar balloon electroscope | 5A20.30 | |
| AJP 31(2),135 | balloon electroscope | 5A20.30 | Balloon electroscopes, helium filled or normal, can be painted with aluminum and charged with a Van de Graaff. |
| TPT 28(2),103 | balloons on Van de Graaff | 5A20.30 | Tape mylar balloons on conducting strings to a Van de Graaff generator. |
| Mei, 29-1.9 | Van de Graaff repulsion | 5A20.30 | An aluminized balloon is hung from a rod attached to the Van de Graaff electrode to demonstrate repulsion of like charges. |
| Bil&Mai, p 240 | mylar balloon electroscope | 5A20.30 | An aluminized balloon is hung from the ceiling and used with acrylic rods and balloons to demonstrate like and opposite charges. |
| PIRA 1000 | electrostatic spheres on air table | 5A20.32 | |
| AJP 38(11),1349 | Coulomb's law balance | 5A20.35 | The PSSC soda straw balance is adapted to make a simple Coulomb's law balance. |
| Mei, 29-1.5 | aluminum sheet electroscope | 5A20.40 | Two squares of aluminum foil are suspended from wires across a glass rod. |
| D&R, E-137 | aluminum foil and straw electroscope | 5A20.40 | A simple electroscope made from copper wire, aluminum foil, and drinking straws. |
| Mei, 29-1.6 | large leaf electroscope | 5A20.41 | A 15" length of 1 1/2" mylar tape is suspended along a brass strip. |
| Mei, 29-1.19 | measuring Coulomb's law | 5A20.50 | An optical lever and damper make this apparatus useful to demonstrate Coulomb's law. Diagram, Construction details in appendix, p. 1311. |
| | **Electrostatic Meters** | **5A22.00** | |
| PIRA 500 | Braun electroscope | 5A22.10 | |
| F&A, Ea-3 | Braun electrostatic voltmeter | 5A22.10 | A well balanced needle measures voltages to a few KV. |
| Mei, 29-1.1 | large Braun electroscope | 5A22.10 | Build this Braun electroscope with a 2' vane. Picture, Diagram. |
| Hil, E-1f | the Leybold Braun electroscope | 5A22.10 | Show the Leybold Braun electroscope with some other electrostatics apparatus. |
| Sut, E-4 | electroscopes and electrometers | 5A22.12 | The Braun electrostatic voltmeter and Zeleny oscillating-leaf electroscope are described and pictured. |
| Hil, E-1a | electroscopes | 5A22.22 | Four types of electroscopes are pictured. |
| Bil&Mai, p 243 | simple tape electroscope | 5A22.24 | A 30 cm piece of tape is hung over a wooden dowel in the shape of an upside down "V". The tape will develop a charge when pulled off the roll. Use a negatively charged PVC rod and a positively charged acrylic rod to determine the charge that is on the tape. |
| PIRA 200 | soft drink can electroscope | 5A22.25 | |
| PIRA 1000 - Old | soft drink can electroscope | 5A22.25 | |
| TPT 28(9),620 | simpler soft-drink-can electroscope | 5A22.25 | The tab of the soft drink can supports the electroscope leaves in this simple version. |
| AJP 40(12),1870 | leaf electrometer | 5A22.26 | Modify a leaf electroscope so it discriminates polarity of charge. |
| PIRA 500 | gold leaf electroscope | 5A22.30 | |
| F&A, Ea-2 | gold leaf electroscope | 5A22.30 | A gold leaf electroscope is projected with a point source. |
| Sut, E-3 | projection electroscopes | 5A22.30 | Lantern and shadow projecting a gold leaf electroscope, make your own electroscope. |
| AJP 36(8),752 | vibrating reed electrometer | 5A22.41 | Circuit diagram for a vibrating reed electrometer. Ten demonstrations using the device are listed. |
| AJP 46(2),190 | oscillating electroscope | 5A22.45 | An insulated indicating wire is charged by corona and rises until it touches a ground, then the cycle repeats. |
| PIRA 1000 | Kelvin electrostatic voltmeter | 5A22.50 | |
| F&A, Ea-4 | Kelvin electrostatic voltmeter | 5A22.50 | A rotating vane electrostatic voltmeter. |
| Mei, 29-3.3 | electrostatic voltmeter | 5A22.51 | Measure voltage with a rotor and vane electrostatic voltmeter. Picture, Construction details in appendix, p.1320. |
| Sut, E-71 | condensing electroscope | 5A22.60 | Charges too small to be detected by an electroscope can be detected with the addition of a variable capacitor. Directions and a drawing. |
| AJP 33(4),340 | electrometer with concentric capacitors | 5A22.65 | Concentric capacitors are mounted on an electrometer with the outer grounded. Insert samples in the inner to measure charge. |

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| PIRA 1000 | electrometer | 5A22.70 | |
| Hil, E-1d | Pasco equipment | 5A22.70 | A Pasco electrometer along with the whole kit of Pasco accessories. |
| Hil, E-1e | Pasco projection meter | 5A22.71 | A remote projection meter for the Pasco electrometer. |
| PIRA 1000 | electric field mill | 5A22.80 | |
| F&A, Ed-5 | electric field mill | 5A22.80 | Contains short explanation of an instrument used to measure the electric field. |
| AJP 43(11),942 | simple field mill | 5A22.81 | A circuit used in a simple field mill. |
| Mei, 29-1.7 | electroscope on a diode tube | 5A22.90 | An aluminum foil electroscope attached to the plate of a rectifier diode tube is discharged when the power is turned on. |
| AJP 28(7),679 | triode electroscope relay | 5A22.91 | An antenna is hooked to a grid of a triode tube that controls a relay turning on a light bulb. Charged rods brought close to the antenna turn the light on or off. |
| Hil, E-1k | negative charge detector | 5A22.95 | The neon light goes out in a triode circuit when negative charge is brought close to a wire connected to the grid. |
| | **Conductors and Insulators** | **5A30.00** | |
| PIRA 500 | wire versus string | 5A30.10 | |
| UMN, 5A30.10 | wire versus string | 5A30.10 | Connect two electroscopes together with wire or string and charge one electroscope. |
| Sut, E-5 | wire versus string | 5A30.10 | Connect a wire or silk thread to an electroscope and show the difference in conductivity. ALSO - some on capacitance. |
| PIRA 1000 | acrylic and aluminum bars | 5A30.15 | |
| Disc 16-25 | conductors and insulators | 5A30.15 | Aluminum and acrylic rods are mounted on a Braun electroscope. Bring a charged rod close to each rod. |
| | **Induced Charge** | **5A40.00** | |
| PIRA 200 | charging by induction | 5A40.10 | Charging by induction using two balls on stands with an electroscope for a charge indicator. |
| Hil, E-1g | charging by induction | 5A40.10 | Charging by induction using two balls on stands. |
| Disc 17-01 | electrostatic induction | 5A40.10 | Use two metal spheres, a charged rod, and an electroscope. Animation shows charges. |
| Sut, E-9 | induced charge | 5A40.12 | Use electroscopes and proof planes to show charging by induction. |
| F&A, Ea-16 | methods of electrostatic induction | 5A40.13 | Various forms of conductors are separated in an electric field. |
| PIRA 1000 | electroscope charging by induction | 5A40.15 | |
| UMN, 5A40.15 | electroscope charging by induction | 5A40.15 | Use conductors on the top of two electroscopes that can be brought into contact to demonstrate charging by induction. |
| F&A, Ea-11 | induction charging | 5A40.15 | Large metal bars on two electroscopes are apart when charging by induction. |
| Bil&Mai, p 240 | induction charging | 5A40.15 | An aluminized balloon is hung from the ceiling and used with acrylic rods and balloons to demonstrate charging by induction. |
| TPT 3(1),29 | charging electroscope by induction | 5A40.16 | Touch the plate of an electroscope while holding a charged rod nearby. Next month may contain answers to impertinent questions raised by high school students. |
| TPT 3(4),185 | charging electroscope by induction | 5A40.16 | Answer to the question of an earlier Physics Teacher. Diagrams show how an electroscope is charged when touched while a charged rod is brought near. |
| Sut, E-23 | charging electroscope by induction | 5A40.16 | Charge an electroscope by touching while holding a charged rod near. |
| D&R, E-135 | charging electroscope by induction | 5A40.16 | Charge an electroscope by induction. Show that the response is different than that of an electroscope charged by conduction. |
| Sut, E-8 | electrostatic charging by induction | 5A40.17 | Pith balls touching both ends of a conductor are charged when a charged rod is brought toward one end. Use another test charge to show the polarity at each end. |
| PIRA 200 | can attracted to charged rod | 5A40.20 | A hoop of light aluminum is attracted to a charged rod. |
| UMN, 5A40.20 | charge propelled cylinder | 5A40.20 | |
| F&A, Ea-15 | can attracted to charged rod | 5A40.20 | A hoop of light aluminum is attracted to a charged rod. |
| D&R, E-085 | can attracted to charged rod | 5A40.20 | A metal soda can is attracted to a charged rod. Seamless aluminum cans work best. |
| Mei, 29-1.15 | charged ball attracted to ground | 5A40.23 | A metalized ball is attracted to a grounded aluminum sheet when a charge is applied to the ball. |
| Sut, E-11 | suspended electrophorus disc | 5A40.23 | Raise an electrophorus disc off the plate with a helical spring, touch the disc to remove induced charge, and show the spring lengthens. |
| AJP 44(6),606 | blow soap bubbles at Van de Graaff | 5A40.24 | Blow neutral soap bubbles at a Van de Graaff generator for intriguing induction effects. Try double bubbles. |
| PIRA 1000 | paper sticks on board | 5A40.25 | |
| Sut, E-15 | paper sticks on the board | 5A40.25 | Hold a piece of paper on a slate blackboard and rub it with fur. |

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| Hil, E-5b | rub paper | 5A40.25 | Rub paper with cat fur while holding it on the board. |
| Sut, E-6 | familiarity breeds contempt | 5A40.26 | Cork filings are first attracted to a charged rod by induced charge, then repelled as they become charged by conduction. |
| PIRA 500 | 2" x 4" | 5A40.30 | |
| UMN, 5A40.30 | 2" x 4" | 5A40.30 | Induced charge is used to move a 2x4 balanced on a watch glass. |
| F&A, Ea-17 | conductivity of a "two by four" | 5A40.30 | Rotate a 2x4 by bringing a charged rod close. |
| D&R, E-085 | 2" X 4" | 5A40.30 | Induced charge is used to move a 2X4 balanced on a watch glass |
| Bil&Mai, p 245 | 2" X 4" | 5A40.30 | A charged balloon is used to move a 2X4 balanced on a watch glass. |
| Disc 17-06 | wooden needle | 5A40.30 | The "needle" is a six foot 2X4. |
| PIRA 500 | metal rod attraction | 5A40.35 | |
| Disc 17-02 | metal rod attraction | 5A40.35 | Place a metal rod on a pivot and show attraction to both positive and negative charged rods. |
| F&A, Ec-5 | forces between electrodes | 5A40.36 | A ball on a flexible rod is attracted to an electrostatic generator by the induced charge. |
| PIRA 500 | deflection of a stream of water | 5A40.40 | |
| UMN, 5A40.40 | deflection of a stream of water | 5A40.40 | A charged rod deflects a stream of water. |
| F&A, Ea-12 | deflection of a water stream | 5A40.40 | A charged rod is held near a stream water flowing from a nozzle. |
| D&R, E-090 | deflection of a water stream | 5A40.40 | A charged rod is held near a fine stream of water flowing from a faucet. |
| Sut, E-41 | deflection of water stream | 5A40.42 | At different ranges the water stream 1) the jet is smooth from nozzle to sink, 2) is attracted to the rod, 3) breaks up into small drops. |
| F&A, Ea-13 | Raleigh fountain | 5A40.43 | A charged rod held near a stream of water directed upward breaks it into drops. |
| TPT, 37(4), 208 | coalescence of raindrops in an electrostatic field | 5A40.44 | Holding a charged rod near a fine spray of water causes an enlargement of the drop sizes. |
| PIRA 1000 | electrostatic generator principles | 5A40.60 | |
| UMN, 5A40.60 | electrostatic generator principles | 5A40.60 | Same as AJP 37(10),1067. |
| AJP 37(2),225 | electrostatic generator principles | 5A40.60 | Manipulate two metal cans and move a metal ball back and forth to show how charging by induction and charge transfers build up charge. |
| AJP 37(10),1067 | electrostatic generator principles | 5A40.60 | Two cans and two balls and cross your hands. |
| PIRA 500 | Kelvin water dropper | 5A40.70 | |
| UMN, 5A40.70 | Kelvin water dropper | 5A40.70 | Sparks are produced by falling water. |
| AJP, 68(12), 1084 | Kelvin water dropper | 5A40.70 | Optimizing the Kelvin water dropper by using a conducting rod on the axis of the charged ring. A simple experiment that gives reliable measurements. |
| F&A, Ea-14 | Kelvin water dropper | 5A40.70 | Sparks are produced by water falling through two rings connected by an "x" arrangement to opposite receivers. |
| Mei, 29-1.24 | Kelvin water dropper | 5A40.70 | A simple Kelvin water dropper made with shower heads enclosed in cans. Diagram. |
| Mei, 29-1.23 | Kelvin water dropper | 5A40.70 | Explanation of and directions for building a Kelvin water dropper. Picture, construction details in appendix, p.1311. |
| Sut, E-25 | Kelvin water dropper | 5A40.70 | A diagram and some construction details are given for the Kelvin water dropper. A "dry water dropper" using steel balls is mentioned. |
| Disc 17-05 | Kelvin water dropper | 5A40.70 | A Kelvin water dropper discharges a small neon lamp. Animation sequence shows principles of operation. |
| AJP 41(2),196 | Kelvin water dropper - ac | 5A40.72 | The Kelvin water dropper is extended to multiphase, multifrequency operation by considering N streams and N cans. A five can version is shown. |
| Mei, 29-1.22 | almost Kelvin water dropper | 5A40.73 | Water drops through a paraffin coated funnel into a brass cup. The funnel and cup are connected to a electroscope. |
| | **Electrostatic Machines** | **5A50.00** | |
| Sut, E-26 | electrostatic generators | 5A50.05 | General discussion of electrostatic machines. |
| PIRA 200 - Old | Wimshurst machine | 5A50.10 | Crank a Wimshurst generator. |
| F&A, Ea-22 | Wimshurst machine | 5A50.10 | An explanation of how the Wimshurst charges by induction. |
| Sprott, 4.1 | Wimshurst machine | 5A50.10 | A wimshurst electrostatic generator producing high voltages at moderate currents is used to show principles of electrostatics. |
| Disc 17-04 | induction generator | 5A50.10 | Shows Wimshurst machine. Animation sequence shows principles of operation. |
| Hil, E-1i | Wimshurst machine | 5A50.11 | Picture of a small Wimshurst machine. |
| AJP 42(4),289 | ac Wimshurst | 5A50.12 | The Wimshurst design is extended to produce three phase ac at 18 kV and 2 Hz. |
| PIRA 1000 | Toepler-Holtz machine | 5A50.15 | |
| Hil, E-1j | Toepler-Holtz machine | 5A50.15 | A large antique Holtz machine used to generate high voltages for old X-ray machines. Will produce a 10" spark. |
| AJP 51(5),472 | two-inductor electrostatic generator | 5A50.16 | A Wimshurst type generator simplified with only one disk for pedagogical purposes. The references for this article are found in AJP 51(9),861. |

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| TPT 3(5),227 | fur and record generator | 5A50.17 | A series of pictures illustrate construction of a simple electrostatic generator built using a hand drill, LP record, and fur. |
| PIRA 500 | dirod electrostatic machine | 5A50.20 | |
| Mei, 29-1.25 | dirod electrostatic machine | 5A50.20 | A rotating electrostatic machine made with a disk and rods. Picture, Diagrams, Construction details in appendix, p. 1312. |
| D&R, E-180 | dirod electrostatic machine | 5A50.20 | Discussion on the use of the "Dirod" machine |
| PIRA 200 | Van de Graaff generator | 5A50.30 | Show sparks from a Van de Graaff generator to a nearby grounded ball. |
| AJP 35(11),1082 | Van de Graaff | 5A50.30 | Design of a good size Van de Graaff. |
| Sut, E-27 | electrostatic generating machines | 5A50.30 | Directions for building a Van de Graaff generator. Reference. |
| D&R, E-160 | Van de Graaff generator | 5A50.30 | Belts from common materials and their maintenance. |
| Sprott, 4.2 | Van de Graaff generator | 5A50.30 | A Van de Graaff generator is used for a variety of electrostatics demonstrations. |
| Bil&Mai, p 246 | Van de Graaff generator | 5A50.30 | Show sparks from a Van de Graaff generator to a nearby grounded wand. |
| PIRA 1000 | Van de Graaff principles | 5A50.31 | |
| AJP 43(12),1108 | Van de Graaff theory | 5A50.31 | A note on the theory of the Van de Graaff. |
| TPT 28(5),281 | electrostatic generator | 5A50.31 | A very practical article covering theory, maintenance, and belt fabrication. |
| F&A, Ec-1 | electrostatic generator | 5A50.31 | An explanation of the Van de Graaff generator. |
| Disc 17-07 | Van de Graaff generator | 5A50.31 | Shows a Van de Graaff with paper streamers, then a long animated sequence on the principles of operation. |
| AJP 30(5),333 | Van de Graaff vs. Simon | 5A50.32 | Theories of Van de Graaff and Simon (AJP 22,318 (1954)) are compared and experiments yield results in accordance with the Simon theory. |
| AJP 32(5),xiii | improvements to toy Van de Graaff | 5A50.34 | Double the length of the spark with two modifications. |
| Mei, 29-1.26 | improvements on the toy Van de Graaf | 5A50.34 | Two improvements to the toy Van de Graaff generator. |
| PIRA LOCAL | Fun Fly Stick | 5A50.35 | A toy that is really a small battery operated Van de Graaff generator. |
| PIRA 1000 | Franklin's electrostatic machines | 5A50.50 | |
| AJP 39(10),1139 | Franklin's electrostatic motors | 5A50.50 | Models of Franklin's first two electric motors are shown. |
| F&A, Eb-5 | electrostatic motor | 5A50.51 | A polyethylene bottle spins as a Wimshurst is connected to brushes alongside the bottle. |
| Mei, 29-1.27 | electrostatic motor | 5A50.52 | A motor operated by electrostatic charges drawn from an electrostatic generator. Picture. |
| Sut, E-117 | electrostatic motor | 5A50.52 | Use a large static machine to drive a smaller one as a motor. |
| AJP 45(2),218 | elecrostatic motor | 5A50.53 | An electrostatic motor with a vane type rotor. |
| AJP 39(7),776 | atmospheric electric field motor | 5A50.55 | Report on the construction of an electret type and corona type motor for operation from the Earth's electric field. |
| | **ELECTRIC FIELDS & POTENTIAL** | **5B00.00** | |
| | **Electric Field** | **5B10.00** | |
| PIRA 200 | hair on end | 5B10.10 | While standing on an insulated stool, charge yourself up with a Van de Graaff generator. |
| UMN, 5B10.10 | hair on end | 5B10.10 | While standing on an insulated stool, charge yourself up with a Van de Graaff generator. |
| Sut, E-46 | hair on end | 5B10.10 | Stand on an insulated stool and hold on to a terminal of a static machine. Disconnect the condensers. |
| Sprott, 4.2 | hair on end | 5B10.10 | An individual standing on an insulating stand puts a hand on a Van de Graaff making their hair stand on end. |
| Bil&Mai, p 246 | hair on end | 5B10.10 | While standing on an insulated stool, charge yourself up with a Van de Graaff generator. |
| F&A, Ec-4 | pithball plate and flying balls | 5B10.13 | Place a plate with pith ball hanging on strings on an electrostatic generator. Also place a cup filled with styrofoam balls on an electrostatic generator. |
| PIRA 500 | Van de Graaff streamers | 5B10.15 | |
| UMN, 5B10.15 | Van de Graaff streamers | 5B10.15 | Attach ribbon streamers to the top of a Van de Graaff generator. |
| F&A, Ec-3 | Van de Graaff streamers | 5B10.15 | A small stand with thin paper strips is placed on an electrostatic generator. |
| Disc 17-08 | Van de Graaff with streamers | 5B10.15 | Show Van de Graaff with paper streamers, then hair on end. |
| AJP 42(2),166 | recoiling tentacles | 5B10.16 | Place the electrostatic plume made out of nylon rope near the other terminal of the Wimshurst machine. |
| Sut, E-42 | electric rosin | 5B10.21 | Melt rosin in a metal ladle and attach to a static machine. When the machine is cranked and the rosin slowly poured out, jets of rosin follow the electric field. |

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| AJP 46(4),435 | electrostatic painting | 5B10.22 | Clip the can to ground and a metal object to be painted to the Van de Graaff generator. Point out that the paint goes around to the back too, and it is thickest on the edges. |
| AJP 34(11),1034 | MgO smoke | 5B10.23 | Fill an unevacuated bell jar with MgO smoke and they will form three dimensional chain-like agglomerates between electrodes. |
| AJP 32(1),xiv | orbiting foil | 5B10.23 | Throw a triangle of aluminum foil into the field of a Van der Graaff and it comes to equilibrium mid-air. Give it a half-twist, and it will orbit in a horizontal circle below the sphere. |
| Mei, 29-1.28 | charge motion in an electric field | 5B10.24 | A charged ball on a dry ice puck is launched toward a Van de Graaff generator. The motion is recorded with strobe photography. |
| PIRA 200 - Old | confetti (puffed wheat) | 5B10.25 | Confetti (puffed wheat, styrofoam peanuts) flies off the ball of an electrostatic generator. |
| UMN, 5B10.25 | styrofoam peanuts | 5B10.25 | |
| F&A, Ec-2 | confetti on electrostatic generator | 5B10.25 | Confetti flies off the ball of an electrostatic generator. |
| Sprott, 4.2 | confetti or aluminum plates | 5B10.25 | Puffed rice or a stack of aluminum plates on a Van de Graaff will fly off when charged. |
| Bil&Mai, p 246 | confetti (puffed rice) and pie plates | 5B10.25 | Confetti (puffed rice) flies off the ball of an electrostatic generator. Place a stack of inverted pie plates on the ball of the generator and watch them fly off one at a time. |
| PIRA 1000 | electrified strings | 5B10.26 | |
| UMN, 5B10.26 | electrified strings | 5B10.26 | A bunch of hanging nylon strings are charged by stroking with cellophane causing repulsion. |
| F&A, Ea-8 | electrified strings | 5B10.26 | Charge a mop of insulating strings. |
| Mei, 29-1.18 | streamers | 5B10.26 | Fray the end of a nylon clothesline and charge with an electrostatic machine to show repulsion. |
| F&A, Ea-10 | shooting down charge | 5B10.26 | Use the piezoelectric pistol to discharge the electrified strings. |
| PIRA 1000 | electric chimes | 5B10.30 | |
| F&A, Eb-9 | electric chimes | 5B10.30 | A ball bounces between charged metal chimes. |
| Mei, 29-1.13 | electric chimes | 5B10.30 | Insert a metalized ping-pong ball between two highly charged metal plates. |
| Sut, E-39 | electric chimes | 5B10.30 | A small metal ball hangs on a thread between two bells attached to an electrostatic machine. |
| D&R, E-060 | electric chimes | 5B10.30 | Suspend a metal hemisphere, bell, or ball between two parallel plates that are connected to an electrostatic generator. |
| AJP 69(1), 50 | electric chimes | 5B10.30 | Franklin's Bells are used to demonstrate and measure charge transport in the laboratory. |
| Disc 16-24 | electrostatic ping-pong balls | 5B10.30 | Conductive ping pong balls bounce between horizontal plates charged with a Wimshurst. |
| Sut, E-43 | jumping particles | 5B10.31 | Aluminum powder bounces between two horizontal plates 1 cm apart attached to a static machine. Metalized pith balls bounce between an electrode at the top of a bell jar and the plate. |
| AJP 45(8),772 | Van de Graaff chime | 5B10.32 | Toss a small foil near the charged sphere (see AJP 32(1),xiv - 5B10.33) and then bring a grounded ball close to show the chime effect. |
| F&A, Ec-6 | electrostatic ping-pong | 5B10.33 | A fluffy cotton ball travels back and forth between an electrostatic generator and a lighted cigar. |
| PIRA 500 | electrostatic ping pong | 5B10.35 | |
| UMN, 5B10.35 | electrostatic ping pong | 5B10.35 | Bounce a conducting ball hanging between two plates charged with a Wimshurst. |
| PIRA 200 | fuzzy fur field tank | 5B10.40 | |
| PIRA 500 - Old | fuzzy fur field tank | 5B10.40 | |
| UMN, 5B10.40 | fuzzy fur field tank | 5B10.40 | "Fur" in mineral oil aligns along field lines from charged electrodes. |
| AJP 32(5),388 | "velveteens" | 5B10.40 | Fine black fiber clippings in castor oil are used to show electric field between electrodes. |
| F&A, Eb-1 | electric fields between electrodes | 5B10.40 | Charged electrodes are placed in a tank of mineral oil containing velveteen and the pattern is projected on the overhead. |
| Mei, 29-2.1 | fuzzy fur field tank | 5B10.40 | Bits of material suspended in oil align with an applied electric field. Several pole arrangements are shown. |
| D&R, E-065 | electric field | 5B10.40 | "Velveteen's" or grass seed in oil will align with the field between electrodes. |
| Disc 17-10 | electric field | 5B10.40 | A pan on the overhead projector contains particles in a liquid that align with the electric field. |
| Mei, 29-2.2 | repelled air bubbles | 5B10.41 | A stream of air bubbles in an oil bath are repelled in the region of an inhomogeneous field. |
| Sut, E-44 | epsom salt on plate | 5B10.42 | Sprinkle Epson salt on a glass plate with two aluminum electrodes. Tap to align the crystals. |

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| AJP 39(3),350 | ice filament growth | 5B10.43 | An ice filament pattern shows the electrical field configuration. Place a PZT transducer on a block of dry ice. |
| TPT 31(4), 218 | electrorheological liquids | 5B10.45 | A liquid whose viscosity is affected by electric fields. In this case a mixture of corn starch in vegetable oil. Let this run out of the bottom of a funnel. Bring a charged rod close to the bottom of the funnel and the flow stops. |
| Sut, E-45 | mapping force with "electric doublet | 5B10.50 | Two pith balls charged oppositely and hanging from a rod are used to map out the field in the region of charged conductors. |
| Mei, 29-3.1 | plotting equipotential lines | 5B10.51 | A method for plotting equipotential lines from electrodes in a pan on water. |
| AJP 30(1),71 | finger on the electrophorus | 5B10.52 | Charge an electrophorus, then trace a circle on it with your finger and probe the resulting field with a pith ball on a long thread. |
| Sut, E-52 | extent of electric field | 5B10.53 | Hold an electroscope several feet away from a static machine and observe the electroscope leaves rise and fall as sparking occurs. |
| AJP 31(2),xii | mapping field potential, voltage | 5B10.54 | A wire held in the flame of a candle and attached to a grounded electroscope is held near a Van de Graaff generator. Mount two candles on an insulator and attach the second to the case of the electroscope to measure voltage. |
| Sut, E-57 | mapping potential field | 5B10.54 | A small alcohol lamp attached to an electrostatic voltmeter can be used to map potential fields. |
| AJP 41(12),1314 | liquid crystal mapping | 5B10.55 | An electrode configuration is painted onto a conducting paper with temperature sensitive encapsulated liquid crystals. Joule heating causes color changes. |
| AJP 42(12),1075 | liquid crystal mapping | 5B10.55 | An alternate method (to AJP 41(12),1314) of preparing liquid crystal displays of electric fields. |
| Mei, 29-2.3 | double brass plate measurement | 5B10.57 | The field around a large sphere is measured by separating two brass plates and measuring the charges with a ballistic galvanometer. |
| F&A, Ec-7 | electric field indicator | 5B10.58 | A point on the end of a 500 Mohm resistor connects to a neon bulb in parallel with a small capacitor. |
| AJP 30(1),19 | electric fields of currents | 5B10.60 | Current carrying conductors are made of transparent conducting ink on glass plates. Sprinkle on grass seeds to demonstrate the electric lines of force inside and outside the conducting elements. |
| AJP 38(6),720 | electric fields of currents | 5B10.61 | Draw a circuit on glass or mylar with a soft lead scoring pencil. Dust the glass with small fibers while the current is flowing. |
| Mei, 29-2.4 | water drop model of charged particle | 5B10.62 | A water drop model demonstrates the motion of a stream of charged particles in an electric field. |
| ref. | other surfaces | 5B10.70 | see 8C20.20,1L20.10 |
| PIRA 1000 | rubber sheet field model | 5B10.70 | |
| AJP 28(7),644 | rubber sheet model for fields | 5B10.70 | Roll balls over a 6'x4' frame with a stretched rubber surface, distorting it with dowels to represent charges. |
| Sut, E-58 | model of field potential | 5B10.70 | A sheet of rubber is pushed up and down with dowels to represent positive and negative charges. |
| Mei, 29-5.1 | stretched membrane field model | 5B10.71 | A rubber sheet stretched over a large quilting hoop models electric fields. |
| | **Gauss' Law** | **5B20.00** | |
| PIRA 200 | Faraday's ice pail | 5B20.10 | With a proof plane and electroscope, show charge is on the outside of a hollow conductor. |
| Sut, E-28 | Faraday's ice pail | 5B20.10 | With a proof plane and electroscope, show charge is on the outside of a hollow conductor. ALSO, "Faraday's bag". |
| Disc 17-15 | Faraday ice pail | 5B20.10 | Charge a bucket with a Wimshurst and try to transfer charge from the inside and outside of the bucket to an electroscope. Show charge is only on the outside of a hollow conductor. |
| AJP 35(3),227 | big Faraday ice pail | 5B20.11 | A 55 gal. drum Faraday ice pail and other stuff. |
| Hil, E-1h | Faraday ice pail | 5B20.12 | A Faraday ice pail made of two concentric wire mesh cylinders connected to a Braun electroscope. |
| PIRA 1000 | Faraday's ice pail on electroscope | 5B20.15 | |
| UMN, 5B20.15 | Faraday's ice pail on electroscope | 5B20.15 | A charged metal pail sits on an electroscope. Use a proof plane to try to transfers charge from the inside or outside of the pail to another electroscope. Only the outside of the pail will show that it has charge. |
| D&R, E-115 | Faraday's ice pail on electroscope | 5B20.15 | A charged metal pail sits on a Braun electroscope. A proof plane is used to show that charge is only removed from the outside of the pail. |
| F&A, Ea-7 | Faraday's ice pail on electroscope | 5B20.15 | A charged copper beaker placed on an electroscope is touched on the outside or inside with a proof plane. |
| Sut, E-13 | Faraday's ice pail - induction | 5B20.17 | A charged ball is moved in and out of the Faraday ice pail and the electroscope deflection noted, then touched to the inside of the pail. |

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| F&A, Ea-21 | butterfly net experiment | 5B20.20 | Turn a charged butterfly net inside out and the charge is still on the outside. |
| PIRA 500 | electroscope in a cage | 5B20.30 | |
| F&A, Ea-20 | shielded electroscope | 5B20.30 | A charged rod is brought close to a gold leaf electroscope in a wire mesh cage. |
| Sut, E-31 | electroscope in a cage | 5B20.30 | Enclose an electroscope in a cage of heavy wire screening. |
| Sprott, 4.7 | Faraday cage | 5B20.30 | Illustrates the fact that a closed conducting surface is at an equipotential and that one cannot detect an electric field within the cage. |
| Disc 17-14 | Faraday cage | 5B20.30 | Bring a charged rod near a Braun electroscope, then cover the electroscope with a wire mesh cage and repeat. |
| PIRA 1000 | electroscope in a cage/Wimshurst | 5B20.31 | |
| UMN, 5B20.31 | electroscope in a cage on Wimshurst | 5B20.31 | A screen cage shields an electroscope from a charged rod. |
| Sut, E-30 | pith balls in a cage | 5B20.33 | Metal coated pith balls are suspended inside and outside of a metal screen cylinder attached to a electrostatic machine. |
| PIRA 200 | radio in a cage | 5B20.35 | Place a wire mesh cage over a radio. |
| UMN, 5B20.35 | radio in a cage | 5B20.35 | |
| Bil&Mai, p 248 | radio in a cage - cell phone | 5B20.35 | Tune a radio to a station with a clear signal. Place the radio inside a pouch made from aluminum window screen and the radio stops receiving signals. Next place a cell phone in the pouch and give it a call. Then wrap the phone in aluminum foil. |
| Disc 21-17 | radio in Faraday cage | 5B20.35 | Place a wire mesh cage over a radio. |
| Mei, 29-1.29 | VTVM in a cage | 5B20.36 | Mount the inputs to a VTVM in a Faraday cage. Show charge transfer from plastic strips. |
| | **Electrostatic Potential** | **5B30.00** | |
| PIRA 500 | surface charge density - balls | 5B30.10 | |
| UMN, 5B30.10 | surface charge density - balls | 5B30.10 | Separate several pairs of balls of different diameters attached to a Wimshurst by the same distance. |
| F&A, Ea-23 | surface charge density | 5B30.10 | Sets of balls of different radius but the same separation are simultaneously attached to a Wimshurst. |
| Bil&Mai, p 252 | surface charge density - balloons | 5B30.10 | Inflate a balloon but do not tie if off. Use wool cloth to charge the balloon and then observe how puffed rice jumps to the balloon when brought near. Release the air in the balloon and observe how the rice jumps to the balloon with greater fury. |
| PIRA 1000 | charged ovoid | 5B30.20 | |
| UMN, 5B30.20 | charged ovoid | 5B30.20 | Proof planes of the same area take charge off the round or pointed end of a zeppelin shape. |
| F&A, Ea-18 | surface charge density | 5B30.20 | Proof planes of the same area take charge from the flat or pointed end of a charged zeppelin shaped conductor. |
| Sut, E-29 | charged Zeppelin | 5B30.20 | Use a proof plane and electroscope to compare charge densities at different points on a egg shaped conductor. |
| Bil&Mai, p 250 | charged Zeppelin | 5B30.20 | A Zeppelin shaped Styrofoam ball has pieces of tinsel attached. Charge with a Van de Graaff generator and observe the strands of tinsel at the point position themselves closer to each other than the strands at the rounded end. |
| Sut, E-60 | charge distribution on spheres | 5B30.22 | Read this one. Determine the charge distribution as spheres are brought close to a charged sphere. |
| Mei, 29-2.8 | surface charge density with cans | 5B30.24 | Transfer charge from the edge of a can on a source to the inside of a second can. |
| Sut, E-61 | charge on spheres | 5B30.25 | Spheres of different diameters are brought to the same potential and inserted into a Faraday ice pail to show different charges. |
| Sut, E-49 | spark gaps | 5B30.26 | Connect an electrostatic voltmeter to the terminals of a static machine and observe the voltage while varying the spark gap. |
| Mei, 29-3.2 | measure the second derivative of pot | 5B30.27 | A two point probe measures potential, and a five point probe measures the second derivative of potential. Diagram. |
| Sut, E-59 | potential during discharge | 5B30.28 | An electroscope is connected to the ball of the electric chime to observe the decrease on potential as the ringing diminishes. |
| TPT, 37(1), 10 | "crying" electrostatics | 5B30.29 | Construct an electrophorous apparatus with a foam board, aluminum pie plate, Styrofoam cup, neon bulb, amplifier and speakers to produce electrophorus "crying" sound. |
| PIRA 200 - Old | lightning rod | 5B30.30 | Insert a sphere and point of the same height between horizontal metal plates charged by a Wimshurst. |
| UMN, 5B30.30 | lightning rod | 5B30.30 | Insert a sphere and point of the same height between horizontal metal plates charged by a Wimshurst. |

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| F&A, Eb-7 | lightning rod | 5B30.30 | Sparks jumping from a plane to a sphere will stop when a point is inserted. |
| Disc 17-11 | lightning rod | 5B30.30 | Sparks discharge from a large ball suspended over a model house with a small ball in the chimney until a point is raised above the small ball. |
| PIRA 200 | point and ball with Van de Graaff | 5B30.35 | |
| PIRA 500 - Old | point and ball with Van de Graaff | 5B30.35 | |
| UMN, 5B30.35 | point and ball with Van de Graaf | 5B30.35 | Hold a ball close to a Van de Graaff generator and then bring a point close. |
| Disc 17-09 | Van de Graaff and wand | 5B30.35 | With paper streamers as a field indicator, bring a ball and point close to the Van de Graaff. |
| PIRA 500 | electric wind | 5B30.40 | |
| UMN, 5B30.40 | electric wind | 5B30.40 | A point attached to a Wimshurst blows a candle flame. |
| F&A, Eb-3 | electric wind | 5B30.40 | A candle between pointed and plane electrodes attached to a Wimshurst will blow the flame. |
| Sut, E-37 | electric wind | 5B30.40 | A candle flame held near a point connected to the positive side of an electrostatic generator will repel the flame as if there is a breeze of ions. |
| D&R, E-185 | electric wind | 5B30.40 | A point and plate or two parallel plates will blow a candle flame when connected to an electrostatic generator. |
| Bil&Mai, p 246 | electric wind | 5B30.40 | A candle flame held near the dome of a Van de Graaff generator will be deflected away from the dome. |
| Disc 17-13 | point and candle | 5B30.40 | Attach a sharp point to one terminal of a Toepler-Holtz generator and point it at a candle flame. |
| AJP 30(5),366 | history of the electric wind | 5B30.41 | Covers discovery and early investigations, the dust controversy, and recent studies and applications. |
| Sut, A-6 | corona discharge in air | 5B30.42 | The corona discharge from a point towards a candle flame and a pinwheel spinning. |
| F&A, Eb-6 | cooling with electric wind | 5B30.43 | The electric wind from needle points cools a glowing nichrome wire heater. |
| Sut, E-36 | corona current | 5B30.44 | A 1/2 Meg resistor in series with a galvanometer measure the current in a corona discharge from an electrostatic machine. |
| F&A, Eb-2 | corona discharge | 5B30.45 | A charged aluminum rod with a needle at one end will charge a nearby sphere with like charge if the needle is pointed to the sphere and with opposite charge if the needle is pointed away. |
| Sut, E-32 | escape of charge from a point | 5B30.45 | When charge is induced on an electrode with a point, the induced charge will escape and the charge on the induced electrode will be the same as on the inducing electrode. |
| Sut, E-35 | charge by pointing | 5B30.45 | Charge a conductor by proximity to a point attached to a static machine. |
| Mei, 29-1.10 | discharging from a point | 5B30.46 | Three balloons filled with illuminating gas are suspended from a point and charged. The blunt end of a brass rod has little effect but the pointed end discharges the balloons when pointed at them. |
| Sut, E-33 | darning needle discharge | 5B30.46 | The blunt end of a darning needle is placed on the charged conductor of an electroscope and the electroscope is discharged. |
| Sut, E-34 | collapse the field | 5B30.47 | The point of a grounded needle is brought near a charged tinsel tassel and the tassel collapses. |
| F&A, Eb-13 | electrical discharge from water drop | 5B30.48 | A drop of water placed on the positive electrode of a Wimshurst will form a corona but spit droplets when placed on the negative electrode. |
| AJP 32(9),713 | point cathode effect | 5B30.49 | A point is biased to 1200 V in a Wilson cloud chamber. |
| PIRA 500 | pinwheel | 5B30.50 | |
| UMN, 5B30.50 | pinwheel | 5B30.50 | A pinwheel spins when attached to a Wimshurst generator. |
| F&A, Eb-10 | electrostatic pinwheel | 5B30.50 | A conducting pinwheel spins when connected to a Wimshurst. |
| Sut, E-38 | pinwheel | 5B30.50 | A pinwheel rotates when connected to either terminal of a static machine. |
| D&R, E-185 | pinwheel - ionic drive | 5B30.50 | A pinwheel connected to an electrostatic generator shows the principle of an ionic drive. |
| Disc 17-12 | pinwheel | 5B30.50 | Place a pinwheel on a Van de Graaff generator. |
| F&A, Eb-11 | electrostatic solar system | 5B30.51 | A double pinwheel rotates when connected to a Wimshurst. |
| PIRA 500 | Cottrell precipitator | 5B30.60 | |
| UMN, 5B30.60 | Cottrell precipitator | 5B30.60 | |
| F&A, Eb-12 | electrostatic precipitator | 5B30.60 | Clear smoke in a chimney with points that are connected to a Wimshurst. |
| Mei, 30-4.5 | Cottrell precipitator | 5B30.60 | Clear a smoke filled tube by a discharge from wire points. |
| Sut, A-5 | smoke precipitation | 5B30.60 | Demonstrate smoke particles precipitating in a strong electric field in an artificial chimney. |
| D&R, E-190 | smoke precipitator | 5B30.60 | A large plastic soft drink bottle filled with smoke.  Precipitation occurs when the electrodes are connected to an electrostatic generator. |
| Disc 17-16 | smoke precipitation | 5B30.60 | Attach a Wimshurst to terminals at each end of a glass tube filled with smoke. |

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| Sut, E-53 | energy in the discharge | 5B30.90 | Light some alcohol or a Bunsen burner with the spark from a static machine. |
| Sut, E-55 | gas explosion by spark | 5B30.91 | A spark plug hooked to a static machine is used to explode a mixture of hydrogen and oxygen in a closed container. |
| Sprott, 2.23 | gas explosion by spark | 5B30.91 | A small amount of ethanol placed in a plastic bottle with nails in the sidewall is made to explode and blow a cork a considerable distance. A Tesla coil provides the spark. |
| Sut, E-48 | the human discharge chain | 5B30.95 | All students hold hands with one student holding one knob of a static machine and the other holding a metal rod near the other knob. |
| AJP, 65(6), 553-555 | the human discharge chain | 5B30.95 | A discussion of the "kids holding hands and discharging a Van de Graaff generator" demonstration. Taken from the point of view of each person being an element in a R/C circuit. |
| Sut, E-47 | discharge through body | 5B30.96 | A student standing on the floor touches other students standing on insulated stands holding on to the two knobs of a static machine. |
| | **CAPACITANCE** | **5C00.00** | |
| | **Capacitors** | **5C10.00** | |
| PIRA 500 | sample capacitors | 5C10.10 | |
| UMN, 5C10.10 | sample capacitors | 5C10.10 | Show many capacitor examples. |
| Hil, E-4a | capacitors | 5C10.10 | Several types of capacitors are shown. |
| Bil&Mai, p 249 | simple capacitor - Leyden jars | 5C10.10 | Charge a Leyden jar with a PVC rod. Use an electroscope to show that charge is stored, and can be added to the Leyden jar. |
| Bil&Mai, p 260 | sample capacitors | 5C10.10 | Gather several types of capacitors. Dissect one capacitor and pull out the rolled capacitor plates and carefully unroll to show the capacitor is composed of 4 layers. |
| Bil&Mai, p 254 | capacitor model | 5C10.12 | A model capacitor is constructed using plastic cups, a balloon, and Tygon tubing. |
| Sut, E-62 | simple spherical capacitor | 5C10.15 | Charge a 8" sphere several times with an electrophorus, then repeat with a insulated conductor near, then repeat with a grounded conductor near. The number of sparks required to reach a potential varies. |
| PIRA 200 | parallel plate capacitor | 5C10.20 | Change the spacing of a charged parallel plate capacitor while it is attached to an electroscope. |
| UMN, 5C10.20 | parallel plate capacitor | 5C10.20 | Change the spacing of a charged parallel plate capacitor while attached to an electroscope. |
| F&A, Ed-1 | field and voltage | 5C10.20 | Vary the spacing of a charged parallel plate capacitor while the voltage is measured with an electroscope. |
| Sut, E-69 | parallel plate capacitor | 5C10.20 | Charge a simple capacitor of two parallel movable plates and the divergence of electroscope leaves varies as the plates are moved. |
| Hil, E-4d | capacitance and voltage | 5C10.20 | Separate charged plates while an electroscope is attached. |
| AJP 70(5), 502 | parallel plate capacitor | 5C10.20 | Determination of the electric field ouside a parallel plate capacitor and comparison to the magnetic field outside a long solenoid. |
| Bil&Mai, p 258 | parallel plate capacitor | 5C10.20 | A parallel plate capacitor is constructed from wooden dowels and pie plates. Use a homemade capacitance meter to explore the capacitance / distance relationship. |
| Disc 18-19 | parallel plate capacitor | 5C10.20 | Charge parallel plates with a rod, watch the electroscope as the distance between the plates is changed. Animation sequence. |
| PIRA 1000 | battery and separable capacitor | 5C10.21 | |
| Disc 18-22 | battery and separable capacitor | 5C10.21 | Charge a parallel plate capacitor to 300 V, then move the plates apart until an electroscope deflects. |
| PIRA 1000 | dependence of capacitance on area | 5C10.30 | |
| Sut, E-73 | dependence of capacitance on area | 5C10.30 | As a chain is lifted out of a hollow charged conductor on an electroscope, the deflection decreases. When let back down, it increases again. |
| Sut, E-74 | dependence of area on capacitance | 5C10.31 | A long rectangular sheet of charged tin foil is rolled up while attached to an electroscope. |
| Sut, E-75 | dependence of capacitance on area | 5C10.32 | Hook up a charged radio tuning condenser to an electroscope. |
| Mei, 29-4.5 | Chinese lantern capacitor | 5C10.33 | Vary the length of an aluminum painted Chinese lantern to show the change of capacitance. |
| PIRA 1000 | rotary capacitor | 5C10.35 | |
| Disc 18-21 | rotary capacitor | 5C10.35 | Charge a large rotary capacitor with a rod and watch an electroscope as the overlap is changed. |
| AJP 28(7),675 | C=i/(dv/dt) demonstrator | 5C10.40 | Vary a potentiometer so that a constant current is maintained while charging a capacitor from a 90 volt battery. Measure the time. |
| Mei, 29-1.30 | inducing current with a capacitor | 5C10.50 | A charged ball moving between the plates of a parallel plate capacitor will induce a current in the external circuit. |

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| | **Dielectric** | **5C20.00** | |
| PIRA 200 | capacitor with dielectrics | 5C20.10 | Insert and remove a dielectric from a charged parallel plate capacitor while it is attached to an electroscope. |
| UMN, 5C20.10 | capacitor with dielectrics | 5C20.10 | Insert and remove a dielectric from a charged parallel plate capacitor while attached to an electroscope. |
| F&A, Ed-2 | dielectrics | 5C20.10 | The voltage is measured with an electroscope as dielectrics are inserted between parallel plates of a charged capacitor. |
| Sut, E-70 | capacitor with dielectrics | 5C20.10 | Various dielectrics are inserted between two charged metal plates to show the difference in deflection on an electroscope. |
| Disc 18-20 | parallel plate capacitor dielectrics | 5C20.10 | Charge a parallel plate capacitor with a rod, insert dielectrics and observe the electroscope. Animation. |
| Mei, 29-4.1 | capacitor with dielectrics | 5C20.11 | Six demonstrations with a parallel plate capacitor and dielectrics. |
| AJP 73 (1), 52 | capacitor with dielectrics | 5C20.11 | Using a parallel plate capacitor to determine the dielectric constant of different materials. |
| Hil, E-4b | equation Q=CV | 5C20.12 | The bottom of a parallel plate capacitor is mounted on an electroscope, charge the top plate, touch the bottom, lift off the top. |
| Hil, E-4c | C-V relationships | 5C20.13 | An automated device to charge a capacitor and separate the plates. Reference: AJP 22(3),146. |
| Sut, E-40 | intervening medium | 5C20.14 | Bring a charged rod close to an electroscope and interpose various materials between the two. |
| PIRA 1000 | helium dielectric | 5C20.17 | |
| UMN, 5C20.17 | helium dielectric | 5C20.17 | Helium is blown into a charged parallel plate capacitor. |
| PIRA 1000 | force on a dielectric | 5C20.20 | |
| Disc 18-24 | force on a dielectric | 5C20.20 | A counterbalanced acrylic dielectric is pulled down between parallel plates when they are charged with a small Wimshurst generator. |
| AJP 59(8),763 | force on a dielectric - glass plate | 5C20.21 | A microscope slide is pulled into the gap between parallel plates of a capacitor. |
| Mei, 29-4.14 | force on a dielectric | 5C20.22 | A elongated paraffin ellipsoid in a parallel plate capacitor turns when the field is turned on, kerosene climbs between parallel plates. |
| PIRA 1000 | attraction of charged plates | 5C20.25 | |
| Mei, 29-4.12 | attraction of charged plates | 5C20.25 | A brass plate fitted with an insulating handle can lift a lithographic stone plate when 300 V dc is applied. |
| Mei, 29-4.13 | attraction of charged plates | 5C20.26 | The top plate of a parallel plate capacitor is mounted on a triple beam balance so the force can be measured with and without dielectrics as the voltage is varied. Pictures, Construction details in appendix, p.1322. |
| AJP 43(10),924 | attraction of charged plates | 5C20.27 | The permittivity of free space is measured using a Mettler balance to determine the force between the plates of a parallel plate capacitor. |
| PIRA 200 - Old | dissectible condenser | 5C20.30 | A capacitor is charged, disassembled, passed around, assembled, and discharged with a spark. |
| UMN, 5C20.30 | dissectible condenser | 5C20.30 | Same as Ed-3. |
| F&A, Ed-3 | dissectible condenser | 5C20.30 | A capacitor is charged, disassembled, passed around, assembled, and discharged with a spark. |
| Sut, E-64 | dissectible condenser | 5C20.30 | The inner and outer conductors of a charged Leyden jar are removed and brought into contact, then reassembled and discharged in the usual manner. |
| Disc 18-25 | dissectible capacitor | 5C20.30 | Charge a capacitor and show the discharge, then charge again and take it apart. Handle it, try to discharge it, reassemble it, and discharge it. |
| PIRA 1000 | bound charge | 5C20.35 | |
| UMN, 5C20.35 | bound charge | 5C20.35 | |
| Sut, E-65 | bound charge | 5C20.35 | The two coatings of a Leyden jar can be grounded successively without much loss of charge. When the two coatings are connected, there is a discharge. |
| Mei, 29-4.8 | impedance of a dielectric | 5C20.40 | Place a small parallel plate capacitor in series with a phonograph pickup. Insert different dielectrics. High dielectrics have low impedance. |
| F&A, Ed-4 | breath figures | 5C20.50 | Blow on a glass plate that has been polarized with the image of a coin. |
| Sut, E-66 | Lichtenberg figures | 5C20.51 | A pattern is traced on a dielectric from the two polarities of a charged Leyden jar. Litharge and flowers of sulfur sprinkled on adhere to the areas traced out with the different polarities. |
| PIRA 1000 | displacement current | 5C20.60 | |
| AJP 42(3),246 | displacement current | 5C20.60 | A toroidal coil is either placed around a wire leading to a large pair of capacitor plates to demonstrate Ampere's law or inserted between the capacitor plates to demonstrate displacement current. |
| AJP 32(12),916 | displacement current | 5C20.61 | Measure the displacement current in a barium titanate capacitor. |
| AJP 33(6),512 | displacement current comment | 5C20.61 | The experiment in AJP 32,916,(1964) has nothing to do with displacement current in Maxwell's sense. |

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| AJP 33(6),512 | displacement current comment comment | 5C20.61 | More semantics. |
| Mei, 33-4.1 | displacement current | 5C20.61 | Measure the displacement current in a barium titanate capacitor. Diagrams, Derivation. |
| | **Energy Stored in a Capacitor** | **5C30.00** | |
| PIRA 1000 | Leyden jar and Wimshurst | 5C30.10 | |
| F&A, Eb-8 | Leyden jar | 5C30.10 | Sparks from a Wimshurst are no longer but are much more intense when a Leyden jar is connected. |
| D&R, E-210 | Leyden jar | 5C30.10 | Sparks from an electrostatic generator are intensified when a Leyden jar or aluminum plates are connected in parallel with spark gap. |
| Disc 18-18 | Leyden jars on Toepler-Holtz | 5C30.10 | The Toepler-Holtz produces weak sparks without the Leyden jars and strong less frequent sparks with the jars connected. |
| Disc 18-26 | grounded Leyden jar | 5C30.15 | Charge a capacitor with a Wimshurst, ground each side separately, spark to show the charge is still there. |
| PIRA 1000 | exploding capacitor | 5C30.20 | |
| PIRA 200 | short a capacitor | 5C30.20 | Charge a large electrolytic (5000 mfd) capacitor to 120 V and short with a screwdriver. |
| UMN, 5C30.20 | short a capacitor | 5C30.20 | A 5600 microF capacitor is charged to 120 V and shorted. |
| Disc 18-23 | exploding capacitor | 5C30.20 | Four 1000 microF capacitors are charged to 400 V storing about 320 Joules. Short them with a metal bar. |
| AJP 37(5),566 | capacitor and calorimeter | 5C30.25 | Discharge a capacitor into a resistor in an aluminum block with an embedded thermistor to measure the temperature increase. |
| ref. | light the bulb | 5C30.30 | see 5F30.10 |
| PIRA 200 | light a bulb with a capacitor | 5C30.30 | Charge a large electroylitic capacitor and connect it to a lamp. |
| UMN, 5C30.30 | light the bulb | 5C30.30 | A 5600 microF capacitor is charged to 120 V and discharged through a light bulb. |
| PIRA 1000 | lifting weight with a capacitor | 5C30.35 | |
| F&A, Ed-8 | energy stored in a capacitor | 5C30.35 | A capacitor is discharged through a small motor lifting a weight. |
| AJP 72(5), 662 | energy stored in a capacitor | 5C30.35 | Further study and results for the two-capacitor problem. |
| AJP 68(7), 670 | energy stored in a capacitor | 5C30.35 | A discussion of the puzzle of the missing energy in a capacitor that is charged from a power supply, battery, or another capacitor, with neither resistance or inductance in the circuit. |
| AJP 70(4), 415 | energy stored in a capacitor | 5C30.35 | The puzzle of the missing energy in a capacitor that is charged from another capacitor. In a zero-resistance circuit it can be shown that radiation accounts for the energy loss. |
| Mei, 29-4.10 | lifting a weight with a capacitor | 5C30.35 | A DC motor, powered by a charged capacitor, lifts a weight. |
| Bil&Mai, p 263 | lift a weight with a capacitor | 5C30.35 | A Genecon generator, powered by a charged capacitor, lifts a 100 g mass. |
| Mei, 29-4.11 | discharge a capacitor thru wattmeter | 5C30.36 | A high impedance low rpm dc motor (wattmeter) is used to discharge a capacitor. |
| F&A, Ed-7 | charge on a capacitor | 5C30.37 | A capacitor is discharged through a ballistic galvanometer. |
| Sut, E-262 | capacitors and ballistic galvanometer | 5C30.37 | Charge different capacitors to different voltages and discharge through a ballistic galvanometer. |
| PIRA 1000 | series/parallel Leyden jars | 5C30.40 | |
| Sut, E-67 | addition of potentials | 5C30.40 | Charge Leyden jars in parallel and discharge, charge in parallel again and connect in series before discharging. Compare length and intensity of the sparks. |
| Sut, E-68 | series and parallel condensers | 5C30.41 | Charge four Leyden jars in parallel and discharge singly and with three together. Next charge three in series with one in parallel and discharge singly and three in series. Compare length and intensity of sparks. |
| PIRA 1000 | series/parallel capacitors | 5C30.42 | |
| Disc 18-27 | series/parallel capacitors | 5C30.42 | Charge a single capacitor, two series capacitors, and two parallel capacitors to the same potential and discharge through a ballistic galvanometer. |
| PIRA 1000 | Marx and Cockroft-Walton | 5C30.50 | |
| AJP 56(9),822 | Marx and Cockroft-Walton circuits | 5C30.50 | Intentionally low voltage models of the Marx generator and the Cockroft-Walton circuit allow the waveforms to be shown as a demonstration without high voltage probes or danger. |
| F&A, Ep-1 | Marx generator | 5C30.50 | Switching capacitors from parallel to series to generate high voltages. |
| Mei, 29-4.4 | Arkad'ev capacitor-bank transformer | 5C30.50 | Switching of charged capacitors from parallel to series. |
| PIRA 1000 | residual charge | 5C30.60 | |
| Sut, E-63 | residual charge | 5C30.60 | Charge and discharge a Leyden jar, Wait a few seconds and discharge it again. |
| Mei, 29-4.6 | residual charge | 5C30.61 | After discharging a Leyden jar, light a neon tube up to 100 times. Also - show the polarity of charge on the dielectric with a triode. |

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| | **RESISTANCE** | **5D00.00** | |
| | **Resistance Characteristics** | **5D10.00** | |
| PIRA 500 | resistor assortment | 5D10.10 | |
| UMN, 5D10.10 | resistor assortment | 5D10.10 | |
| Mei, 30-1.1 | scaled up resistor box | 5D10.11 | Rebuild an old resistance box with larger numbers. |
| TPT 33(6), 340 | tapered resistors | 5D10.15 | Resistors whose resistance per unit length varies along the resistor. Commonly found on batteries as the "test strip" for checking the battery's voltage and in some computer applications. |
| TPT 37(7), 400 | tapered resistors | 5D10.15 | Tapered resistors made with a # 1 pencil. |
| TPT 28(8), 570 | tapered resistors | 5D10.15 | More about the liquid crystal tester that comes on batteries or with battery packs. |
| TPT 34(5), 276 | tapered resistors | 5D10.15 | Temperature profile of the Duracell test strip. |
| TPT 34(1), 16 | tapered resistors | 5D10.15 | Does a test strip measure voltage or current? |
| PIRA 500 | characteristic resistances | 5D10.20 | |
| UMN, 5D10.20 | characteristic resistances | 5D10.20 | Connect one meter lengths of various wires in series and measure the voltage across each. |
| F&A, Eg-3 | characteristic resistance | 5D10.20 | Measure voltages on a commercial board with seven one meter lengths of various wires in series so all carry the same current. |
| Disc 17-18 | resistance wires | 5D10.20 | Place 6V across a set of wires of different lengths and/or diameters and measure the currents. |
| Sut, A-9 | resistance characteristic of arc | 5D10.22 | Measure the current and potential across a small arc as the series resistance is varied. |
| PIRA 200 | resistance model | 5D10.40 | |
| PIRA 500 - Old | resistance model | 5D10.40 | |
| UMN, 5D10.40 | resistance model | 5D10.40 | Balls are rolled down an incline with pegs. |
| F&A, Eg-1 | model of resistance | 5D10.40 | A ball is rolled down a board with randomly spaced nails. |
| Mei, 40-1.1 | charge motion demonstrator | 5D10.40 | Small balls are rolled down a board with nails scattered in an almost random pattern. Diagram. |
| D&R, E-300 | resistance model | 5D10.40 | Ball bearings are rolled down an inclined bed of nail to simulate current flow in a wire. |
| Bil&Mai, p 270 | resistance model | 5D10.40 | Two soda bottles are connected together one inside the other to model EMF and resistance. |
| Disc 17-22 | electron motion model | 5D10.40 | Ball bearings are simultaneously rolled down two ramps, one with pegs and one without. |
| PIRA 1000 | current model with Wimshurst | 5D10.50 | |
| Bil&Mai, p 268 | burn a resistor | 5D10.60 | Voltage is increase slowly through a resistor until it bursts into flames to illustrate the relationship between voltage, current, and resistance in simple DC circuits. |
| | **Resistivity and Temperature** | **5D20.00** | |
| PIRA 200 | wire coil in liquid nitrogen | 5D20.10 | A lamp glows brighter when a series resistance coil is immersed in liquid nitrogen. |
| Sut, H-103 | resistance at low temperature | 5D20.10 | A lamp glows brighter when a series resistance coil is immersed in liquid air. |
| Disc 17-21 | cooled wire | 5D20.10 | A copper coil in series with a battery and lamp is immersed in liquid nitrogen. |
| Sut, H-104 | resistance at low temperature | 5D20.11 | A "C" battery, 3 V flashlight bulb, and a copper wire coil make a hand held temp coefficient of resistivity apparatus. |
| AJP 49(1),88 | audible temperature dependent resistance | 5D20.12 | The resistor plunged into liquid nitrogen is part of a voltage controlled oscillator that drives a speaker. |
| Sut, E-164 | cooling | 5D20.12 | Current is increased in a long U of iron wire until it glows, then half is inserted into a beaker of water. |
| AJP 48(11),940 | superconducting wire | 5D20.14 | Cool a coil of NbTi wire in a series circuit with a 12 volt car battery and lamp first in liquid nitrogen, then helium. The voltage across the coil is monitored and the lamp brightness is observed. |
| PIRA 1000 | flame and liquid nitrogen | 5D20.15 | |
| UMN, 5D20.15 | flame and liquid nitrogen | 5D20.15 | Resistance coils are heated and cooled with a test light bulb in series. |
| F&A, Eg-4 | temperature dependence of resistance | 5D20.15 | Two sets of bulbs in series with coils, one put in liquid nitrogen and the other in a flame. |
| D&R, E-280, H-010 | temperature dependence of resistance | 5D20.15 | A filament from a 200 W bulb with glass envelope removed is connected to a digital meter. Heat it with a heat lamp. |
| Sut, E-166 | temperature coefficent of resistance | 5D20.16 | Two coils of different material but the same resistance are placed in a Wheatstone bridge and either is heated or cooled. |
| PIRA 200 - Old | iron wire in flame | 5D20.20 | Heat a coil of iron wire in series with a battery and a lamp and the lamp will dim. |
| Mei, 30-1.4 | iron wire in a flame | 5D20.20 | A coil of forty turns of iron wire is heated in a flame while connected in series with a light bulb circuit. |

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| Sut, E-165 | putting the light out by heat | 5D20.20 | A coil of iron wire wound on a porcelain core in series with a lamp and battery is heated until the lamp goes out. |
| Disc 17-20 | heated wire | 5D20.20 | Heat a coil of iron wire in series with a battery and a lamp. |
| Sut, E-163 | flame | 5D20.21 | A coil of nickel wire connected to a battery and galvanometer is heated in a flame. |
| PIRA 500 | carbon and tungsten light bulbs | 5D20.30 | |
| F&A, Eg-5 | positive and negative resistance coefficients | 5D20.30 | Measure current and resistance at various voltages for a carbon and tungsten bulb. |
| Disc 18-09 | carbon and tungsten lamps | 5D20.30 | Plot current vs. voltage for carbon and tungsten lamps. |
| UMN, 5D20.31 | resistance of light bulbs | 5D20.31 | The V/I curves for tungsten and carbon filament lamps are shown on a dual trace storage oscilloscope. |
| D&R, E-450, E-470 | resistance of light bulbs | 5D20.31 | The V/I curves for a variety of bulbs are plotted to show resistance is inversely proportional to power. |
| AJP 53(6),546 | temperature of incandescent lamps | 5D20.32 | Two silicon solar cells with interference filters measure the light at different wavelengths for use in determining the temperature of the filament. |
| Sut, E-169 | resistance thermometer | 5D20.40 | Attach No. 14 copper leads to a platinum coil and use with a Wheatstone bridge. |
| PIRA 1000 | thermistors | 5D20.50 | |
| Mei, 40-1.4 | thermistors | 5D20.50 | Use a good kit of commercial thermistors and display the differential negative resistance of a fast thermistor on a transistor curve tracer. |
| Disc 16-17 | thermistor | 5D20.50 | Show the resistance of a thermistor placed in an ice water bath. |
| PIRA 200 | conduction in glass at high temperature | 5D20.60 | |
| PIRA 500 - Old | conduction in glass at high temperature | 5D20.60 | |
| UMN, 5D20.60 | conduction in glass | 5D20.60 | |
| AJP 58(1),90 | conduction in glass at high temperature | 5D20.60 | A simple version of glass conduction using binder clips and window glass. |
| Mei, 30-1.3 | conduction in glass at high temperature | 5D20.60 | Heat a capillary tube in a Bunsen burner until it is hot enough to sustain a current that maintains a bright glow. |
| Sut, E-168 | conduction in glass | 5D20.60 | Heat a glass tube with a flame until it is hot enough to sustain conduction. Vary the current by changing the ballast resistance. |
| Sut, E-167 | negative temperature coefficient of resistance | 5D20.61 | A Nerst glower must be heated with a flame until the resistance is low enough to sustain electrical heating. |
| | **Conduction in Solutions** | **5D30.00** | |
| PIRA 500 | conduction through electrolytes | 5D30.10 | |
| F&A, Ef-1 | conductivity of solutions | 5D30.10 | Dip two metal electrodes in series with a light bulb in various solutions. |
| Sut, E-193 | conduction through electrolytes | 5D30.10 | Immerse two copper plates in series with a lamp in distilled water, add barium hydroxide, then sulfuric acid. |
| Sut, E-192 | conduction through electrolytes | 5D30.10 | Put two copper plates in series with a lamp in distilled water and salt or acid is added. |
| D&R, E-260 | conductivity of solutions | 5D30.10 | A pigtail socket connected to an AC line cord testing the conductivity of salt water, sugar water, tap water, and distilled water. |
| Disc 18-13 | conductivity of solutions | 5D30.10 | Two electrodes in series with a 110 V lamp are dipped into distilled water, salt water, a sugar solution, a vinegar solution, and tap water. |
| PIRA 1000 | salt water string | 5D30.13 | |
| AJP 32(9),713 | electrolytic conduction on chamios | 5D30.15 | Suspend a chamois between ringstands, show no conduction with a battery, resistor, meter. Soak in distilled water, repeat, then sprinkle on salt |
| PIRA 1000 | migration of ions | 5D30.20 | |
| F&A, Ef-3 | speed of ions | 5D30.20 | Show KMnO4 migrating with current towards the positive electrode in KNO3. |
| Mei, 30-3.2 | migration of ions | 5D30.20 | Permanganate ions migrate in an electric field. |
| Sut, E-206 | ionic speed | 5D30.21 | Dip two platinum electrodes into an ammoniated copper sulfate solution containing some phenophthalein. |
| Sut, E-207 | ionic speed | 5D30.22 | Blue moves from the anode of in a potassium chloride gel when 120 volts is applied. |
| Sut, E-208 | ionic speed | 5D30.23 | Measuring the speed of hydrogen and hydroxyl ions in a potassium chloride gel. |
| PIRA 1000 | pickle glow | 5D30.30 | |
| Disc 18-15 | pickle frying | 5D30.30 | Apply high voltage across a pickle and it lights at one end. |
| | **Conduction in Gases** | **5D40.00** | |
| PIRA 200 | Jacob's ladder | 5D40.10 | A arc rises between rabbit ear electrodes attached to a high voltage transformer. |

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| UMN, 5D40.10 | Jacob's ladder | 5D40.10 | A arc rises between rabbit ear electrodes attached to a high voltage transformer. |
| F&A, Em-3 | Jacob's ladder | 5D40.10 | A spark forms across "rabbit ears" on a 15 KV transformer. |
| Sut, A-7 | Jacob's ladder | 5D40.10 | Jacob's ladder and other spark demonstrations. Diagram. |
| Hil, E-11b | climbing spark | 5D40.10 | A 15 KV transformer is hooked to rabbit ears. |
| Sprott, 4.5 | Jacob's ladder | 5D40.10 | A rising electrical discharge occurs with a high voltage AC power supply connected to a pair of conducting bars close together at the bottom and farther apart at the top. |
| Disc 25-08 | Jacob's ladder | 5D40.10 | Apply high voltage AC to rabbit ears. |
| PIRA 1000 | conduction of gaseous ions | 5D40.20 | |
| Sut, E-50 | conduction of gaseous ions | 5D40.20 | A nearby flame will discharge an electroscope. |
| D&R, S-130 | conduction of gaseous ions from a flame | 5D40.20 | A nearby flame will discharge an electroscope. |
| F&A, Eb-4 | discharge with flame | 5D40.21 | A flame connected to a high voltage source is inserted between charged parallel plates. |
| Mei, 30-4.6 | blowing ions by a charged plate | 5D40.25 | Compressed air blows ions from a flame through the area between charged parallel plates onto a mesh hooked to an electrometer. |
| Mei, 30-4.7 | discharge by ions in a tube | 5D40.25 | Electrodes at the bottom, middle, and top of a tube are connected to an electrometer while a Bunsen flame is burned at the bottom. |
| Sut, A-4 | recombination of ions | 5D40.27 | Ions from a flame are drawn past a series of charged plates attached to a Zeleny electroscope. |
| Sut, E-51 | separating ions from flame | 5D40.28 | Shadow project a flame between two charged metal plates to observe separation of gas into two streams of oppositely charged ions. |
| PIRA 1000 | ionization by radioactivity | 5D40.30 | |
| Sut, A-112 | ionization by radioactivity | 5D40.30 | Discharge an electroscope with a radioactive source. |
| D&R, S-130 | ionization by radioactivity | 5D40.30 | Discharge an electroscope with a weak radioactive source. |
| Sut, A-1 | ionization in air | 5D40.32 | Various sources of ionization are brought near parallel wires attached to a 100 V battery and a Zeleny electroscope. |
| Sut, A-2 | saturation | 5D40.33 | The voltage across a plate close to a wire mesh is increased with a radioactive source nearby and the current is observed with a Zeleny electroscope. |
| Sut, A-3 | ion mobilities | 5D40.34 | A second mesh is inserted into the apparatus of A-2 and an alternating potential increased until the electroscope oscillates. |
| Mei, 30-4.3 | conduction in air by ions | 5D40.35 | An electrometer measures the current between parallel plates as a flame is burned between them or an alpha source is held nearby. |
| Mei, 30-4.8 | Cerberus smoke detector | 5D40.36 | Combustion products decrease conductivity in a chamber with an alpha source. |
| PIRA 1000 | conduction from a hot wire | 5D40.40 | |
| Mei, 30-4.4 | conduction from hot wire | 5D40.40 | A constantan wire held near a charged electroscope causes discharge when it is heated red hot. |
| ref. | thermionic effect | 5D40.41 | see 5M20.15 |
| Sut, A-77 | thermionic effect in air | 5D40.41 | A Zeleny electroscope indicates electron emission from a wire when it is heated. |
| PIRA 1000 | thermionic emisson | 5D40.42 | |
| Disc 25-03 | thermionic emission | 5D40.42 | A commercial tube. Apply 90 V forward and reverse and monitor the current. |
| PIRA 1000 | neon bulb | 5D40.50 | |
| Disc 18-08 | neon bulb resistivity | 5D40.50 | A neon lamp lights at about 80 V and shuts off at about 60 V. |
| PIRA 1000 | x-ray ionization | 5D40.80 | |
| Sut, A-103 | ionization by X-rays | 5D40.80 | Discharge an electroscope with X-rays. |
| Disc 24-20 | X-ray ionization | 5D40.80 | Discharge an electroscope with X-rays. |
| Sut, A-104 | ionization by X-rays | 5D40.81 | An X-ray beam is passed through a simple ionization chamber. |
| AJP 49(7),695 | electrohydrodynamics | 5D40.99 | read this again - practical examples are ink jet printing and electrically driven convection. |
| | **ELECTROMOTIVE FORCE & CURRENT** | **5E00.00** | |
| | **Electrolysis** | **5E20.00** | |
| PIRA 500 | electrolysis of water | 5E20.10 | |
| F&A, Ef-2 | electrolysis of water | 5E20.10 | DC passed through slightly acidic water evolves hydrogen and oxygen at the electrodes. |
| F&A, Ef-6 | gas coulombmeter | 5E20.10 | The volume of gas from electrolysis is measured. |
| Sut, E-202 | electrolysis of water | 5E20.10 | The Hoffman apparatus for electrolysis of water. |
| Disc 18-16 | electrolysis | 5E20.10 | The standard commercial electrolysis apparatus. |
| AJP 31(2),139 | electrolysis of water modification | 5E20.11 | Place Tygon tubing over the wire coming out the bottom to protect it from the acid. |
| Sut, E-201 | electrolysis of water | 5E20.12 | A projection electrolytic cell for showing the evolution of gas. |

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| Sut, E-203 | explosion of hydrogen and oxygen | 5E20.15 | Make soap bubbles with the gases from electrolysis of water and blow them to droplets. |
| Mei, 30-3.3 | phenolphthalein electrolysis indicator | 5E20.21 | Phenophthalein is used as an indicator in electrolysis demonstrations. |
| Mei, 30-3.4 | purple cabbage electrolysis indicator | 5E20.22 | Use purple cabbage as an indicator for electrolysis demonstrations. |
| Sut, E-209 | electrolysis of sodium sulfate | 5E20.22 | Use purple cabbage as an indicator to show electrolysis of sodium sulfate. |
| Sut, E-211 | electrolysis of Na ions through glass | 5E20.25 | Sodium is plated on the inside of a lamp inserted into molten sodium nitrate. |
| AJP 29(5),xi | mass transfer in electrolysis | 5E20.28 | Measure the current while transferring mass by plating copper to obtain a semi quantitative determination of the Faraday. |
| Sut, E-213 | mass of Na atom by electrolysis | 5E20.29 | A method of determining the mass of a sodium atom by electrolysis. |
| Sut, E-214 | electrolytic rectifier | 5E20.30 | Electrodes of aluminum and lead in a saturated solution of sodium bicarbonate form a rectifier. |
| Mei, 30-3.6 | oxidation of ferrous to ferric iron | 5E20.40 | Put ferrous iron in hot water with nitric acid and heat. |
| Sut, E-210 | electric forge | 5E20.60 | Melt an iron rod cathode in a strong sodium sulfite solution. |
| | **Plating** | **5E30.00** | |
| PIRA 1000 | copper flashing of iron | 5E30.10 | |
| F&A, Ee-1 | copper flashing of iron | 5E30.10 | Polished iron is plated in a copper sulfate solution. |
| PIRA 500 | electroplating copper | 5E30.20 | |
| F&A, Ef-4 | electroplating copper | 5E30.20 | Copper and carbon electrodes in a copper sulfate bath. |
| Disc 18-17 | electroplating | 5E30.20 | Copper is plated onto a carbon electrode in a copper sulfate bath. |
| Sut, E-195 | electroplating - lead tree | 5E30.24 | Current is passed between lead electrodes in a saturated solution of lead acetate causing fern like clusters to form on the cathode. |
| Sut, E-196 | electroplating - tin tree | 5E30.26 | Current is passed between electrodes of copper and tin in a acid solution of stannic chloride. With copper as the cathode, tin crystallizes as long needles. |
| Sut, E-197 | electroplating | 5E30.28 | Plate with copper or silver by connecting the object to the negative terminal and using copper sulfate or silver nitrate solution. |
| PIRA 1000 | silver coulomb meter | 5E30.40 | |
| F&A, Ef-5 | silver coulombmeter | 5E30.40 | Silver is plated in a silver nitrate bath onto a platinum cup. |
| Mei, 30-3.1 | silver coulombmeter | 5E30.40 | A silver coulombmeter shows a 1 g change in anode weight when 1 amp is passed for 1000 sec. |
| | **Cells and Batteries** | **5E40.00** | |
| AJP 48(5),405 | Volta's EMF concept | 5E40.01 | The distinction between EMF and electrostatic potential difference is discussed. |
| AJP 44(5),464 | contact potentials: history, etc | 5E40.05 | The history, concepts, and persistent misconceptions on the contact potentials between metals. |
| Bil&Mai, p 271 | battery potential model | 5E40.07 | Two soda bottles connected by aquarium tubing are used to model the high-potential and low-potential terminals of a battery. |
| PIRA 500 | EMF dependence on electrode material | 5E40.10 | |
| UMN, 5E40.10 | EMF dependence on electrode material | 5E40.10 | |
| F&A, Ee-2 | dependence of EMF on electrode material | 5E40.10 | Two stands each hold several strips of different metals which can be paired and dipped into a dilute acid bath. |
| AJP 76 (3), 218 | battery effect - battery discharge model | 5E40.10 | A simple model that yields behavior similar to what is observed by a single discharging voltaic cell. |
| Disc 18-14 | battery effect | 5E40.10 | Combinations of copper, lead, zinc, and iron are dipped into a dilute sulfuric acid solution. |
| Sut, E-72 | contact potential difference | 5E40.15 | The contact potential difference between copper and zinc can be demonstrated using a condensing electroscope. |
| PIRA 1000 | voltaic cell | 5E40.20 | |
| Sut, E-198 | voltaic cell | 5E40.20 | A voltaic cell is made with copper and zinc electrodes in a sulfuric acid solution. |
| D&R, E-360 | human battery | 5E40.20 | A copper sheet electrode and an aluminum sheet electrode are connected to a voltmeter. Place a hand on each electrode and observe the voltage ( you are the electrolyte). |
| Sut, E-119 | voltaic cells | 5E40.20 | Short a few voltaic cells in series through a loop of iron or nichrome wire. |
| AJP 77 (10), 889 | voltaic cell - voltaic pile | 5E40.20 | Picture and description of a 19th century voltaic pile that has survived intact. |
| Sut, E-199 | cardboard model voltaic cell circuit | 5E40.21 | A cardboard model illustrates potential difference and electromotive force in a voltaic cell circuit. |
| PIRA 200 | lemon battery/voltaic cell | 5E40.25 | |
| PIRA 500 - Old | lemon battery/voltaic cell | 5E40.25 | |

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| UMN, 5E40.25 | lemon battery/voltaic cell | 5E40.25 | Stick copper and galvanized steel electrodes into a lemon and attach a voltmeter. |
| TPT 28(5),329 | lemon screamer,lasagna cell | 5E40.25 | A little tutorial on electrochemistry for those using the lemon screamer and other interesting cells. |
| Mei, 30-3.5 | lemon battery | 5E40.25 | Zinc and copper strips are hooked to a galvanometer and stuck into fruits and vegetables. |
| D&R, E-320, E-360 | lemon battery | 5E40.25 | Copper and galvanized iron electrodes in a lemon are connected to a digital meter. |
| Sut, E-200 | voltaic cell polarization | 5E40.26 | Heat the copper cathode in a Bunsen burner flame to oxidize the surface. |
| F&A, Ee-3 | Crowsfoot or gravity cell | 5E40.40 | A zinc-zinc sulfate/copper-copper sulfate battery. |
| Sut, E-115 | adding dry cells | 5E40.50 | Charge an electroscope with a number of 45 V B batteries in series. |
| Sut, E-116 | dry cell terminals | 5E40.51 | Hook up several dry cells in series to a condensing electroscope, remove the capacitance and test polarity with charged rods. |
| PIRA 500 | lead acid simple battery | 5E40.60 | |
| UMN, 5E40.60 | lead acid simple battery | 5E40.60 | A simple lead acid battery with two electrodes is charged for a short time and discharged through a bell. |
| F&A, Ee-4 | storage battery | 5E40.60 | Two lead plates in a sulfuric acid solution are charged and then discharged through a doorbell. |
| Sut, E-204 | storage cells | 5E40.60 | The elementary lead storage cell is charged and discharged on the lecture table. |
| Sut, E-120 | simple battery | 5E40.60 | Charge two lead plates in 30% sulfuric acid and discharge through a flashlight bulb. |
| Sut, E-205 | storage cells | 5E40.61 | Melt nails with a storage battery. |
| AJP 30(6),470 | lead-salt cell | 5E40.62 | Instead of acid, use a saturated salt solution of sodium bicarbonate and magnesium sulfate. |
| TPT 46(9),544 | aluminum-air battery | 5E40.62 | How to make a battery using aluminum and copper electrodes with salt water as the electrolyte. |
| PIRA 500 | internal resistance of batteries | 5E40.70 | |
| UMN, 5E40.70 | internal resistance of batteries | 5E40.70 | |
| PIRA 1000 | weak and good battery | 5E40.75 | |
| Disc 18-03 | internal resistance of batteries | 5E40.75 | Measure similar no load voltage on identical looking batteries and then apply a load to each and show the difference in voltage between a good and weak battery. |
| | **Thermoelectricity** | **5E50.00** | |
| PIRA 200 | thermocouple | 5E50.10 | Two iron-copper junctions, one in ice and the other in a flame, are connected to a galvanometer. |
| UMN, 5E50.10 | thermocouple | 5E50.10 | Attach a voltmeter to the iron wires of two copper-iron junctions while they are differentially heated. |
| F&A, Et-1 | thermocouple | 5E50.10 | Two iron-copper junctions, one in ice and the other in a flame, are connected to a galvanometer. |
| D&R, H-014 | thermocouple | 5E50.10 | Heat a junction of two dissimilar metal that are connected to a digital voltmeter. A collection of such junctions will make a thermopile. |
| Disc 16-20 | thermocouple | 5E50.10 | Place a twisted wire thermocouple in a flame and observe the current on a lecture table galvanometer. |
| Hil, H-1a | thermocouples | 5E50.11 | Heating two metals causes a deflection on a galvanometer. |
| AJP 29(4),273 | thermoelectric generator | 5E50.12 | Review of a commercial thermoelectric generator made from 150 constantan/nickel-molybdenum thermocouples in series. |
| Sut, E-179 | Seebeck effect | 5E50.15 | The thermoelectric effect of copper-iron junctions. |
| Sut, E-181 | Seebeck and Peltier effects | 5E50.17 | Send current through a copper-iron-copper circuit for several seconds and immediately disconnect and switch to a galvanometer. |
| Mei, 30-5.3 | copper-iron junctions ring | 5E50.18 | Sixty copper-iron junctions in series are arrayed in a ring heated simultaneously with a Bunsen burner producing 90 mA. |
| Sut, E-183 | thermoelectric compass | 5E50.19 | Bars of copper and iron are joined to form a case for a compass needle. The needle will indicate the direction of the current as one or the other junction is heated. |
| Hil, E-6a.1 | thermocouple coil magnet | 5E50.19 | Heat a thermocouple loop and the current produces a magnetic field that can be detected by a compass needle. |
| Sut, E-184 | thermoelectric effect in a wire | 5E50.20 | Show that a piece of soft iron wire connected to a galvanometer has little thermoelectric effect until the wire is kinked. |
| Sut, E-185 | Thompson effect | 5E50.25 | A flame moved along a long wire will "push ahead" current. |
| PIRA 500 | thermoelectric magnet | 5E50.30 | |
| UMN, 5E50.30 | thermoelectric magnet | 5E50.30 | Heat one side of a heavy copper loop closed by an unknown metal to generate thermoelectricity for an electromagnet. |
| F&A, Et-3 | thermoelectric magnet | 5E50.30 | A ring of copper shorted by iron forms a thermocouple that powers an electromagnet when one end is in water and the other is heated in a flame. |

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| Sut, E-182 | thermoelectric magnet | 5E50.30 | One end of a heavy copper bar bent into a loop and closed with a copper-nickel alloy is heated, the other cooled. An electromagnet made with a soft iron shell can support 200 lbs. Picture. |
| Hil, H-1b | thermocouple magnet | 5E50.30 | A Bunsen burner heats one side of a thermocouple magnet supporting over 10 Kg. |
| D&R, E-340, H-374 | thermoelectric magnet | 5E50.30 | Enough current to run an electromagnet is produced by heating one side of a thermoelectric junction. |
| Disc 16-18 | thermoelectric magnet | 5E50.30 | Heat and cool opposite sides of a large thermocouple. Suspend a large weight from an electromagnet powered by the thermocouple current. |
| F&A, Et-4 | 3M Aztec lamp | 5E50.36 | A thermocouple is built into a kerosene lamp. |
| PIRA 1000 | Peltier effect | 5E50.60 | |
| F&A, Et-2 | thermoelectric cooler | 5E50.60 | A Peltier device is used to cool a drop of water. |
| D&R, H-374 | Peltier effect | 5E50.60 | A discussion of the Peltier effect. |
| Disc 16-19 | thermoelectric heat pump | 5E50.60 | Mount aluminum blocks with digital thermometers on either side of a Peltier device. Run the current both ways. |
| Sut, E-180 | Peltier effect | 5E50.61 | Directions for making an antimony-bismuth junction and an apparatus to show heating and cooling. |
| Mei, 30-5.1 | Peltier effect | 5E50.62 | Directions for building a Peltier effect device. |
| Mei, 30-5.2 | pyroelectric crystals | 5E50.90 | Demonstrate the temperature effect on the polarization of pyroelectric crystals. Picture. |
| Mei, 30-6.6 | domains of electric polarization | 5E50.93 | Tiny BaTiO3 crystals are heated on a microscope slide until the domains disappear. |
| | **Piezoelectricity** | **5E60.00** | |
| Mei, 30-6.4 | piezoelectric model | 5E60.05 | A ball and spring model of the piezoelectric effect. |
| PIRA 500 | quartz crystal scraped | 5E60.10 | |
| Mei, 30-6.3 | Rochelle salt demos | 5E60.12 | Ferroelectricity, hysteresis, Curie-point, and the direct piezoelectric effect are demonstrated with a Rochelle salt. Diagrams, Construction and Preparation details in appendix, p.1322. |
| Sut, E-186 | piezoelectric effect - Rochelle salt | 5E60.13 | A Rochelle salt is hooked to a neon lamp or electrostatic voltmeter. |
| Mei, 30-6.8 | piezoelectric sheets | 5E60.15 | Make sheets of polycrystalline Rochelle salt that show piezoelectric effects. |
| AJP 29(7),iv | PZT sources | 5E60.16 | Two sources for ceramic lead-zirconate-titnante (PZT), 1961. |
| PIRA 500 | piezoelectric sparker | 5E60.20 | |
| Disc 16-26 | piezoelectric sparker | 5E60.20 | Attach the commercial piezoelectric sparker to a Braun electroscope. |
| AJP 45(2),218 | piezoelectric gas lighter modified | 5E60.21 | Mount a sphere on the end of a piezoelectric gas lighter. |
| PIRA 1000 | piezoelectric gun | 5E60.25 | |
| UMN, 5E60.25 | piezoelectric gun | 5E60.25 | A piezoelectric gun is used to discharge a set of charged nylon strings. |
| F&A, Ea-9 | piezoelectric pistol | 5E60.25 | One end of a piezoelectric crystal is attached to a needle point in the pistol. |
| PIRA 1000 | stress vs. voltage | 5E60.30 | |
| Mei, 30-6.1 | stress vs. voltage | 5E60.30 | Measure the voltage of a Seignette salt crystal under various stresses produced by a mass on a lever arm. |
| PIRA 1000 | piezoelectric speaker | 5E60.40 | |
| Mei, 30-6.2 | piezoelectric speaker | 5E60.40 | Excite a Seignette salt crystal with an audio voltage and couple it to a sounding board. |
| Sut, E-187 | converse piezoelectric effect | 5E60.41 | Connect an audio oscillator to a large Rochelle salt crystal and the sound can be distinctly heard. |
| Mei, 30-6.9 | piezoelectric speaker | 5E60.42 | Apply an audio oscillator to a Rochelle salt and amplify with a wood sounding board. |
| Mei, 30-6.7 | resonating capacitor | 5E60.45 | A HYK capacitor (containing BaTiO3) resonates mechanically at a number of frequencies in the audio range. |
| Sut, E-188 | piezoelectric oscillator | 5E60.47 | Four Rochelle salt crystals are mounted at the center of a long square cross section steel bar and driven by a circuit. Circuit diagrams. |
| Mei, 30-6.5 | hysteresis in barium titanate | 5E60.60 | A circuit for showing hysteresis in ferroelectric crystals on the oscilloscope. |
| | **DC CIRCUITS** | **5F00.00** | |
| | **Ohm's Law** | **5F10.00** | |
| AJP 53(6),552 | charge density in circuits | 5F10.05 | Two demonstrations: first, an electroscope is used to probe the charge density along a large resistance attached to a 5 KV supply, and second, an example where current is flowing through a resistance with no change in potential. |
| PIRA 200 | Ohm's law | 5F10.10 | Measure current and voltage in a simple circuit. Change the voltage or resistance. |
| UMN, 5F10.10 | Ohm's Law | 5F10.10 | An ammeter, voltmeter, rheostat, and battery pack are connected to demonstrate Ohm's law. |

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| F&A, Eg-2 | Ohm's law | 5F10.10 | A battery, rheostat, and meters in a circuit. |
| F&A, Eo-1 | Ohm's law | 5F10.10 | Measure current and voltage in a simple circuit. |
| D&R, E-380 | Ohm's law | 5F10.10 | Measure current and voltage of a simple resistor circuit. |
| Disc 17-19 | Ohm's law | 5F10.10 | Place 2, 4, and 6 V across a resistor and measure the current, then graph. |
| Mei, 30-2.1 | water analogy circuit | 5F10.12 | A water analogy illustrates voltage drops across a dc circuit. |
| PIRA 1000 | water Ohm's law analog | 5F10.15 | |
| Sut, E-114 | water analog | 5F10.15 | A water analog of Ohm's law. |
| Sut, E-159 | IR drop in a wire | 5F10.15 | Clip wires from the terminals of flashlight lamps at various points along a stretched wire carrying 2 - 5 amps. |
| PIRA 1000 | potential drop along a wire | 5F10.20 | |
| Sut, E-158 | potential drop along a wire | 5F10.20 | Lecture galvanometers configured as a voltmeter and ammeter measure current and voltage on several samples of wire of the same length. A slide clip can be used to vary length. |
| Disc 18-01 | voltage drop along wire | 5F10.20 | Measure the voltage at six points on a long resistance wire. |
| PIRA 1000 | potential drop with Wimshurst | 5F10.25 | |
| Sut, E-113 | potential drop with static machine | 5F10.25 | A 3 m long wood bar is attached at one end to one terminal of a static machine. The other end can be grounded or insulated. Attach several electroscopes along the bar to show flow of charge and potential drop. |
| Sut, E-153 | high voltage Ohm's law | 5F10.26 | Two ends of a dry stick are attached to a static machine. Measure with an electrostatic voltmeter and microammeter. |
| | **Power and Energy** | **5F15.00** | |
| PIRA 1000 | electrical equivalent of heat | 5F15.10 | |
| F&A, He-4 | electrical equivalent of heat | 5F15.10 | Measure the voltage and current to a heating coil in a calorimeter. |
| F&A, Eh-3 | heat and electrical energy | 5F15.10 | A heating coil in a calorimeter. |
| Mei, 26-4.4 | electrical equivalent of heat | 5F15.10 | Voltage, current to a heater and temperature rise in water are measured. |
| Sut, E-178 | electrocalorimeter | 5F15.10 | Determine the power delivered by temperature change in water and compare to that computed from voltage, current, and time. |
| F&A, He-7 | flow calorimeter | 5F15.11 | Water is heated electrically as it flows through a tube. |
| Sut, E-118 | heating by current from a static machine | 5F15.12 | The ends of a piece of wood sealed in a glass tube are attached to a static machine. The half watt dissipated heats the air and an attached manometer measures the volume change. |
| UMN, 5F15.15 | KWH meter and loads | 5F15.15 | Measure the power consumed by an assortment of household appliances. |
| Bil&Mai, p 282 | meters and loads | 5F15.15 | A circuit breaker in a power strip is used to measure the power consumed by an assortment of household appliances. A voltmeter and an amp meter are also used. |
| Sut, E-171 | heating with current | 5F15.16 | Large currents are passed through No. 18 nichrome wire and the volts and amps are measured. |
| AJP 77 (6), 516 | heating with current | 5F15.16 | Current, voltage, and resistance measurements on long lengths of conducting wire show a nonlinear component. The nonlinear behavior can be modeled using principles of heat transfer with a thermal reservoir. |
| Sut, E-174 | heating wires in series | 5F15.17 | Several lengths of different wires of the same length are soldered together in series and a piece of paper is hung from each by soft wax. As current is passed through the wire, the paper falls off at different times. |
| PIRA 500 | hot dog cooker | 5F15.20 | |
| UMN, 5F15.20 | hot dog/pickle cooker | 5F15.20 | |
| Sut, E-176 | hot dog cooker | 5F15.20 | Hook nails to 110V and place them on and then in a hot dog. |
| D&R, E-425 | hot dog cooker | 5F15.20 | Insert aluminum nails in a hot dog and cook with 110 volts. |
| Disc 18-07 | hot dog frying | 5F15.20 | Apply 110 V through a hot dog and cook it. |
| PIRA 1000 | fuse with 30v lamp | 5F15.30 | |
| Sut, E-173 | fuse-wire problem | 5F15.31 | With fuse wires of different diameters connected in parallel, which will burn out first? |
| Mei, 30-1.6 | vaporize wire with 500 amp surge | 5F15.32 | Short a low voltage high current transformer with zinc coated iron wire. |
| Sprott, 4.4 | vaporize wire - exploding wire | 5F15.32 | A thin wire or strip of aluminum foil vaporizes when a large capacitor discharges through it. |
| Sut, E-172 | fuse wire | 5F15.33 | Fuse wire is used with a miniature house circuit. |
| F&A, Eh-5 | fuses | 5F15.34 | Fuse wire of different sizes are connected across a heavy copper buss. |
| PIRA 200 | fuse with increasing load | 5F15.35 | A fuse wire will eventually fail when the load on the circuit is increased. |
| PIRA 1000 - Old | fuse with increasing load | 5F15.35 | A fuse wire will eventually fail when the load on the circuit is increased. |
| PIRA 1000 | voltage drops in house wires | 5F15.40 | |
| Disc 18-05 | voltage drops in house wires | 5F15.40 | Two resistance wires substituting for house wiring glow when they power a load of lamps and heaters. |
| PIRA 1000 | I2R losses | 5F15.45 | |

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| Disc 18-06 | I2R losses | 5F15.45 | Copper and nichrome wires in series show different amounts of heating due to current. A paper rider on the nichrome wire burns. |
| | **Circuit Analysis** | **5F20.00** | |
| PIRA 200 | Kirchhoff's voltage law | 5F20.10 | Measure the voltages around a three resistor and battery circuit. |
| UMN, 5F20.10 | Kirchhoff's voltage law | 5F20.10 | Same as Eo-2. |
| F&A, Eo-2 | Kirchhoff's voltage law | 5F20.10 | Measure the voltages around a three resistor and battery circuit. |
| Bil&Mai, p 278 | Kirchhoff's voltage law | 5F20.10 | Glowing resistors (light bulbs) are used to visually compare voltages of series and parallel circuits. |
| Disc 18-02 | sum of IR drops | 5F20.10 | Measure the voltages across three resistors and a battery in a series circuit. |
| F&A, Eo-3 | voltage divider | 5F20.13 | A simple series circuit of a battery and two resistors. |
| PIRA 500 | continuity of current | 5F20.15 | |
| UMN, 5F20.15 | continuity of current | 5F20.15 | Same as Eo-4. |
| F&A, Eo-4 | continuity of current | 5F20.15 | An ammeter can be inserted into any branch of a circuit to show currents in and out of a node. |
| Disc 17-27 | conservation of current | 5F20.16 | Measure the currents entering and leaving a node. |
| PIRA 1000 | superposition of current | 5F20.20 | |
| UMN, 5F20.20 | superposition of current | 5F20.20 | Same as Eo-7. |
| F&A, Eo-7 | superposition of currents | 5F20.20 | Measure the current from one battery, a second in another position, and the combination in a circuit. |
| Mei, 30-2.6 | superposition | 5F20.20 | Shows a standard superposition circuit. |
| PIRA 1000 | reciprocity | 5F20.25 | |
| Mei, 30-2.7 | reciprocity | 5F20.25 | Shows a standard reciprocity circuit. |
| PIRA 1000 | potentiometer | 5F20.30 | |
| UMN, 5F20.30 | potentiometer | 5F20.30 | A slide wire potentiometer is used with a battery and demonstration galvanometer. |
| F&A, Eg-7 | potentiometer | 5F20.30 | A slide wire potentiometer with a standard cell. |
| Bil&Mai, p 275 | potentiometer | 5F20.30 | A homemade slide wire potentiometer is used with a battery. A light bulb is used as the visual indicator of voltage. |
| Sut, E-160 | rheostat as potential divider | 5F20.31 | Contrast the slide wire rheostat when used as a rheostat or potential divider. |
| Sut, E-161 | long potentiometer | 5F20.32 | Use a ten foot length of nichrome wire as a slide wire potentiometer. |
| Hil, E-3c | rheostat potential divider | 5F20.33 | A rheostat and six volt battery demonstrate a potential divider. |
| PIRA 1000 | Wheatstone bridge | 5F20.40 | |
| F&A, Eg-6 | Wheatstone bridge - slide wire | 5F20.40 | The slide wire Wheatstone bridge. |
| Sut, E-156 | Wheatstone bridge - slide wire | 5F20.40 | Two nichrome wires are stretched across the lecture bench and sliding clips connected to a galvanometer are used to find equal potential points. |
| Sut, E-157 | Wheatstone bridge - human galvanometer | 5F20.41 | Stretch a loop of close line previously soaked in salt solution in a parallelogram and hook the ends to a 110 V line. Touch two points of the same potential without shock. |
| Hil, E-3b | Wheatstone bridge | 5F20.42 | A demonstration Wheatstone bridge with a built in meter and several plug in resistors. |
| PIRA 1000 | light bulb Wheatstone bridge | 5F20.45 | |
| UMN, 5F20.45 | lightbulb Wheatstone bridge | 5F20.45 | A Wheatstone bridge configuration with lightbulbs for resistors. |
| F&A, Eh-2 | light bulb Wheatstone bridge | 5F20.45 | Four light bulbs in a Wheatstone bridge arrangement with light bulb indicator. |
| Mei, 30-2.3 | light bulb Wheatstone bridge | 5F20.45 | A light bulb Wheatstone bridge using 110 ac. |
| Sut, E-155 | Wheatstone bridge | 5F20.45 | Four 60 W lamps in a diamond bridge with a 10 W lamp as the indicator. An additional 6 V lamp can be switched in when the circuit is balanced. |
| Disc 17-25 | Wheatstone bridge | 5F20.45 | Three 110 V lamps and a rheostat make up the diamond of a Wheatstone bridge and a small lamp serves as an indicator. |
| PIRA 200 | series and parallel light bulbs | 5F20.50 | A light bulb board with switches allows configuration of several combinations of series and parallel lamps. |
| UMN, 5F20.50 | series and parallel light bulbs | 5F20.50 | |
| F&A, Eh-1 | series and parallel light bulbs | 5F20.50 | A light bulb board with switches allows configuration of several combinations. |
| Sut, E-177 | parallel and series light bulbs | 5F20.50 | Three similar wattage lamps in series, three in parallel. |
| Hil, E-3a.1 | series-parallel circuits | 5F20.50 | A series-parallel circuit with three bulbs and six switches can be connected 14 ways. |
| D&R, E-430 | series and parallel light bulbs | 5F20.50 | Series-parallel circuits with three light bulbs. |
| Bil&Mai, p 273 | series and parallel light bulbs | 5F20.50 | A light bulb board with switches allows configuration of several combinations. |
| Bil&Mai, p 276 | series and parallel light bulbs | 5F20.50 | Two 3-wire outlets are wired to allow configurations of several combinations of series and parallel light bulbs. |
| Disc 17-24 | series/parallel light bulbs | 5F20.50 | Three 110 V lamps are wired in series and three are wired in parallel. |
| PIRA 1000 | light bulb board - 12 V | 5F20.51 | |

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| UMN, 5F20.51 | light bulb board - 12 V | 5F20.51 | A board with 12V bulbs and a car battery allow combinations of up to three series or three parallel loads. |
| PIRA 1000 | series and parallel resistors | 5F20.55 | |
| Disc 17-23 | series/parallel resistors | 5F20.55 | Measure the current flowing through a wire resistor with 6 V applied and then series and parallel combinations. |
| Sut, E-175 | wire combinations | 5F20.56 | A wire circuit is arranged so a segment of n length can have 1 or n wires in parallel. Drawing. |
| PIRA 1000 | equivalent resistance | 5F20.60 | |
| F&A, Eo-5 | equivalent series resistance | 5F20.60 | A series of resistors in a circuit are replaced by a single resistor. |
| TPT 2(3),131 | parallel resistance - integral value | 5F20.61 | A formula for obtaining integral values of resistors in parallel to obtain an integral equivalent resistance. |
| F&A, Eo-6 | equivalent parallel resistance | 5F20.61 | Parallel resistors are replaced by a single resistor in a circuit. |
| Mei, 30-2.4 | Thevenin's equivalent resistance | 5F20.63 | A Wheatstone bridge resistance circuit is used to reduce resistor combinations to an equivalent resistance. |
| AJP 46(7),762 | equivalent circuit flasher | 5F20.64 | A neon flasher circuit shows the combination rules for series and parallel combinations of resistance and capacitance by timing light flashes. |
| AJP 32(12),967 | large circuit boards | 5F20.71 | A modular circuit board made for 500 student auditoriums. |
| Hil, E-2b | general circuits board | 5F20.72 | A circuit board laid out so meters can be plugged in and readings taken for demonstrations of series-parallel circuits and Kirchhoff's laws. |
| Hil, E-3d | three-way switch | 5F20.75 | A large circuit board demonstrates a three way switch. |
| Hil, E-3e | one boat, river, six people | 5F20.79 | An electrical circuit for solving the problem of getting across the river. |
| Mei, 30-2.5 | equivalent resistance analog computer | 5F20.95 | Using the equivalent resistance of a circuit as an analog computer for finding the focal length of an optical problem. |
| | **RC Circuits** | **5F30.00** | |
| PIRA 200 | capacitor and light bulb | 5F30.10 | A large electrolytic capacitor, a light bulb, and a 120 V dc supply in series show a long time constant. |
| UMN, 5F30.10 | capacitor and light bulb | 5F30.10 | A 5600 microF capacitor is charged and discharged through 7.5 and 40 W light bulbs. |
| F&A, En-11 | long RC time constant | 5F30.10 | A 5600 microF capacitor, a light bulb, and a 120 V dc supply in series show a long time constant where the bulb dims as the capacitor charges. |
| Mei, 29-4.2 | light the bulb | 5F30.11 | Charge a capacitor with DC and discharge through a light bulb, try the same thing with AC. |
| Bil&Mai, p 265 | light the bulb | 5F30.11 | A capacitor is charged and discharged through a light bulb. Use a 9 volt battery. |
| F&A, Ed-6 | discharge a capacitor | 5F30.12 | Discharge a capacitor through a resistor. Read the voltage with a meter. |
| PIRA 1000 | RC time constant on galvanometer | 5F30.15 | |
| Sut, E-259 | RC time constant on galvanometer | 5F30.15 | A series RC circuit with a galvanometer. Diagram. |
| AJP 41(5),745 | RC voltage follower | 5F30.16 | Use a voltage follower to isolate the circuit from the display. |
| PIRA 500 | RC time constant on scope | 5F30.20 | |
| UMN, 5F30.20 | RC time constant on scope | 5F30.20 | A circuit with a slow time constant (.1 - 10 sec.) is charged and discharged and the current and voltage are displayed on a dual trace storage scope. |
| D&R, E-405 | RC time constant on scope | 5F30.20 | A square wave charges and discharges a capacitor and the charging time is observed on the oscilloscope. |
| Disc 18-28 | RC charging curve | 5F30.20 | Show charging and discharging an RC circuit with a battery on an oscilloscope. |
| F&A, En-10 | RC time constant | 5F30.21 | Show the time constant from an RC circuit on an oscilloscope. |
| F&A, Eo-12 | RC time constant | 5F30.21 | A plug in circuit board for showing RC time constants on the oscilloscope. |
| F&A, En-8 | time constant of an capacitive circuit | 5F30.22 | The time constant of a RC circuit driven by the calibration signal is shown on an oscilloscope. |
| Mei, 30-2.2 | finding R from time constant | 5F30.28 | A circuit to measure high resistances by using an RC charging time. |
| PIRA 1000 | series and parallel capacitors | 5F30.50 | |
| Sut, E-261 | series and parallel capacitors | 5F30.50 | Two 2 microF capacitors in series or parallel with a 40 W lamp. |
| Bil&Mai, p 261 | series and parallel capacitors | 5F30.50 | 6 capacitors are connected to a test board in parallel and series arrangements. Use a capacitance meter to explore the relationships. |
| PIRA 1000 | neon relaxation oscillator | 5F30.60 | |
| Mei, 29-4.3 | blinking neon bulb | 5F30.60 | A neon bulb in parallel with a capacitor will light periodically as the capacitor charges and discharges. |
| Mei, 33-1.2 | RC relaxation oscillator | 5F30.60 | An RC relaxation oscillator has a neon lamp across the capacitor providing a visible discharge. |
| Sut, E-263 | RC flasher circuit | 5F30.60 | A neon lamp in parallel with the capacitor in a series RC circuit. |
| Hil, E-4f | flashing neon light | 5F30.60 | A battery powered neon light oscillator. |
| Hil, E-4e | neon relaxation oscillator | 5F30.60 | A circuit for a neon relaxation oscillation oscillator. Reference: AJP 13(12),415. |

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| D&R, E-240 | neon relaxation oscillator | 5F30.60 | A simple neon relaxation oscillator with circuit diagram. |
| D&R, E-400 | relaxation oscillator | 5F30.60 | A relaxation oscillator with an oscilloscope connected across the capacitor to monitor charging time. Many neon or argon bulbs will work. |
| Disc 18-29 | relaxation oscillator | 5F30.60 | An RC neon light relaxation oscillator. |
| Mei, 33-1.3 | relaxation siren oscillator | 5F30.61 | A double RC relaxation oscillator with slow and fast periods gives a siren waveform. |
| AJP 40(5),763 | backward and forward waves | 5F30.68 | RC circuits are used to get a wave in neon bulbs that goes from the sink to the source. |
| Hil, E-4g | capacitance operated relay | 5F30.71 | References but no information on the circuit. Bring your hand close to a aluminum plate and the relay triggers. |
| Hil, A-10a | fun circuit | 5F30.80 | One box has switches that control two lights in another box but only one wire connects the two boxes. |
| | **Instruments** | **5F40.00** | |
| PIRA 1000 | sensitivity and resistivity of a galvanometer | 5F40.10 | |
| AJP 29(6),373 | sensitivity and resistance of a galvanometer | 5F40.10 | A circuit for the determination of galvanometric constants. |
| F&A, Ej-5 | sensitivity and resistance of galvanometer | 5F40.10 | Use external resistors to measure the resistance and sensitivity of a galvanometer. |
| Sut, E-154 | voltmeter and electroscope | 5F40.15 | Connect series resistance to a galvanometer to make a voltmeter with low sensitivity and measure several dry batteries in series with both the voltmeter and an electroscope. |
| PIRA 1000 | galvanometer as ammeter and voltmeter | 5F40.20 | |
| F&A, Ej-6 | converting a galvanometer to a voltmeter | 5F40.20 | Knowing the resistance and sensitivity of a galvanometer, add a series resistance and check with a voltage. |
| Disc 17-26 | galvanometer as voltmeter and ammeter | 5F40.20 | A galvanometer is used with shunt and series resistors. |
| PIRA 1000 | loading by voltmeter | 5F40.21 | |
| Disc 18-04 | loading by a voltmeter | 5F40.21 | Measure the voltage across a high resistance circuit with high and low impedance voltmeters. |
| F&A, Ej-7 | converting a galvanometer to a ammeter | 5F40.25 | Knowing the resistance and sensitivity of a galvanometer, add a shunt resistance and measure a current. |
| F&A, Ej-3 | hot wire ammeter | 5F40.30 | A crude hot wire galvanometer. |
| Sut, H-11 | hot wire ammeter | 5F40.30 | Diagram of a hot wire ammeter. (E-171). |
| F&A, Ej-4 | iron vane meter | 5F40.35 | Repulsion from induced magnetism in two soft iron bars in a solenoid forms the basis of a heavy current ammeter. |
| Hil, E-2d | multimeters | 5F40.50 | A couple multimeters are pictured. |
| | **MAGNETIC MATERIALS** | **5G00.00** | |
| | **Magnets** | **5G10.00** | |
| PIRA 500 | magnet assortment | 5G10.10 | |
| UMN, 5G10.10 | magnet assortment | 5G10.10 | |
| AJP 55(1),10 | letters on magnets | 5G10.13 | Remarkably, the letters on the magnet, are two of the three that can be read from either end or in a mirror. |
| Hil, E-6c | various magnets | 5G10.14 | Various magnets are pictured. |
| Hil, E-6d | strong magnets | 5G10.14 | Various strong magnets are shown. |
| PIRA 1000 | lodestone | 5G10.15 | |
| UMN, 5G10.15 | lodestone | 5G10.15 | Show that the lodestone attracts small nails. |
| AJP 77 (8), 729 | lodestone | 5G10.15 | An article with a picture describing lodestone and some of its history. |
| Bil&Mai, p 288 | lodestone | 5G10.15 | Hang a piece of lodestone from the ceiling with a piece of string or thread. Notice that it will always come to rest pointing in the same direction. |
| PIRA 1000 | lodestone suspended | 5G10.16 | |
| F&A, Er-5 | lodestone | 5G10.16 | Magnetite is suspended in a magnetic field. |
| Sut, E-84 | permanent magnets | 5G10.16 | Pick up nails with a cobalt steel magnet. Also - levitation, elastic collisions. |
| Sut, E-77 | lodestone | 5G10.16 | Two pieces of magnetite in paper stirrups come to rest on the magnetic meridian. Poles are identified and repulsion and attraction are demonstrated. |
| Disc 19-02 | lodestone | 5G10.16 | A large lodestone is suspended in a cradle with the south pole painted white. A bar magnet is used to show attraction and repulsion. |
| PIRA 200 | break a magnet | 5G10.20 | |
| PIRA 500 - Old | break a magnet | 5G10.20 | |
| UMN, 5G10.20 | break a magnet | 5G10.20 | Show a magnet attracts nails, break it and repeat. |
| F&A, Er-12 | forming new magnetic poles | 5G10.20 | Break a magnet. |
| Sut, E-93 | break a magnet | 5G10.20 | Magnets of hard or hardened steel are broken and the pieces shown to be magnetized. |
| Disc 19-05 | broken magnet | 5G10.20 | A broken magnet still exhibits north and south poles. |

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| PIRA 1000 | Which is a magnet? | 5G10.30 | |
| F&A, Es-9 | magnet and non-magnet | 5G10.30 | Two bars look alike, one is a magnet and the other is not. |
| Sut, E-85 | Which is a magnet? | 5G10.30 | With two similar bars of iron, one magnetized, use the end of one to lift the middle of the other. |
| Sut, E-79 | two south pole magnet | 5G10.35 | How to induce four poles in a knitting needle, the same poles at each end. |
| Mei, 32-3.5 | no pole magnet | 5G10.36 | Make a circularly polarized magnet in a steel ring and then break it in half. |
| PIRA 1000 | lowest energy configuration of magnets | 5G10.50 | |
| AJP 33(4),346 | magnetic interactions | 5G10.50 | Magnets float in water with the north pole up constrained by a ring magnet. Place up to 22 magnets in the tub and show equilibrium configurations. |
| Disc 19-06 | lowest energy configuration | 5G10.50 | Magnets held vertically in corks are placed in a dish of water. When a coil around the dish is energized, the magnets move to the lowest energy configuration. |
| TPT 41(3), 158 | Gauss Accelerator - Gauss Rifle | 5G10.55 | A Gauss rifle made from 4 square neodymium magnets and 5/16 inch ball bearings. The energy analysis shows the change in potential energy of the rifle as a function of the accumulated displacement of the ball bearings. |
| TPT 42(1), 24 | Gauss Accelerator - Gauss Rifle | 5G10.55 | A Gauss accelerator made from spherical magnets and ball bearings. Measurements of both the change in potential energy and the change in kinetic energy are presented. |
| Bil&Mai, p 108 | Gauss accelerator - Gauss rifle | 5G10.55 | A Gauss rifle made from 3 square neodymium magnets and 1 inch ball bearings. Add two more stages of magnets and balls to observe an increased effect. |
| TPT 3(5),226 | cast magnetic field | 5G10.90 | Iron filings are cast in gelatin. |
| F&A, Er-13 | magnetic monopole | 5G10.90 | Iron filings cast in acrylic over one pole of a magnet. |
| Sut, E-81 | isolated pole | 5G10.90 | An "isolated pole" is demonstrated by passing a long magnetized knitting needle through a cork and floating it on water. |
| | **Magnet Domains & Magnetization** | **5G20.00** | |
| PIRA 500 | Barkhausen effect | 5G20.10 | |
| UMN, 5G20.10 | Barkhausen effect | 5G20.10 | Amplify the signal from a small coil as it is flipped in a magnetic field with copper, soft iron, and steel cores. |
| F&A, Es-1 | Barkhausen effect | 5G20.10 | Magnetic domains in the core of a small coil can be heard flipping as a magnet is moved by using and an audio amplifier. |
| Mei, 32-3.10 | Barkhausen effect | 5G20.10 | Insert various cores into a coil connected to an audio amplifier and spin a magnet around it. |
| Mei, 32-3.11 | Barkhausen effect | 5G20.10 | Stretch a iron-nickel alloy wire through a coil and bring a magnet close to demonstrate sudden simultaneous magnetization. |
| Sut, E-94 | Barkhausen effect | 5G20.10 | Soft iron and hard steel cores are placed in a small coil attached to an audio amplifier and the assembly is inserted into a magnetic field. |
| AJP 73 (4), 367 | Barkhausen effect | 5G20.10 | A Barkhausen demonstration where the noise is converted to a voltage that is monitored with a data acquisition system. |
| Hil, E-10d | Barkhausen effect | 5G20.10 | A soft iron core inserted in a small coil connected to the input of an audio amplifier. |
| Disc 19-19 | Barkhausen effect | 5G20.10 | Pulses from moving a magnet near a coil wrapped around a soft iron core are amplified. |
| AJP 39(7),832 | spin-flop transition model | 5G20.15 | A mechanical model of the spin-flip transition in antiferromagnets. |
| PIRA 500 | ferro-optical garnet | 5G20.20 | |
| UMN, 5G20.20 | ferro-optical garnet | 5G20.20 | View a commercial ferro-optical garnet between crossed Polaroids with a color TV on a microscope as the field in the coil is changed. |
| Mei, 32-3.8 | ferromagnetic garnet | 5G20.21 | Examine a crystal of M3Fe2(FeO4)3 in a polarizing microscope. Diagrams, Reference: AJP,27(3),201. |
| Mei, 32-3.9 | Weiss domains | 5G20.22 | Examine a Gadolinium-Iron-Garnet crystal in a polarizing microscope as the magnetic field and temperature are changed. Picture, Reference: AJP,27(3),201. |
| AJP 29(11),789 | optical ferromagnetic domains | 5G20.23 | Examine thin polished crystals under a low powered microscope in polarized light. Add a small coil to change the field. |
| Mei, 32-3.2 | iron filing domains | 5G20.27 | A tube of compressed iron filings is magnetized and then the iron filings are agitated. |
| PIRA 200 | magnetic domain model | 5G20.30 | An array of small compass needles shows domain structures. |
| F&A, Es-2 | magnetic domains | 5G20.30 | An array of small compass needles shows domain structures. |
| Disc 19-16 | magnetic domain model | 5G20.30 | A set of compass needles on pins. |
| UMN, 5G20.31 | compass arrays | 5G20.31 | |
| Mei, 32-3.7 | compass array | 5G20.31 | An array of compass needles made of spring steel strip stock shows domains under different magnetic field conditions. |

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| Sut, E-91 | compass array | 5G20.31 | A set of magnetic needles on pivots orients randomly until a magnet is brought close. Barkhausen model - A compass array above an electromagnet will show that the needles align discontinuously as the field is increased. |
| AJP 54(12),1130 | Heisenberg anitferromagnet model | 5G20.36 | A simple mechanical model demonstrates phase transitions in a Heisenberg antiferromagnet. |
| PIRA 1000 | induced magnetic poles | 5G20.45 | |
| Sut, E-82 | induced magnetic poles | 5G20.45 | A chain of nails is supported by a magnet, each becoming a magnet by induction. |
| Sut, E-88 | magnetic induction | 5G20.46 | A soft iron bar held colinear with a permanent magnet will become magnetized by induction. Use a compass needle to show the far pole of the bar is the same as the near pole of the magnet. |
| PIRA 500 | pound iron bar | 5G20.50 | |
| UMN, 5G20.50 | pound iron bar | 5G20.50 | |
| F&A, Er-8 | magnetization in the Earth's field | 5G20.50 | Hammer the end of a soft iron bar in the Earth's magnetic field. |
| Mei, 32-3.4 | pound iron bar | 5G20.50 | Pound a soft iron bar held in the Earth's field, a permalloy bar does not need to be pounded. |
| Sut, E-80 | hammer an iron bar | 5G20.50 | Hammer a soft iron bar held parallel to the field of the Earth. A bar of permalloy is magnetized by simply holding it in the Earth's field. |
| Sut, E-112 | magnetic induction in Earth's field | 5G20.50 | Hammer the end of a soft iron rod held parallel to the Earth's field. Hold a permalloy rod parallel while picking up pieces of permalloy ribbon, then turn perpendicular. |
| D&R, B-370 | hammer an iron bar | 5G20.50 | Hammer the end of a soft iron reinforcing rod in the Earth's magnetic field. |
| PIRA 500 | permalloy bar | 5G20.55 | |
| UMN, 5G20.55 | permalloy bar | 5G20.55 | |
| F&A, Er-9 | permalloy bar | 5G20.55 | Iron filings stick to a permalloy bar held parallel to the Earth's magnetic field but fall off when it is held perpendicular. |
| Disc 19-21 | permalloy in Earth's field | 5G20.55 | A small strip of iron sticks to a permalloy rod when it is held in the direction of the Earth's field. |
| Hil, E-6a.2 | permalloy rod | 5G20.56 | Hold a permalloy rod near a compass needle. |
| PIRA 1000 | magnetization by current | 5G20.60 | |
| Sut, E-127 | magnetization and demagnetization | 5G20.60 | Place an iron core in a solenoid. Magnetize with direct current and demagnetize by reducing alternating current to zero. |
| Sut, E-83 | magnetization by current | 5G20.60 | Place a piece of steel in a solenoid connected to a direct current source. |
| Disc 19-17 | magnetizing iron | 5G20.60 | Place an iron bar in a solenoid and pulse a large current. |
| PIRA 1000 | magnetization by contact | 5G20.61 | |
| Disc 19-15 | magnitizing iron by contact | 5G20.61 | Stroke a nail on a permanent magnet and it will pick up iron filings. |
| PIRA 1000 | demagnitization by hammering | 5G20.62 | |
| Sut, E-78 | magnetization and demagnetization | 5G20.62 | Stroke a steel needle with a permanent magnet to magnetize and pass it through an AC solenoid to demagnetize. |
| Disc 19-18 | demagnitizing iron by hammering | 5G20.62 | Magnetize an iron bar in a solenoid, then pound it to demagnetize. |
| PIRA 500 | electromagnet - lift a person | 5G20.70 | |
| F&A, Es-5 | electromagnet | 5G20.70 | A simple electromagnet. |
| Disc 19-12 | electromagnet with 1.5 V battery | 5G20.70 | A magnet powered by a 1.5 V battery lifts a large weight. |
| PIRA 1000 | electromagnet | 5G20.71 | |
| UMN, 5G20.71 | electromagnet | 5G20.71 | |
| Sut, E-126 | electromagnet | 5G20.71 | An electromagnet with 25 turns of wire and one dry cell can lift over 200 lbs. |
| PIRA 1000 | large electromagnet | 5G20.72 | |
| F&A, Es-11 | magnet holding with small battery | 5G20.72 | An electromagnet energized with a small battery holds several Kg. |
| AJP 29(2),86 | large electromagnet | 5G20.72 | Apparatus Drawings Project No. 13: A simple low cost electromagnet with 4"x4" pole faces, field of 1 weber/m2 with a .5 cm gap. |
| Disc 19-11 | large electromagnet | 5G20.72 | This magnet is made with 3000 turns and carries 25 amps. |
| PIRA 1000 | magnetically suspended globe | 5G20.73 | |
| Sprott, 5.5 | magnetically suspended globe | 5G20.73 | Alternating current in a pair of magnet coils produces a magnetic field of a shape and strength that can levitate an aluminum ball. |
| AJP 44(5),478 | magnetically suspended globe | 5G20.73 | A hollow iron globe is suspended from a solenoid with an iron core using a feedback system based on the height of the ball. |
| AJP 34(7),623 | magnetic circuit | 5G20.74 | An iron loop with a coil on one side, a flux meter on the other, and a removable section for substituting various materials. |
| Mei, 32-3.16 | measuring magnetic flux | 5G20.74 | Measure magnetic flux with and without a iron path. Not a good description. |
| PIRA 1000 | retentivity | 5G20.75 | |
| UMN, 5G20.75 | retentivity | 5G20.75 | |

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| Sut, E-96 | retentivity | 5G20.75 | Two soft iron cores form a split toroid with a few turns of wire around one half. When the coil is energized the iron is strongly magnetized. When the current is off, the two pieces are still difficult to separate but once apart no longer attract. |
| Sut, E-95 | retentivity | 5G20.75 | A soft iron bar will cling to a "U" shaped electromagnet when the current is turned off but no longer attract after it is pulled away. |
| Mei, 32-3.26 | different cores | 5G20.76 | An electromagnet is made with replaceable yoke to show the effect of different materials on lifting strength. |
| | **Paramagnetism and Diamagnetism** | **5G30.00** | |
| PIRA 200 | paramagnetism and diamagnetism | 5G30.10 | |
| PIRA 500 - Old | paramagnetism and diamagnetism | 5G30.10 | |
| UMN, 5G30.10 | paramagnetism and diamagnetism | 5G30.10 | Paramagnetic and diamagnetic crystals are inserted between the poles of a large electromagnet. |
| Mei, 32-2.1 | paramagnetism and diamagnetism | 5G30.11 | Small samples of bismuth, aluminum, glass, etc between the poles of a strong electromagnet with an inhomogeneous magnetic field. Picture. |
| Mei, 32-3.12 | paramagnetic and ferromagnetic | 5G30.13 | A small sphere of Pyrothit suspended near one pole of a horseshoe magnet will show paramagnetic and ferromagnetic behavior in different orientations. |
| PIRA 1000 | pull the sample | 5G30.15 | |
| UMN, 5G30.15 | John Davis setup | 5G30.15 | |
| Disc 19-22 | paramagnetism and diamagnetism | 5G30.15 | Samples of bismuth and copper sulfate are suspended by threads. A large horseshoe magnet attracts the copper sulfate and repels the bismuth. |
| AJP 28(7),678 | dollar bill attraction | 5G30.16 | A dollar bill is attracted by a magnet. |
| AJP 28(7),678 | paramagnetism and diamagnetism in a level | 5G30.16 | Pull the bubble in a carpenter's level with a magnet. Also, pull liquid air drops around on a sheet of paper. |
| AJP 30(6),453 | pole faces for big electromagnet | 5G30.17 | Apparatus Drawings Project No. 29: Large electromagnet accessories, one of four. Plans for pole faces to go on the electromagnet from No. 13 for use in para and diamagnetism demonstrations. |
| Sut, E-102 | paramagnetism and diamagnetism | 5G30.18 | Specifications are given for building an electromagnet suitable for the demonstration. Paramagnetic and diamagnetic substances are listed. |
| TPT, 36(9), 553 | inexpensive demonstration of the magnetic properties of matter | 5G30.19 | Qualitative discussion of magnetic properties presents a simple, general-purpose way to demonstrate the magnetic nature of many types of matter. |
| PIRA 1000 | paramagnetism of liquid oxygen | 5G30.20 | |
| Sut, H-111 | paramagnetism of liquid oxygen | 5G30.20 | Liquid oxygen sticks to the pole pieces of a strong electromagnet until it evaporates. |
| F&A, Es-3 | paramagnetism | 5G30.21 | A test tube of liquid oxygen swings into the gap of an electromagnet. |
| F&A, Es-4 | paramagnetism | 5G30.25 | Copper sulfate and bismuth crystals are suspended in a magnetic field. |
| Hil, E-10b | paramagnetism of bismuth | 5G30.25 | A bismuth crystal is suspended between the poles of an electromagnet. |
| Mei, 32-2.2 | para and dia in para and dia solutio | 5G30.30 | A paramagnetic body is suspended in a paramagnetic solution. Repeat same with diamagnetic. |
| TPT 40(7), 440 | diamagnetic grapes | 5G30.35 | Observe the diamagnetic or paramagnetic properties of common items such as grapes, rosin, salt, aluminum foil, etc., using a a neodymium magnet and a sensitive pivot. |
| TPT 41(2), 75 | diamagnetic water | 5G30.40 | Cover a neodymium magnet with about 1 mm of water in a petri dish. The diamagnetism of water can be easily observed. |
| TPT 41(2), 122 | diamagnetic levitation of graphite | 5G30.45 | A diamagnetic levitator using 4 or 9 - one half inch square neodymium magnets and a thin square of pyrolite graphite. |
| AJP 69(6), 702 | diamagnetic graphite | 5G30.50 | Discussion and analysis of commercial and homemade diamagnetic levitators. The levitators all have the basic design of levitating a small neodymium magnet between two slabs of graphite. |
| AJP 70(2), 188 | diamagnetic graphite | 5G30.50 | More comments on AJP 69(6), 702. |
| TPT 35(8), 463 | diamagnetic bismuth | 5G30.55 | Place a bismuth sample on an electronic balance. The balance will show a positive "mass" when a neodymium magnet is brought near the top. |
| | **Hysteresis** | **5G40.00** | |
| PIRA 500 | hysteresis loop on scope | 5G40.10 | |
| UMN, 5G40.10 | hysteresis loop on scope | 5G40.10 | Show the hysteresis loops for laminated steel and ferrite cores as saturation is reached. |
| F&A, Es-10 | hysteresis loop | 5G40.10 | The hysteresis loop of a core is displayed on an oscilloscope. |
| Disc 20-28 | hysteresis curve | 5G40.10 | The Leybold setup shown on a scope. |
| Sut, E-101 | hysteresis loop on scope | 5G40.11 | The hysteresis loop for the iron core of a transformer is shown on a oscilloscope. Diagram and circuit hints. |

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| Mei, 32-3.17 | hysteresis on the scope | 5G40.12 | A circuit for showing the hysteresis curve of a transformer on an oscilloscope. Also modifications for using various cores and coils. |
| AJP 55(10),933 | improved hysteresis loop on scope | 5G40.13 | A circuit, Hall probe, and storage oscilloscope allow plotting the hysteresis loop point by point or automatically. |
| AJP 34(10),960 | hysteresis without induction | 5G40.14 | Two coils are mounted on a rotating disk in the air gap of an electromagnet. As the field is varied, the hysteresis loop is plotted. |
| AJP 58(8),794 | hysteresis loop | 5G40.15 | This circuit makes it possible to display hysteresis loops of inductors with only one winding. |
| AJP 39(8),964 | hysteresis on x-y | 5G40.16 | An op amp circuit for plotting the hysteresis curve slowly on an x-y recorder. |
| Sut, E-100 | magnetization and hysteresis | 5G40.20 | A small mirror on a compass needle is used to detect the magnetic field as the current to a solenoid containing an iron bar is increased and decreased stepwise. |
| Hil, E-10C | simple hysteresis | 5G40.21 | Parallel iron bars suspended in a coil show hysteresis when slowly magnetized and demagnetized. |
| Mei, 32-3.13 | hysteresis plot | 5G40.25 | A ballistic galvanometer search coil gives readings of the magnetization and residual magnetization of a sample as it is magnetized in opposite directions and a plot is generated. |
| Mei, 32-3.25 | plotting hysteresis | 5G40.27 | A core with a removable link and built in flux meter are used to plot a hysteresis curve. |
| Mei, 32-3.15 | hysteresis in a motor | 5G40.31 | The I V curve from a generator is proportional to the normally obtained B H curve. |
| Mei, 32-3.14 | hysteresis loop with old TV | 5G40.41 | The hysteresis loop of a sample placed in one deflection coil is traced on an old TV tube. |
| PIRA 1000 | hysteresis waste heat | 5G40.50 | |
| Disc 20-29 | hysteresis waste heat | 5G40.50 | Water is boiled by magnetic hysteresis waste heat. |
| | **Magnetostriction and Magnetoresistance** | **5G45.00** | |
| PIRA 1000 | magnetostrictive resonance | 5G45.10 | |
| Mei, 32-4.1 | magnetostrictive resonance | 5G45.10 | Drive a nickel rod by a coil at one end at a frequency that corresponds to a natural harmonic of sound waves. |
| Mei, 32-4.2 | magnetostrictive Newton's rings | 5G45.20 | One end of a ferromagnetic rod in a coil touches one plate of a Newton's rings apparatus. |
| PIRA 1000 | magnetostriction of nickel wire | 5G45.30 | |
| Mei, 32-4.3 | magnetostriction of nickel wire | 5G45.30 | An optical lever arrangement shows magnetostriction of nickel wire. |
| Sut, E-109 | magnetostriction | 5G45.31 | Nickel constricts and cobalt steel lengthens when magnetized. Place sample rods in a solenoid and show the effect by optical lever. |
| Mei, 32-4.5 | inverse magnetostrictive effect | 5G45.35 | The inverse magnetostrictive effect in nickel wire. |
| Mei, 32-4.4 | delta E effect | 5G45.40 | The magnetostrictive resonance is measured with and without an external field. |
| Mei, 32-4.6 | Bi-spiral | 5G45.60 | The magnetoresistance of a Bi-spiral in a magnetic field. Picture. |
| PIRA 1000 | magnetoresistance | 5G45.70 | |
| Mei, 40-1.14 | magnetoresistance | 5G45.70 | Measure the magnetoresistance of a bismuth spiral placed in a large electromagnet. |
| Mei, 40-1.15 | corbino disk | 5G45.80 | A corbino disk (InSb) in one arm of a Wheatstone bridge is placed in a large electromagnet. |
| | **Temperature and Magnetism** | **5G50.00** | |
| PIRA 200 | Curie point | 5G50.10 | |
| PIRA 500 - Old | Curie point | 5G50.10 | |
| UMN, 5G50.10 | Curie point | 5G50.10 | Iron under magnetic attraction is heated until it falls away. Upon cooling it is again attracted. |
| F&A, Es-8 | Curie temperature | 5G50.10 | A counterweighted iron wire is attracted to a magnet until heated red with a flame. |
| F&A, Es-6 | Curie point | 5G50.11 | A long soft iron wire held up by a magnet falls off when the wire is heated past the Curie point. |
| Sut, E-104 | Curie Point | 5G50.11 | A length of soft iron wire heated with 110 V DC through a rheostat shows loss of magnetic properties when it passes through recalescence. |
| Mei, 32-3.20 | Curie point | 5G50.12 | A pendulum bob with iron wire tips is attracted to a magnet where it is heated until it loses its magnetism and falls away. The cycle repeats. Picture, Diagram. |
| AJP 73(12), 1191 | Curie point with Monel metal | 5G50.13 | Observing the hysteresis loop of Monel 400 as its temperature is increased through its Curie point. |
| AJP 37(3),334 | Curie point with Monel metal | 5G50.13 | Monel metals have curie points between 25 C and 100 C depending on the alloy. |
| Hil, E-10a.1 | Curie temperature | 5G50.14 | A nickel wire falls away from a magnet when heated. |

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| PIRA 1000 | Curie nickel | 5G50.15 | |
| Sut, E-103 | Curie point of nickel | 5G50.15 | A rod of nickel is attracted to a magnet when cool but swings away when heated. Many hints and diagram. |
| D&R, B-390 | Curie temperature of nickel | 5G50.15 | Canadian quarters or dimes hanging in series from a magnet are heated until they fall away. |
| Disc 19-24 | Curie Nickel | 5G50.15 | A Canadian nickel is attracted to a magnet until it is heated with a torch. |
| AJP 56(1),45 | nickel hysteresis surface | 5G50.16 | Pictures of a 3-D HMT hysteresis surface for nickel. |
| PIRA 1000 | thermomagnetic motor | 5G50.20 | |
| Mei, 32-3.22 | thermomagnetic motor | 5G50.20 | Local heating of permalloy tape or nickel rings in a magnetic field will cause rotation. AJP 5(1),40. |
| Mei, 32-3.21 | Monel wheel | 5G50.20 | The rim of a wheel of Monel tape is placed in the gap of a magnet and heat is applied to one side to make the wheel turn. |
| Sut, E-110 | magnetic heat motor | 5G50.20 | A thin strip of magnetic alloy around the rim of a well balanced wheel is placed in the gap of a magnet with a light focused on a point just above the magnet. Heating changes the magnetic properties and the wheel rotates. |
| Disc 19-25 | Curie temperature wheel | 5G50.20 | A rim of nickel on a wheel is heated just above the point where the rim passes through the gap of a magnet. |
| AJP 58(6),545 | magnetic heat engine | 5G50.22 | A gadolinium strip forming the rim of a Plexiglas wheel is heated and cooled on opposite sides of a magnetic field, and a weight is lifted by the resulting rotation. |
| Hil, E-10a.2 | Curie temperature motor | 5G50.23 | A soft iron disk heated on an edge turns very slowly when a magnet is oriented correctly. |
| AJP 55(1),48 | Curie point engine | 5G50.24 | Use the Curie point engine as a simple demonstration of the Carnot principle. |
| PIRA 1000 | dysprosium in liquid nitrogen | 5G50.25 | |
| Disc 19-23 | dysprosium in liquid nitrogen | 5G50.25 | A piece of dysprosium is attracted to a magnet when cooled to liquid nitrogen temperatures but drops away when it warms up. |
| Mei, 32-3.19 | phase change and susceptibility | 5G50.30 | Heat the long iron wire and watch the sag. A ferrite ring and coil connected to a galvanometer show change in ferromagnetic susceptibility. |
| Mei, 32-3.18 | hysteresis breakdown at Curie temperature | 5G50.35 | Elaborate apparatus to show hysteresis loop and breakdown at Curie temperature. Picture, Diagrams, Materials list in appendix, p. 1333. |
| Mei, 32-5.1 | adiabatic demagnetization | 5G50.40 | The temperature of a piece of gadolinium is measured with a thermocouple while it is between the poles of an electromagnet. |
| PIRA 200 | Meissner effect | 5G50.50 | Cool a superconductor and a magnet floats over it due to magnetic repulsion. |
| UMN, 5G50.50 | Meissner effect | 5G50.50 | |
| Sprott, 5.6 | superconductors | 5G50.50 | High- temperature superconductors used with permanent magnets illustrate the Meissner effect. |
| AJP 76 (2), 106 | superconductivity | 5G50.50 | This Resource Letter provides a guide to the literature on superconductivity. |
| Disc 16-14 | superconductors | 5G50.50 | Place a small powerful magnet over a disc of superconducting material cooled to liquid nitrogen temperature. |
| TPT 28(4),205 | levitating magnet | 5G50.51 | A long article on levitation over superconductors showing several variations. |
| AJP 72(2), 243 | levitating magnet | 5G50.51 | Investigates why a cylindrical permanent magnet rotates when levitated above a superconductor. |
| AJP 56(7),617 | Meissner effect | 5G50.52 | Repulsion of the magnet and superconductor hanging from threads. Also, levitation of the magnet over the superconductor. |
| AJP 56(11),1039 | Meissner effect with a cork and salt | 5G50.53 | A magnet/cork in a vial filled with salt water so the float just sinks is placed over the superconductor. |
| AJP 39(1),113 | Meissner effect with liquid He | 5G50.55 | Technique for levitating a magnet over liquid He. |
| TPT 28(6),395 | floating magnet demonstration | 5G50.55 | A room temperature magnet is suspended 2 cm above a liquid helium cooled (5l/hr) lead plate in a supercooled container. Students can play with the magnet and feel the force. Discussion of what the Meissner effect really is. |
| AJP 59(1),16 | detailed explanation of levitation | 5G50.56 | Theoretical article - a discussion of levitation and other effects using Maxwell's work on eddy currents in thin conducting sheets instead of the London equation. |
| AJP 57(10),955 | Meissner oscillator | 5G50.58 | A pivoting needle with magnets on the ends oscillates between two superconducting discs. |
| | **MAGNETIC FIELDS & FORCES** | **5H00.00** | |
| | **Magnetic Fields** | **5H10.00** | |
| PIRA 500 | magnetic paper clip arrow | 5H10.10 | |

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| F&A, Er-6 | compass | 5H10.11 | A compass is used to find poles. |
| Sut, E-76 | compass needles & magnet | 5H10.11 | A large compass needle or dip needle is used as an indicator of magnetic field. |
| D&R, B-115 | homemade compass | 5H10.11 | Magnetize a knitting needle, drive through a cork, and float on water. |
| Mei, 32-3.1 | magnetoscope | 5H10.12 | A magnetoscope is constructed by hanging needles from the edge of a small brass disc. |
| D&R, B-010 | paper clip detector | 5H10.12 | A magnetoscope is constructed from hanging paper clips. |
| PIRA 500 | dip needle | 5H10.15 | |
| F&A, Er-7 | dip needle | 5H10.15 | A dip needle is used to show the inclination of the Earth's magnetic field. |
| Sut, E-111 | dip needle | 5H10.15 | Use a dip needle to find the local direction of the Earth's field. |
| Hil, E-6b | dip needle | 5H10.15 | A very large dip needle is shown next to the standard catalog size. Check it out. |
| D&R, B-115 | dip needle | 5H10.15 | Dip needle is used to indicate the direction of Earth's field relative to horizontal. |
| Disc 19-03 | dip needle | 5H10.15 | Turn a compass on its side. Animation. |
| PIRA 200 | Oersted's effect | 5H10.20 | Explore the field around a long wire with a compass needle. |
| UMN, 5H10.20 | Oersted's effect | 5H10.20 | Demonstrate Oersted's effect with a compass needle and a long wire carrying a heavy current. |
| F&A, Ei-8 | Oersted's effect | 5H10.20 | A compass needle is used to explore the field around a long wire. |
| Hil, E-7b | Oersted's effect | 5H10.20 | A compass deflects above and below a current carrying wire. ALSO- jumping wire. |
| D&R, B-105 | Oersted's effect | 5H10.20 | A compass needle is used to explore the field around a current carrying wire. |
| Disc 19-08 | Oersted's needle | 5H10.20 | Hold a current carrying wire over a bar magnet on a pivot and the magnet moves perpendicular to the wire. |
| Mei, 31-1.18 | Oersted's effect on the overhead projector | 5H10.22 | Four compass needles are arrayed around a vertical wire running through Plexiglas for use on the overhead projector. |
| Hil, E-7c | Oersted's effect on the overhead projector | 5H10.22 | Adapting the Oersted effect to the overhead projector. |
| Sut, E-122 | Oersted's effect | 5H10.23 | A current of 50 amps is passed through a heavy vertical wire and the field is investigated using a compass needle. |
| Sut, E-191 | magnetic field of current through electrolyte | 5H10.23 | A compass needle detects the magnetic field from 2 amps flowing in an electrolyte. |
| Mei, 31-1.19 | field independent of conductor type | 5H10.25 | A magnetic field produced current in copper, electrolyte, and a gas discharge tube is detected by a large compass needle. |
| Sut, E-121 | Oersted's effect | 5H10.25 | A heavy current from a storage cell is passed through a long wire and a compass needle is used to investigate the nearby field. Electrolyte or plasma may be substituted for the wire. |
| Mei, 31-1.25 | carrying large currents | 5H10.26 | Use flat braided brass cable instead of copper wire to carry large currents. |
| PIRA 200 | magnet and iron filings | 5H10.30 | Sprinkle iron filings on a glass sheet placed on top of a bar magnet. |
| UMN, 5H10.30 | magnet and iron filings on the overhead projector | 5H10.30 | |
| F&A, Er-4 | field of a magnet | 5H10.30 | Iron filings are sprinkled on a sheet of Plexiglas over a magnet. |
| Sut, E-89 | iron filings on the overhead projector | 5H10.30 | Sprinkle iron filings on a magnet between two glass plates. |
| D&R, B-110 | magnet and iron filings on the overhead projector | 5H10.30 | Iron filings are sprinkled on an acrylic tray over a magnet. |
| Disc 19-04 | magnetic fields around bar magnets | 5H10.30 | Sprinkle iron filings on a glass sheet covering a bar magnet. |
| AJP 36(11),1015 | particles in oil | 5H10.31 | A suspension of carbonyl nickel powder in silicon oil is used as an indicator of magnetic field. |
| AJP 38(6),777 | iron filings in glycerine | 5H10.31 | A sandwich of iron filings in glycerine between two glass plates. |
| Sut, E-90 | iron filings in glycerin | 5H10.31 | Soft iron bars extend the poles of a permanent magnet into a projection cell with iron filings in a equal mixture of glycerin and alcohol. |
| Bil&Mai, p 290 | iron filings in oil | 5H10.31 | Fill a small soda bottle with mineral oil and add some iron filings. Insert a test tube into the neck of the bottle and secure. Slide a cow magnet into the test tube and observe the three dimensional magnetic field lines. |
| AJP 41(4),566 | iron bars & 83 ton magnet | 5H10.32 | Students gather around a large electromagnet while holding iron bars. |
| AJP 42(3),259 | comment | 5H10.32 | On the health hazards of magnetic fields. |
| AJP 42(3),259 | reply to comment | 5H10.32 | Reply to the comment on the health hazards of magnetic fields - Field gradient is 1000 times weaker than exposure that has been studied. |
| TPT 3(7),320 | iron filings on glass plate stack | 5H10.33 | Make a 3-D view of magnetic fields by sprinkling iron filings on a series of stacked glass plates. |
| PIRA 1000 | area of contact | 5H10.50 | |

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| Sut, E-97 | area of contact | 5H10.50 | One end of a magnet 1 cm in diameter is truncated to .5 cm. The small end lifts a much larger piece of iron than the large one. |
| Sut, E-98 | area of contact | 5H10.51 | An electromagnet supports less weight when the face of the ring is against the pole than when the curved edge is. Diagram. |
| Sut, E-99 | area of contact | 5H10.52 | A soft iron truncated cone will support less weight when the large end is in contact with the face of an electromagnet. |
| PIRA 1000 | gap and field strength | 5H10.55 | |
| Mei, 32-3.23 | gap and field strength | 5H10.55 | Vary the gap of a magnet and measure the field with a gaussmeter. |
| TPT 28(2), 124 | field strength and gaussmeter | 5H10.55 | A mechanical device for measuring the magnet field of small permanent magnets. |
| TPT 40(5), 288 | field strength and gaussmeter | 5H10.55 | The magnetic field along the axis of a long finite solenoid measured with a gaussmeter. |
| TPT 40(5), 308 | magnetic fields with an IC chip | 5H10.57 | Measuring the fields of disk magnets with a homemade IC chip probe. |
| AJP 54(1), 89 | magnetic fields with an IC chip | 5H10.57 | Measuring magnetic fields with an IC chip probe in the introductory lab. |
| PIRA 1000 | shunting magnetic flux | 5H10.60 | |
| Sut, E-108 | shunting magnetic flux | 5H10.60 | Pick up a steel ball with a bar magnet, then slide a soft iron bar along the magnet toward the ball until it drops off. |
| PIRA 1000 | magnetic shielding | 5H10.61 | |
| Disc 19-20 | magnetic shielding | 5H10.61 | Slide sheets of copper, aluminum, and iron between an electromagnet and an acrylic sheet separating nails from the magnet. |
| Sut, E-107 | magnetic screening | 5H10.62 | Displace a hanging soft iron bar by attraction to a magnet, then interpose a sheet of iron. |
| Mei, 32-3.6 | magnetic shielding | 5H10.63 | A test magnet is used to show the shielding properties of a soft iron tube with various magnetic field generators. |
| PIRA 1000 | magnetic screening | 5H10.65 | |
| Sut, E-106 | magnetic screening | 5H10.65 | Hold a magnet above a nail attached to the table by a string, then interpose a sheet of iron. |
| Sut, E-105 | magnetic screening | 5H10.65 | Two horizontal sheets of glass separated by an air space intervene between an electromagnet and collection of nails being held up. Insert a sheet of iron into the space and the nails drop. |
| Mei, 29-4.7 | Compass in a changing magnetic field | 5H10.75 | Meiners places this demonstration in the Capacitors and Dielectrics section. (????) A compass is placed in the gap of an electromagnet and the field is reversed at various rates. |
| Mei, 31-1.22 | sensitive magnetometer | 5H10.80 | Building and operating a sensitive magnetometer. |
| | **Fields and Currents** | **5H15.00** | |
| PIRA 200 | iron filings around a wire | 5H15.10 | Iron filings are sprinkled around a vertical wire running through the center of a Plexiglas sheet. |
| UMN, 5H15.10 | field of wire and iron filings | 5H15.10 | |
| F&A, Ei-9 | magnetic field around a wire | 5H15.10 | Iron filings show the field of a wire passing through a sheet of Plexiglas. |
| Mei, 31-1.17 | iron filings around a wire | 5H15.10 | Iron filings are sprinkled around a vertical wire running through Plexiglas. |
| D&R, B-110 | iron filings around a wire | 5H15.10 | Iron filings are sprinkled around a current carrying wire, single loop, and solenoid. |
| Bil&Mai, p 301 | magnetic field around a wire | 5H15.10 | Iron filings are sprinkled around a current carrying solenoid. |
| Disc 19-09 | magnetic fields around currents | 5H15.10 | Iron filings around a current carrying wire, loop, coil, and solenoid. |
| Sut, E-130 | uniform and circular fields | 5H15.12 | Use iron filings to show the resultant of a vertical wire passing through a uniform field. |
| PIRA 1000 | right hand rule | 5H15.13 | |
| Disc 19-07 | right hand rule | 5H15.13 | Move a compass around a vertical wire with a current, reverse the current. Animation of the right hand. |
| PIRA 1000 | Biot-Savart law animation | 5H15.15 | |
| Disc 19-14 | Biot-Savart law | 5H15.15 | Animation. |
| PIRA 1000 | parallel wires and iron filings | 5H15.20 | |
| UMN, 5H15.20 | parallel wires and iron filings | 5H15.20 | |
| PIRA 1000 | anti-parallel wires and iron filings | 5H15.25 | |
| UMN, 5H15.25 | anti-parallel wires and iron filings | 5H15.25 | |
| PIRA 200 | solenoid and iron filings | 5H15.40 | A solenoid is wound through a piece of Plexiglas for use with iron filings on the overhead projector. |
| UMN, 5H15.40 | solenoid and iron filings | 5H15.40 | |
| F&A, Ei-10 | field of a solenoid | 5H15.40 | Iron filings show the field of a solenoid wound through a sheet of Plexiglas. |
| Mei, 31-1.20 | solenoid and iron filings | 5H15.40 | A solenoid is wound through a piece of Plexiglas for use with iron filings on the overhead projector. |
| TPT 28(4),244 | iron filings in a ziploc bag | 5H15.41 | Seal an iron filing/glycerol mixture in a ziploc bag. |
| Sut, E-129 | iron filings in glycerin | 5H15.41 | A glass cylinder filled with iron filings in a solution of glycerin and alcohol is inserted into a solenoid. |

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| Mei, 31-1.21 | length of a solenoid | 5H15.43 | A large solenoid is constructed to make it easy to change the spacing of turns and therefore the length. A magnetometer or coil is used to show field strength, Picture, Diagrams. |
| Sut, E-92 | small coils in a solenoid | 5H15.45 | A no iron magnetism model. An array of small coils is mounted inside a large solenoid. Small springs keep the small coils aligned randomly when no current is applied. |
| AJP 56(5),478 | demountable Helmholtz coils | 5H15.46 | On making large square demountable Helmholtz coils. |
| Hil, E-9d | Helmholtz coils | 5H15.46 | Generation of a large uniform magnetic field by Helmholtz coils. |
| Hil, E-9c | long solenoid | 5H15.47 | The long solenoid used in the e/m experiment is shown. |
| PIRA 200 - Old | field of a toroid | 5H15.50 | Iron filings show the field of a toroid which is wound through a sheet of Plexiglas. |
| UMN, 5H15.50 | torroid and iron filings | 5H15.50 | Same as Ei-11. |
| F&A, Ei-11 | field of a toroid | 5H15.50 | Iron filings show the field of a toroid wound through a sheet of Plexiglas. |
| Mei, 32-1.1 | iron filings on the overhead | 5H15.60 | Iron filings in a viscous liquid permit field configurations to be shown. More. |
| Sut, E-123 | iron filings on the overhead | 5H15.60 | Iron filings are sprinkled on glass plates that have a single wire, parallel wires, and a solenoid passing through holes. |
| Mei, 32-3.3 | filings in castor oil | 5H15.61 | Small iron filings are sprinkled onto a thin layer of castor oil and a magnetic field is applied. |
| AJP 28(2),147 | quantitative field of a coil | 5H15.65 | Apparatus Drawings Project No. 2: A search coil is mounted on a movable arm with provision for reading angle and distance. |
| | **Forces on Magnets** | **5H20.00** | |
| PIRA 200 | magnets on a pivot | 5H20.10 | One magnet is placed on a pivot, the other is used to attract or repel the first. |
| UMN, 5H20.10 | magnets on a pivot | 5H20.10 | A magnet is placed in a cradle. A second magnet is used to attract and repel the first. |
| F&A, Er-2 | interaction between bar magnets | 5H20.10 | Bar magnets on pivots. |
| Disc 19-01 | magnetic attraction/repulsion | 5H20.10 | One magnet is placed on a pivot, the other is used to attract or repel the first. |
| PIRA 1000 | snap the lines of force | 5H20.15 | |
| UMN, 5H20.15 | snap the lines of force | 5H20.15 | |
| PIRA 500 | levitation magnets | 5H20.20 | |
| UMN, 5H20.20 | levitation magnets | 5H20.20 | Two ring magnets are placed on an upright test tube with like poles facing. |
| F&A, Er-11 | levitation of magnetic discs | 5H20.20 | Two disc magnets are suspended with like poles facing on an inverted test tube. |
| D&R, B-060 | levitation by repulsion | 5H20.20 | Ring magnets on a vertical rod will form an oscillating system. |
| F&A, Er-10 | magnetic suspension | 5H20.21 | Two notched bar magnets are held with like poles facing. |
| AJP, 65(4), 286-292 | spin stabilized magnet levitation. The Levitron toy. | 5H20.22 | A treatise on the toy that consists of a spinning magnet that levitates itself above a large circular magnet. |
| PIRA 1000 | centrally levitating magnets | 5H20.23 | |
| PIRA 1000 | linearly levitating magnets | 5H20.24 | |
| PIRA 1000 | inverse square law | 5H20.30 | |
| UMN, 5H20.30 | inverse square law | 5H20.30 | Same as AJP 31(1),60. |
| AJP 41(12),1332 | inverse square law - magnetism | 5H20.30 | A balance to measure the repulsion of two bar magnets. See AJP 31(1),60. |
| AJP 31(1),60 | inverse square law - magnetism | 5H20.30 | A balance is made out of a meter stick with a magnet on one end facing the pole of another similar magnet. Adjust the distance between the magnets and slide the counterbalance along the meter stick until equilibrium is reached. |
| Sut, E-86 | magnetic balance | 5H20.30 | Use a bar magnet brought near a second bar magnet counterweighted and on a knife edge to roughly verify the inverse square law. |
| Sut, E-87 | hanging magnets | 5H20.33 | Hang two magnets horizontally and parallel. Use the inverse square law to compute the pole strength from the length of the suspension, the saturation, and mass of the magnets. |
| PIRA 1000 | inverse square law balance | 5H20.35 | |
| UMN, 5H20.35 | inverse square law | 5H20.35 | |
| AJP 51(11),1023 | inverse squared power - magnetism | 5H20.35 | Three simple variations of magnets levitating in a glass tube are used to show a force varying with the inverse of the distance squared. |
| PIRA 1000 | inverse fourth law - dipoles | 5H20.40 | |
| AJP 74(6), 510 | inverse fourth law - dipoles | 5H20.40 | The paper extends previous work on the inverse fourth law dipole-dipole force by using the more powerful rare earth magnets. |
| Mei, 32-1.2 | inverse fourth power - magnetism | 5H20.40 | Equipment shows the force between two dipoles varies as the inverse fourth power of the separation. Pictures. |
| PIRA 1000 | inverse seventh law - magnet/iron | 5H20.50 | |

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| Mei, 32-1.3 | inverse seventh power - magnetism | 5H20.50 | Apparatus to show the force between a magnet and a piece of soft iron varies with the inverse seventh of the separation. Diagram, Picture. |
| | **Magnet / Electromagnet Interaction** | **5H25.00** | |
| PIRA 1000 | magnet in a coil | 5H25.10 | |
| UMN, 5H25.10 | magnet in a coil | 5H25.10 | |
| F&A, Er-1 | interaction of magnet and coil | 5H25.10 | A solenoid on a pivot and a magnet on a pivot interact. |
| F&A, Ei-7 | interaction of flat coil & bar magnet | 5H25.10 | A bar magnet is mounted in a large flat coil. |
| Sut, E-124 | magnet in a coil | 5H25.10 | The deflection of a compass needle in the center of a large coil placed in the plane of the magnetic meridian is proportional to the tangent of the current. |
| D&R, B025, B-030, & B-230 | magnet in a coil | 5H25.10 | A large compass, magnet, or solenoid shows the field inside a set of Helmholtz coils. |
| Disc 19-10 | solenoid bar magnet | 5H25.10 | A suspended solenoid reacts with a bar magnet only when the current is on. |
| F&A, Er-3 | period of a bar magnet | 5H25.15 | A magnet oscillates in a coil proportional to the square of the current in the coil. |
| PIRA 1000 | jumping magnet | 5H25.20 | |
| UMN, 5H25.20 | jumping magnet | 5H25.20 | Place a bar magnet in a vertical transformer and apply DC with a tap switch. |
| PIRA 1000 | force on a solenoid core | 5H25.25 | |
| Sut, E-128 | force on solenoid core | 5H25.25 | When a solenoid is energized a iron core is violently drawn into the coil. |
| Sut, E-137 | unipolar motor | 5H25.60 | Two magnetized knitting needles mounted as the legs of an "H" suspended by a string rotate when a current flows upward through a rod. |
| TPT, 36(8), 474 | a different twist on the Lorentz force and Faraday's law | 5H25.65 | An analysis of the interplay between rotating magnets and currents is illuminated using a homopolar magnet structure. |
| Mei, 31-1.30 | floating magnetic balls | 5H25.70 | Thousands of small magnetic balls floating freely on the surface of water form hills and hollows when excited by an AC magnetic field. Pictures. |
| AJP 43(1),111 | Ampere's ants | 5H25.75 | A fun hall display: hide a pushbutton controlled magnetic stirrer under a dish of iron filings. |
| | **Force on Moving Charges** | **5H30.00** | |
| PIRA 200 | cathode ray tube | 5H30.10 | Deflect the beam in an open CRT with a magnet. |
| UMN, 5H30.10 | cathode ray tube | 5H30.10 | A magnet or battery connected to the plates is used to deflect the beam of an open CRT. |
| F&A, Ep-11 | e/m for electrons | 5H30.10 | Deflect the beam in an open CRT with a magnet. |
| D&R, B-015 | cathode ray tube | 5H30.10 | Deflect the beam on the tube face of an old CRT with a magnet. |
| Sprott, 5.1 | cathode ray tube | 5H30.10 | A permanent magnet brought near a cathode ray tube causes a displacement or distortion of the pattern on the fluorescent screen. |
| Sut, A-72 | measurement of e/m | 5H30.11 | Use the Earth's field to deflect the beam in an oscilloscope. |
| Sut, A-73 | measurement of e/m | 5H30.12 | Deflect the beam of an oscilloscope with large solenoids. |
| Sut, A-74 | measurement of e/m | 5H30.13 | Deflect the beam of an oscilloscope by current in wires parallel to the axis of the tube. |
| Mei, 31-1.11 | another tube | 5H30.14 | A Hg tube producing a visible beam is deflected by external magnetic field. Pictures. |
| PIRA 1000 | bending an electron beam | 5H30.15 | |
| UMN, 5H30.15 | bending an electron beam | 5H30.15 | |
| F&A, Ep-8 | bending of an electron beam | 5H30.15 | An electron beam hitting a fluorescent screen in a tube is bent by a magnet. |
| Sut, A-71 | deflection of cathode rays | 5H30.15 | A thin beam along a fluorescent screen is bent by a magnet or charged rod. |
| D&R, B-015 | bending an electron beam | 5H30.15 | An electron beam hitting a fluorescent screen in a tube is bent by a magnet. |
| Disc 20-03 | deflected electron beam | 5H30.15 | A thin electron beam made visible by a fluorescent screen is bent when a magnet is brought near. |
| AJP 51(6),572 | induced charges and the Crookes tube | 5H30.16 | A discussion of unwanted deflections of the beam in the Crookes' tube due to induced charge. |
| AJP 29(10),708 | CRT and Earth's field | 5H30.17 | A CRT is mounted so it can be oriented in any direction and rotated about its axis. Find the position that results in no deflection from the Earth's field, turn 90 degrees. |
| AJP 38(9),1133 | analog computer simulation | 5H30.19 | The motion of a charged particle in a magnetic field is investigated with an analog computer. Circuit diagram for the computer is given. |
| PIRA 200 - Old | e/m tube | 5H30.20 | Show the beam of the small e/m tube in Helmholtz coils on TV. A hand held magnet gives a corkscrew. |

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| UMN, 5H30.20 | e/m tube | 5H30.20 | The beam of the small e/m tube in Helmholtz coils is shown on TV. A hand held magnet gives a corkscrew. |
| F&A, Ei-18 | forces on an electron beam | 5H30.21 | A beam of free electrons is bent in a circle by large Helmholtz coils. |
| AJP 77 (12), 1102 | forces on an electron beam | 5H30.21 | Two methods for measuring the charge to mass ratio e/m of the electron using thermionic emissions as that exploited in vacuum tube technology. |
| Sut, A-20 | magnetic deflection of cathode rays | 5H30.22 | A beam from a lime-spot cathode in a large bulb is made circular by Helmholtz coils. |
| Sut, A-19 | "Aurora Borealis" | 5H30.22 | A magnet is brought near a 12 L bulb with a lime-spot cathode. |
| AJP 29(1),26 | Classen's e/m | 5H30.24 | Apparatus Drawings Project No. 11: for the advanced undergraduate laboratory. |
| PIRA 1000 | magnetic mirror | 5H30.25 | |
| AJP 31(5),397 | magnetic mirror | 5H30.25 | The effect is better with the Leybold tube. |
| AJP 31(6),459 | Van Allen belt | 5H30.25 | Use the tube and magnets to demonstrate trapping of charged particles by the Earth's magnetic field. |
| Disc 20-04 | fine beam tube | 5H30.25 | A fine beam tube between Helmholtz coils. |
| AJP 30(12),867 | magnetic mirror effect | 5H30.26 | Bring a bar magnet near the Cenco e/m tube causing charges to spiral into a converging magnetic field. |
| AJP 35(10),968 | e/m modificaton | 5H30.29 | Use a half wave rectifier for filament heating. |
| AJP 35(2),157 | e/m modification - Welch | 5H30.29 | Use ac instead of dc to heat the filament. |
| PIRA 1000 | rotating plasma | 5H30.30 | |
| F&A, Ei-17 | rotating plasma | 5H30.30 | A plasma tube powered by an induction coil is placed over an electromagnet. |
| Sut, E-151 | pinching mercury | 5H30.40 | A thread of mercury in a glass tube is pinched in two by the interaction of the current and the conductor. |
| Mei, 31-1.8 | bending arc | 5H30.41 | A dc arc bends and may break as a bar magnet is brought close and closer. |
| PIRA 1000 | electromagnetic pump | 5H30.50 | |
| F&A, Ei-14 | electromagnetic pump | 5H30.50 | Mercury is pumped in a tube built so current flows at right angles to the applied magnetic field. |
| Mei, 31-1.9 | electromagnet pump | 5H30.50 | Current flowing in mercury while in a magnet field causes the mercury to move through a channel. Also shows a paddlewheel version. |
| Mei, 31-1.10 | electromagnetic pump | 5H30.50 | A closed circuit version of the electromagnetic mercury pump. |
| Hil, E-7g.2 | magnetic pump | 5H30.51 | Copper sulfate solution flows in a circle when placed between the poles of a magnet with a current from the center to edge. |
| AJP 38(3),389 | MHD pump | 5H30.52 | Three versions of MHD pumps: the one for lecture demonstration consists of a loop of Pyrex tubing with NaK as the fluid. |
| PIRA 1000 | ion motor | 5H30.55 | |
| Mei, 31-1.13 | ion motor | 5H30.55 | An ion motor for the overhead projector with cork dust in a copper sulfate solution. |
| Sut, E-194 | rotation of an electrolyte in a magnetic field | 5H30.55 | Cork dust floating on a solution of zinc chloride in a circular container rotates when current is passed through the solution in the presence of a magnetic field. |
| AJP, 75 (4), 361 | rotation of an electrolyte - magnetic field | 5H30.55 | Description of the magnetohydrodynamic flow of an electrically conducting fluid between two stationary coaxial cylindrical electrodes. A neodymium - iron - boron magnet is used. |
| Disc 20-06 | ion motor | 5H30.55 | Cork dust shows the motion of copper sulfate an ion motor. Animation. |
| F&A, Ei-13 | force on a conducting fluid | 5H30.56 | Salt solution rotates when placed in a circular dish over a magnet with electrodes at the center and edge. |
| | **Force on Current in Wires** | **5H40.00** | |
| PIRA 200 | parallel wires | 5H40.10 | Long vertical parallel wires attract or repel depending on the current direction. |
| UMN, 5H40.10 | parallel wires | 5H40.10 | Long vertical parallel wires attract or repel depending on the current direction. |
| F&A, Ei-1 | force between parallel wires | 5H40.10 | Current can be passed parallel or antiparallel in long hanging wires. |
| Sut, E-148 | parallel wires | 5H40.10 | Two heavy vertical wires 1 cm apart pass 15 - 20 amps in the same or opposite directions. |
| Hil, E-9b | parallel conductors | 5H40.10 | Vertical parallel wires pass 15 amps. |
| Bil&Mai, p 295 | parallel wires | 5H40.10 | Long vertical parallel wires attract or repel depending on the current direction. |
| AJP 31(1),59 | parallel wires, etc | 5H40.11 | Rectangular loops of solid wire hang on pivots from two stands. Used together, demonstrate parallel wires, or one stand alone can be used for wire in a magnetic field or induced emf. |
| Mei, 31-1.26 | parallel wires | 5H40.12 | Parallel wires with one being a loop free to turn in pools of mercury. |
| AJP 45(1),106 | parallel wires ammeter | 5H40.13 | Modification of the Project Physics exp. 36 gives an accuracy of 3%. |
| F&A, Ei-4 | force between parallel wires | 5H40.14 | Radial wires (like clock hands) spring apart when current is passed. |
| PIRA 200 | interacting coils | 5H40.15 | Two hanging loops attract or repel depending on current direction. |

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| Sut, E-149 | parallel wires and loops | 5H40.15 | A narrow loop formed by hanging a flexible wire opens when current is passed. Two loops in proximity attract or repel depending on current direction. |
| PIRA 500 | pinch effect simulation | 5H40.20 | |
| UMN, 5H40.20 | pinch effect simulation | 5H40.20 | Same as AJP 32(11),xxiv. |
| AJP 32(11),xxiv | pinch effect simulation | 5H40.20 | Six no. 18 wires are connected loosely between two terminals. Pass 20 amps and the bundle is attracted. |
| Mei, 31-1.27 | pinch effect | 5H40.20 | Six vertical parallel wires are loosely hung in a circular arrangement. |
| Disc 19-13 | pinch wires | 5H40.20 | Six wires in parallel attract when current passes through each in the same direction. Then sets of three wires each have current flowing in opposite directions. |
| Mei, 31-1.28 | pinch effect | 5H40.21 | A high voltage capacitor is discharged through a cylinder of aluminum foil strips. |
| PIRA 1000 | filament and magnet with AC/DC | 5H40.23 | |
| Sut, E-139 | vibrating lamp filament | 5H40.23 | A tube lamp with a straight filament on AC will vibrate when placed between the poles of a magnet. |
| Hil, E-7d | vibrating lamp filament | 5H40.23 | A magnet is brought near carbon filament lamps, one powered by AC, the other by DC. The images are projected. |
| D&R, B-020 | vibrating lamp filament | 5H40.23 | A lamp filament on AC will vibrate when a magnet is brought near. |
| Disc 20-07 | AC/DC magnetic contrast | 5H40.23 | A magnet is brought near a carbon lamp filament powered by DC, then AC. |
| Sut, E-140 | AC driven sonometer | 5H40.24 | A sonometer tuned to resonate at a harmonic of 60 Hz is driven by passing AC through the wire while between the poles of a magnet. |
| PIRA 1000 | dancing spiral | 5H40.25 | |
| F&A, Ei-2 | dancing spiral | 5H40.25 | Current is passed through a limp copper spring dangling in a pool of mercury causing it to dance. |
| Sut, E-150 | dancing spring | 5H40.25 | A helix of fine wire hanging vertically into a pool of mercury contracts and breaks contact repeatedly. |
| D&R, B-120 | dancing Slinky | 5H40.25 | Pass a current through a small Slinky on the overhead and watch contraction. |
| PIRA 200 | jumping wire | 5H40.30 | A wire is placed in a horseshoe magnet and connected to a battery. The wire jumps out of the magnet. |
| F&A, Ei-12 | magnetic force on a wire | 5H40.30 | A wire is placed in a horseshoe magnet and connected to a battery. |
| Bil&Mai, p 292 | jumping wire | 5H40.30 | A wire is place between the poles of a horseshoe magnet and connected to a battery. The wire will either jump into or out of the magnet depending on current direction in the wire. |
| F&A, Ei-20 | jumping wire | 5H40.31 | A large heavy wire clip rests in pools of mercury between the poles of a strong magnet. |
| Sut, E-132 | aluminum bar in a magnet | 5H40.32 | An aluminum bar in a magnet has its ends in mercury. Short the mercury pools to a storage battery and the aluminum bar hits the ceiling. |
| Sut, E-141 | electomagnetic circuit breaker | 5H40.33 | A wire hangs into a pool of mercury and between the poles of a "U" shaped magnet. As current is passed through the wire, it deflects out of the mercury and breaks the circuit. |
| Sut, E-131 | lead foil in magnet | 5H40.34 | A strip of lead foil is supported vertically between the poles of a "U" magnet so it is free to move a few cm when a few dry cells are connected through a reversing switch. |
| PIRA 1000 | jumping wire coil | 5H40.35 | |
| UMN, 5H40.35 | jumping wire | 5H40.35 | A coil of wire wound around one pole of a horseshoe magnet jumps off when energized. |
| D&R, B-020 | jumping wire | 5H40.35 | Connect a battery to a wire hanging in a strong magnetic field. |
| Disc 20-01 | jumping wire coil | 5H40.35 | Run twenty amps through a wire in a horseshoe magnet. |
| PIRA 1000 | long wire in field | 5H40.36 | |
| UMN, 5H40.36 | long wire in field | 5H40.36 | |
| UMN, 5H40.37-PIRA LOCAL | take apart speaker | 5H40.37 | Add abstract in Handbook.FM |
| TPT 45(5), 274 | Lorentz force - jumping wire with a twist | 5H40.38 | The Lorentz force on a current carrying wire situated in a magnetic field. Demonstrates a slow varying alternating current by means of an optical lever. |
| PIRA 500 | current balance | 5H40.40 | |
| Sut, E-138 | current balance | 5H40.40 | An open rectangle of aluminum wire is balanced between the poles of a "U" magnet until current is passed through the part perpendicular to the field. |
| Mei, 31-1.2 | triangle on a scale in a magnet | 5H40.42 | A triangular loop of wire is hung from a spring scale in the mouth of a electromagnet and the current in the loop is varied. |
| AJP 53(12),1213 | improved current balance | 5H40.43 | Improvements on the Sargent-Welch current balance increasing the range to 20 A. |

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| AJP 45(6),590 | modified current balance | 5H40.43 | Add molten Wood's metal contacts to the Sargent Welch current balance. |
| F&A, Ei-5 | current balance | 5H40.43 | The Welch current balance. |
| TPT 2(3),128 | current balance | 5H40.44 | Design of a current balance with a rectangular coil on knife edges and stationary windings with parallel conductors. |
| Sut, E-152 | Maxwell's rule | 5H40.46 | Demonstrates an electric circuit that can change shape to include the maximum possible magnetic flux. A heavy wire connects two metal boats floating in mercury troughs with electrodes at one end. |
| AJP 31(1),xiii | CERN floating wire pulley | 5H40.48 | Shows a pulley for the "floating wire" technique of simulating a beam of particles in magnetic fields. The method can be adapted to measure the radius of curvature of a wire in a magnetic field. |
| PIRA 500 | Barlow's wheel | 5H40.50 | |
| F&A, Ei-15 | Barlow's wheel | 5H40.50 | A copper disk with current flowing from the center to a pool of mercury at the edge rotates when placed between the poles of a horseshoe magnet. |
| Mei, 31-1.5 | Barlow's wheel | 5H40.50 | A potential is applied from the axle of a wheel to a pool of mercury at the rim while the wheel is between the poles of a magnet. |
| Sut, E-136 | Barlow's wheel | 5H40.50 | Current passes from the bearings of a copper wheel mounted vertically to a pool of mercury at the base. A "U" shaped magnet is mounted so the current is perpendicular to the magnetic field. |
| Hil, E-7g.1 | Barlow's wheel | 5H40.50 | A picture of the standard vertical disc in a pool of mercury. |
| Disc 20-05 | Barlow's wheel | 5H40.50 | Current flows radially in a disc mounted between the poles of a magnet. |
| Mei, 31-1.6 | Barlow's wheel | 5H40.52 | The copper disk in Barlow's wheel is replaced by a cylindrical Alnico magnet with the field parallel to its axis. |
| AJP 29(9),635 | homopolar motor | 5H40.53 | Variation of Barlow's wheel. An Alnico disk, magnetized in the direction of the axis, rotates around the axis when a current is made to flow from the axis to the rim. |
| AJP 70(10), 1052 | homopolar motor | 5H40.53 | An argument for the relativeistic viewpoint for a homopolar motor. |
| AJP 38(11),1273 | conducting spiral | 5H40.55 | A conducting spiral is constructed as a simplified unipolar machine. |
| Sut, E-133 | electromagnetic swing | 5H40.60 | Switch the current direction in a wire loop swing mounted above one pole of a vertical bar magnet to build up a pendulum motion. |
| Sut, E-134 | magnetic grapevine | 5H40.61 | A very flexible wire suspended alongside a vertical bar magnet will wrap itself around the magnet when there is a current in the wire. |
| Sut, E-142 | electromagnetic conical pendulum | 5H40.62 | A vertical wire is suspended loosely from above a vertical solenoid into a circular trough of mercury. As current is passed through the wire, it rotates in the trough. |
| PIRA 1000 | Ampere's motor | 5H40.70 | |
| Sut, E-143 | Ampere's frame | 5H40.70 | A coil on a reversing switch is placed between the poles of strong magnets. |
| Disc 20-02 | Ampere's frame | 5H40.70 | A magnet is brought near and rotates a large current carrying loop. |
| Mei, 31-1.3 | Ampere's motor | 5H40.71 | A copper rod rolls along two electrified rails over ring magnets sandwiched between steel plates. |
| Mei, 31-1.4 | Ampere's motor | 5H40.71 | A wheel on electrified rails over a large vertical field produced by electromagnets rolls back and forth depending on the current direction. Picture. |
| Sut, E-135 | Ampere's motor | 5H40.71 | As the current is reversed in a rod rolling horizontally on a track between the poles of a strong magnet, the direction of motion reverses. |
| Bil&Mai, p 297 | Ampere's motor | 5H40.71 | An aluminum pipe rolls along two electrified rails that have flat ceramic magnets glued between them. The magnets must all have the same poles facing up. |
| | **Torques on Coils** | **5H50.00** | |
| PIRA 200 | model galvanometer | 5H50.10 | |
| PIRA 500 - Old | model galvanometer | 5H50.10 | |
| UMN, 5H50.10 | model galvanometer | 5H50.10 | A crude galvanometer with a large coil and magnet demonstrates the essentials. |
| F&A, Ej-2 | galvanometer with permanent magnet | 5H50.10 | An open galvanometer with a permanent magnet. |
| F&A, Ej-1 | elements of a galvanometer | 5H50.10 | A large working model of a galvanometer. |
| Sut, E-145 | d'Arsonval galvanometer | 5H50.10 | A large model d'Arsonval galvanometer is constructed from a coil and a large "U" shaped magnet. |
| Bil&Mai, p 299 | model galvanometer | 5H50.10 | A crude galvanometer with a large coil and magnets demonstrates the essentials. |
| Disc 20-08 | D'Arsonval meter | 5H50.10 | A large open galvanometer. |
| PIRA 1000 | force on a current loop | 5H50.20 | |
| UMN, 5H50.20 | force on a current loop | 5H50.20 | |
| Hil, E-7a | Joseph Henry | 5H50.20 | A rectangular loop of wire aligns perpendicular to a magnetic field. Reference: TPT 3(1),13. |
| PIRA 1000 | short and long coils in a field | 5H50.25 | |

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| UMN, 5H50.25 | short and long coils in a field | 5H50.25 | |
| UMN, 5H50.30 | interacting coils | 5H50.30 | |
| F&A, Ei-6 | interaction of flat coils | 5H50.30 | A small free turning coil is mounted in a larger coil. |
| Mei, 31-1.29 | interacting coils | 5H50.30 | Two horizontal coaxial coils, the inner stationary and the outer larger coil suspended freely, interact when currents are passed through in like or opposite directions. |
| UMN, 5H50.30 - PIRA LOCAL | interacting rotating coils | 5H50.30 | Add abstract in Handbook.FM |
| Mei, 31-2.11 | coil in coils | 5H50.31 | A solenoid attached to a battery is mounted in a large open Helmholtz coils assembly. ALSO - three other demos with the Helmholtz coils. Pictures. |
| D&R, B-035 | torques on plane coils | 5H50.31 | Flat and solenoid coils are suspended in the field of Helmholtz coils |
| F&A, Ei-3 | interacting solenoids | 5H50.32 | Two heavy copper horizontal solenoids pivot in mercury cups about a vertical axis. |
| PIRA 1000 | dipole loop around a long wire | 5H50.35 | |
| Sut, E-125 | solenoid in a magnetic field | 5H50.40 | Suspend a solenoid and show the effects of a bar magnet on it. |
| Sut, E-144 | floating coil | 5H50.41 | A vertical coil energized by a flashlight cell floats in a large pan. Use a bar magnet to move the coil. |
| PIRA 1000 | spinning coil over a magnet | 5H50.45 | |
| UMN, 5H50.45 | spinning coil over a magnet | 5H50.45 | |
| | **INDUCTANCE** | **5J00.00** | |
| | **Self Inductance** | **5J10.00** | |
| PIRA 500 | inductor assortment | 5J10.10 | |
| Hil, E-12a | inductor assortment | 5J10.10 | Sample inductors are shown. |
| PIRA 500 | back EMF - light bulb | 5J10.20 | |
| UMN, 5J10.20 | back EMF | 5J10.20 | A 20 Henry inductor energized by a 12 V battery lights a 120 V 7 1/2 W lamp when the circuit is opened. |
| Mei, 31-3.6 | back EMF | 5J10.20 | When current is cut off in the primary, a meter in parallel shows an induction current in the primary. |
| Sut, E-252 | self inductance | 5J10.20 | Open the switch of a large electromagnet with a lamp in parallel. |
| Sut, E-254 | back EMF | 5J10.21 | A 4.5 V battery lights a neon bulb when the current to an inductor is disrupted. |
| Sut, E-253 | neon back EMF | 5J10.22 | The coils of a electromagnet are connected in parallel with a neon bulb. |
| Hil, E-12d | neon self induction | 5J10.23 | A neon lamp across an inductor will glow on one side during charging and will flash on the other when the current is interrupted. |
| Sut, E-255 | inductance and the wheatstone bridge | 5J10.25 | The galvanometer in a Wheatstone bridge is connected after an inductor has reach steady state or at the same time the current is started in the inductor. |
| AJP 58(3),278 | simulating ideal self-induction | 5J10.26 | A nulling circuit compensates for the steady state current in a coil. |
| PIRA 1000 | back EMF - spark | 5J10.30 | |
| Hil, E-12b | back EMF spark | 5J10.30 | A one inch spark is produced when the switch of a large electromagnet is opened. |
| Disc 21-01 | back EMF spark | 5J10.30 | Disconnect a 6 V battery from a 2000 turn coil to get a spark, enhance with an iron core. |
| Sut, E-256 | electromagnetic inertia | 5J10.32 | A spark will jump across an almost closed loop of wire rather than go around when attached to a Leyden jar. |
| | **LR Circuits** | **5J20.00** | |
| PIRA 200 | RL time constant on scope | 5J20.10 | Show the RL time constant on a scope. |
| UMN, 5J20.10 | RL time constant on scope | 5J20.10 | The current and voltage of a slow time constant RL circuit are displayed on a dual trace storage oscilloscope. |
| F&A, Eo-11 | RL time constant | 5J20.10 | A plug in circuit board with a make before break switch for showing slow RL time constants on the oscilloscope. |
| F&A, En-6 | RL time constant | 5J20.10 | The RL time constant is shown on a scope. |
| D&R, B-315, B-320 | RL time constant | 5J20.10 | Show RL time constant with a projection meter or oscilloscope. |
| F&A, En-7 | time constant of an inductive circuit | 5J20.11 | Compare the time constant of an inductor using different cores on an oscilloscope. |
| PIRA 200 | lamps in series or parallel with an inductor | 5J20.20 | Hook light bulbs in series with a large electromagnet. |
| F&A, En-5 | current in an inductive circuit | 5J20.20 | Light bulbs across and in series with a large electromagnet show the current in an inductive circuit. |
| Mei, 31-3.5 | lamps in series and parallel with an electromagnet | 5J20.20 | Two lamps are used to indicate voltage across and current through a large electromagnet. |
| Hil, E-12c | series lamps with an electromagnet | 5J20.20 | Light bulbs are hooked up in series with a large electromagnet. |
| D&R, B-310 | current in an inductive circuit | 5J20.20 | Light bulbs across and in series with a large inductor show the current in an inductive circuit. Also flash due to back EMF when switch is opened. |

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| Disc 21-03 | lamps in parallel with a solenoid | 5J20.20 | Apply 110 V to a large solenoid with incandescent and neon lamps in parallel. The neon lamp flashes on the opposite side on discharge. |
| Mei, 31-3.1 | lights in series and parallel | 5J20.21 | A circuit with a 5 H inductor has neon lamps in series and in parallel. |
| Mei, 33-5.1 | inductor characteristics | 5J20.25 | A bulb in parallel with a coil does not burn when powered by dc, but does when coupled to a high frequency source. |
| Sut, E-257 | RL time constant | 5J20.30 | Substitute an inductor and a resistor of the same R in a circuit that lights a neon bulb. |
| | **RLC Circuits - DC** | **5J30.00** | |
| PIRA 500 | RLC ringing | 5J30.10 | |
| UMN, 5J30.10 | RLC ringing | 5J30.10 | The voltages across the L and C of a slow RLC circuit are displayed on a dual trace storage oscilloscope while the circuit is energized and de-energized. |
| F&A, Eo-14 | characteristic times in a parallel | 5J30.10 | Slow parallel RLC ringing on an oscilloscope. |
| F&A, En-9 | ringing circuit | 5J30.10 | Ringing from an RLC circuit is shown on an oscilloscope. |
| F&A, Eo-13 | characteristic times in a series RLC | 5J30.10 | Slow series RLC ringing on an oscilloscope. |
| Hil, A-8c | RLC ringing | 5J30.10 | A circuit for showing LC ringing on a oscilloscope. |
| Disc 21-05 | damped RLC oscillation | 5J30.11 | Discharge a capacitor through a series RLC circuit. Vary the capacitance and resistance. |
| Mei, 33-1.1 | RLC ringing | 5J30.15 | A motor driven commutator switches a circuit from charging to discharging so RLC ringing decay can be observed on an oscilloscope. Picture, Diagram, Construction details in appendix, p.1334. |
| Sut, E-267 | RLC ringing | 5J30.20 | A DC circuit with RC charging and RLC discharging. |
| Sut, E-266 | RLC ringing | 5J30.21 | A circuit to charge a capacitor either with or without an inductance in series. |
| Sut, A-10 | singing arc | 5J30.30 | A ordinary carbon arc is shunted by a series LC circuit. |
| | **ELECTROMAGNETIC INDUCTION** | **5K00.00** | |
| | **Induced Currents and Forces** | **5K10.00** | |
| PIRA 500 | sliding rail | 5K10.10 | |
| UMN, 5K10.10 | sliding rail | 5K10.10 | Slide a brass bar riding on two brass rails out of the mouth of a horseshoe magnet and display the current on a galvanometer. |
| F&A, Eq-1 | sliding rail inductor | 5K10.10 | Slide a bar on rails attached to a galvanometer through the mouth of a horseshoe magnet. |
| F&A, Eq-2 | mu metal shield | 5K10.11 | The sliding rail with a mu-metal shield gives the same result. |
| F&A, Eq-3 | mu metal shield and insulator | 5K10.12 | The sliding rail with an insulated mu metal shield still gives the same result. |
| Sut, E-218 | motional EMF | 5K10.13 | Directions on making an apparatus for demonstrating motional EMF. Reference: Am. Phys. Teacher, 3,57,1935. |
| PIRA 500 | wire, magnet, and galvanometer | 5K10.15 | |
| Sut, E-215 | moving wire with magnet | 5K10.15 | A straight wire connected to a galvanometer is moved rapidly through the poles of a strong magnet. |
| Disc 20-11 | wire and magnet | 5K10.15 | Move a wire connected to a galvanometer in and out of a horseshoe magnet. |
| PIRA 1000 | tape head model | 5K10.16 | |
| Mei, 31-1.1 | swinging bar in a magnet | 5K10.17 | A bar connected to a galvanometer is swung in and out of a permanent magnet. ALSO - two other demonstrations. |
| AJP 49(1),90 | coil pendulum in a magnet | 5K10.18 | A 1 second pendulum with a coil for a bob swings with small amplitude within a uniform magnetic field. All sorts of variations demonstrating forced, free, and damped oscillations are mentioned. |
| AJP 28(8),745 | measuring magnetic induction | 5K10.19 | A rectangular coil in a magnetron magnet is rotated on one side and the other is suspended from a balance. Change the current in the coil and measure the force with the balance. |
| PIRA 200 | induction coil with magnet, galvanometer | 5K10.20 | A magnet is moved in and out of a coil of wire attached to a galvanometer. |
| UMN, 5K10.20 | induction coil with magnet, galvanometer | 5K10.20 | A magnet is moved in and out of a coil of wire attached to a galvanometer. |
| AJP 48(8),686 | big coil | 5K10.20 | Make the coil large enough for the instructor to walk, run, etc. through. |
| AJP 72(3), 376 | induction coil, magnet, PC interface | 5K10.20 | A magnet oscillating through a coil attached to a PC interface. Use this to investigate Lenz's law and the conservation of energy. |
| AJP 70(4), 424 | induction coil, magnet, PC interface | 5K10.20 | A magnet oscillating through a coil attached to a PC interface. Induction or damping can be accurately plotted. |
| AJP 70(6), 595 | induction coil, magnet, PC interface | 5K10.20 | The observed voltage is compared to that predicted by simple calculations when treating the magnet as an ideal dipole and the coil as having infinitesimally thin windings. |
| F&A, Ek-3 | galvanometer, coil and magnet | 5K10.20 | Move a magnet through a coil connected to a galvanometer. |
| F&A, Ek-3 | direction of induced currents | 5K10.20 | Use each end of a magnet with a coil and galvanometer. |

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| Sut, E-216 | induction coil and magnet | 5K10.20 | Move a bar magnet in and out of a coil connected to a galvanometer. Turn the coil with a fixed magnet. |
| Hil, E-8a | induction coil, magnet, galvanometer | 5K10.20 | A many turn coil attached to a projection galvanometer is flipped over or a magnet is thrust through. |
| D&R, B-205 | galvanometer, coil, and magnet | 5K10.20 | Move a magnet through a coil or coil through a magnet while coil is connected to a galvanometer. |
| Bil&Mai, p 304 | coil, magnet, and compass | 5K10.20 | Move a magnet through a coil while the leads of the coil are wrapped 4 times around a compass. |
| PIRA 1000 | 10/20/40 coils with magnet | 5K10.21 | |
| Disc 20-12 | 10/20/40 coils with magnet | 5K10.21 | Coils of 10, 20, and 40 turns are attached to a galvanometer. |
| Mei, 31-2.1 | string and copper induction coils | 5K10.22 | A magnet is passed in and out of a copper coil hooked to a millivoltmeter and string loop hooked to an electrometer. |
| D&R, B-207 | coil, magnet, and voltmeter | 5K10.22 | A plastic tube has an 80 turn coil wrapped on it. Hook this to a voltmeter, place the magnets in the tube, and shake. Observe the meter readings. |
| AJP 28(1),81 | multiple induction coils | 5K10.23 | Wind coils 1:2:4:4:4 with the 2nd and 4th in the opposite sense, all in series. Use with a single pole, then use two poles of a horseshoe magnet in two adjacent coils. |
| Sut, E-217 | number of turns and induced EMF | 5K10.24 | Combine coils of 5 cm diameter with 1,2,5,10,15 turns in various ways to show induced EMF proportional to number of turns. |
| PIRA 500 | coil and lamp, magnet | 5K10.25 | |
| UMN, 5K10.25 | coil and lamp, magnet | 5K10.25 | |
| Disc 20-17 | inductive coil with lamp | 5K10.25 | Swing a coil attached to a lamp through the gap of a horseshoe magnet. |
| TPT, 36(6), 370 | improved flashbulb demonstration of Faraday's law | 5K10.25 | A coil, which is connected to a flashbulb, is inserted between the poles of a large permantent magnet and rapidly pulled out. Current induced by the rapid change in the flux of the magnetic field through the coil fires the flashbulb. |
| Sut, E-224 | induction effects of hitting the bar | 5K10.26 | Put a 600 turn coil connected to a galvanometer around a soft iron bar and hit the bar while oriented parallel and perpendicular to the Earth's field. |
| PIRA 200 | induction with coils and battery | 5K10.30 | Attach one coil to a galvanometer, another to a battery and tap switch. Use a core to increase coupling. |
| UMN, 5K10.30 | induction with coils and battery | 5K10.30 | Two coils face each other, one attached to a galvanometer, the other to a battery and tap switch. Coupling can be increased with various cores. |
| F&A, Ek-4 | galvanometer, coils and battery | 5K10.30 | Two coils are in proximity, one attached to a galvanometer, the other to a switch and battery. |
| Mei, 31-2.2 | induction coils and battery | 5K10.30 | Change the position of the secondary as the current is interrupted in the primary. |
| D&R, B-220, B-350 | induction with coils and battery | 5K10.30 | Primary and secondary coils, one attached to a galvanometer, the other to a battery and switch. Try various core sizes to increase coupling. |
| Disc 20-20 | two coils | 5K10.30 | Changing the current in one coil causes a current in the other. |
| Sut, E-219 | induction coils and battery | 5K10.31 | Two coils are wound on an iron ring, one connected to a galvanometer, the other to a battery and switch. |
| Sut, E-220 | induction coils and battery | 5K10.32 | Two coils, one connected to a galvanometer, the other to a battery through a rheostat to allow continuous variation of current. |
| Mei, 31-2.3 | induction coils and battery | 5K10.33 | The voltage to a long three layered solenoid is interrupted with various layers active and various sensor loops inside. |
| AJP 49(6),603 | discovering induction | 5K10.36 | Repeat the original Faraday experiment and no one realizes the galvanometer twitch is meaningful. |
| Mei, 31-2.4 | ramp induction coils | 5K10.37 | A galvanometer detects a steady current from one Helmholtz coil as a second coil is excited with a voltage ramp. |
| Mei, 31-3.7 | changing the air gap | 5K10.38 | Change the air gap between two coils and show the induced voltage. |
| Mei, 32-3.24 | current from changing air gap | 5K10.39 | Change the size of the air gap in an electromagnet and observe a transient change in the current energizing the coil. |
| PIRA 1000 | induction coils with core | 5K10.40 | |
| F&A, Ek-7 | iron core in mutual inductance | 5K10.40 | The effect of an iron core is demonstrated as a battery is connected to the primary. |
| Sut, E-221 | insert core | 5K10.41 | While one coil has a continuous current, insert and remove cores of iron, copper, and brass. |
| Mei, 31-3.2 | two coils on a toroid | 5K10.42 | Two coils wound on opposite sides of a toroidal core show inductive coupling when current is switched in one coil. |
| Mei, 31-3.3 | large mutual inductance | 5K10.45 | Change the current steadily in a large transformer and watch the voltage in the secondary. |
| PIRA 1000 | current coupled pendula | 5K10.48 | |
| Disc 20-16 | current coupled pendula | 5K10.48 | Interconnected coils are hung as pendula in the gaps of two horseshoe magnets. Start one swinging and the other swings. |

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| F&A, Ek-5 | time integral of induced EMF | 5K10.50 | The induced current from a coil is displayed on a storage oscilloscope while the current is changed at various rates in a second coil. |
| TPT, 36(7), 416 | modulated coil | 5K10.51 | A small coil with core is modulated with the output from a radio after it is placed near the head of a tape player. |
| Bil&Mai, p 311 | modulated coil | 5K10.51 | A 14 turn coil is connected to the headphone output of a radio, tape player, or CD player. Another identical coil connected to a mini amplifier with speaker can pick up the transmission. Use an iron core to enhance the effect. |
| AJP 43(6),555 | induction on the air track | 5K10.52 | A loop of wire on an air cart passes through a magnet. Show on a scope. |
| AJP 53(1),89 | HO car in a magnetic tunnel | 5K10.55 | The induced EMF is observed on an oscilloscope as a brass wheeled train car passes along a track through a large magnet. |
| PIRA 500 | Earth inductor | 5K10.60 | |
| F&A, Ek-6 | Earth inductor | 5K10.60 | The deflection of a ballistic galvanometer from a flip coil is compared to a standard flux. |
| Disc 20-13 | Earth coil | 5K10.60 | Flip the standard Earth coil attached to a galvanometer. |
| Sut, E-222 | Earth inductor | 5K10.61 | Several variations. A large (1.5 m x 6 m) single wire loop, collapse a flexible loop on many turns, a long flexible wire swung like a jump rope are attached to a galvanometer with the damping turn removed. ALSO the commercial loop to a ballistic galvanometer. |
| AJP 29(5),329 | rotating coil magnetometer | 5K10.62 | Orient a motor driven coil in various ways in the Earth's field while the output is displayed on an oscilloscope. |
| AJP 44(9),893 | Earth inductor integrating amp | 5K10.62 | Replace the ballistic galvanometer with an integrating amp (circuit given). |
| AJP 57(5),475 | Earth inductor with VFC | 5K10.62 | A voltage-to-frequency converter replaces the ballistic galvanometer in the Earth inductor demonstration. |
| AJP 52(3),279 | Earth inductor on oscilloscope | 5K10.62 | Subsititute an oscilloscope for the galvanometer and look at the induced voltage versus time. |
| AJP 55(4),379 | Earth inductor integrator | 5K10.62 | Replace the galvanometer with an integrator and voltmeter. |
| AJP 29(5),333 | rotating coil magnetometer | 5K10.63 | Display the signal from a motor driven coil on an oscilloscope. |
| Sut, E-223 | Earth inductor compass | 5K10.63 | A motor driven coil of several hundred turns gives a different galvanometer deflection depending on the orientation. |
| PIRA 1000 | jumping rope | 5K10.65 | |
| UMN, 5K10.65 | jumping rope | 5K10.65 | |
| TPT 37(6), 383 | Earth inductor jump rope | 5K10.65 | Play "jump rope" with a long wire attached to an oscilloscope or galvanometer. |
| D&R, B-210, B-405 | Earth inductor jump rope | 5K10.65 | Play "jump rope" with a long wire attached to an oscilloscope or galvanometer. |
| Bil&Mai, p 306 | Earth inductor jump rope | 5K10.65 | Play "jump rope" with a 50 foot extension cord attached to a galvanometer. The cord must have an East-West alignment. |
| PIRA 1000 | What does a voltmeter measure? | 5K10.70 | |
| UMN, 5K10.70 | What does a voltmeter measure? | 5K10.70 | Same as AJP 50(12),1089. |
| AJP 50(12),1089 | what do voltmeters measure? | 5K10.70 | Two identical voltmeters connected at the same points in a circuit around a long solenoid give different readings. |
| AJP 49(6),603 | paradox | 5K10.71 | Feynman - "When you figure it out, you will have discovered an important principle of electromagnetism". |
| AJP 51(12),1067 | what does a voltmeter measure - letter | 5K10.71 | Add a third voltmeter that can be moved for continuously varying readings. |
| AJP 37(2),221 | Faraday's Law teaser | 5K10.71 | Measure the voltage between two points at the end of an electromagnet through different paths. |
| AJP 38(3),376 | Faraday's Law teaser - addendum | 5K10.71 | Clears up ambiguities in AJP 37(2),221. |
| AJP 45(3),309 | induced current liquid crystal | 5K10.78 | Liquid crystals placed over laminated copper conductors show heating of various configurations. |
| AJP 41(1),120 | Faraday's homopolar generator | 5K10.80 | Turn a large aluminum wheel by hand with the edge of the wheel and a pickoff brush between the poles of a magnet. Show the induced current on a galvanometer. |
| Mei, 31-2.12 | homopolar generator | 5K10.80 | A homopolar generator shows the relation between electric and magnetic fields. Not the most obvious demonstration. |
| AJP 56(9),858 | radial homopolar generator | 5K10.81 | A variation on the axial field homopolar motor (Barlow's wheel). |
| AJP 43(4),368 | Rogowski coil | 5K10.85 | A direct demonstration of Ampere's circuital law using a flexible toroidal coil. |
| AJP 45(11),1128 | magnetic wheel | 5K10.85 | Induced current from a unipolar machine using a magnetic wheel. |
| Mei, 31-1.24 | Rogowski coil | 5K10.85 | A flexible coil hooked to a ballistic galvanometer is used to give a direct measurement of the magnetic potential between two points. |
| Mei, 31-1.23 | Ampere's law | 5K10.85 | Use the Rogowski coil to examine the magnetic field produced by current in a single wire, or two wires of parallel and opposing current. Picture, theory. |

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| Mei, 31-1.7 | rocking plates | 5K10.99 | Demonstrates some difficult concepts of flux linkages using sheets of metal instead of wires. |
| | **Eddy Currents** | **5K20.00** | |
| PIRA 200 | Eddy currents in a pendulum | 5K20.10 | A copper sheet and comb, ring and broken ring, are swung through a large electromagnet. |
| UMN, 5K20.10 | pendulum in a big electromagnet | 5K20.10 | Pendula of solid and comb-like copper plates, solid and slit copper rings, are swung through a large electromagnet. |
| AJP 30(6),453 | Eddy current pendulum | 5K20.10 | Apparatus Drawings Project No. 29: Large electromagnet accessories, one of four. Plans for a large eddy current pendulum to go on the large electromagnet from No. 13. |
| F&A, El-3 | Eddy currents in a pendulum | 5K20.10 | A copper sheet and comb, ring and broken ring, are swung through a large electromagnet. |
| TPT 25(4), 223 | Eddy current pendulum | 5K20.10 | Pendulums of solid copper, sliced copper, aluminum, and Lucite swing through the poles of a large permanent horn magnet. |
| Disc 20-24 | Eddy current pendulum | 5K20.10 | Copper, wood, etc. bobs are swung in a large permanent magnet. |
| Sut, E-227 | magnetic brake | 5K20.11 | A heavy copper disk swings as a pendulum between the poles of an electromagnet. |
| Hil, E-8d.2 | Eddy current pendulum | 5K20.11 | A pendulum with a copper plate bob is swung through a big electromagnet. |
| D&R, B-285 | magnetic brake | 5K20.11 | Solid and slotted copper or aluminum sheets are swung through the poles of a permanent or electromagnet. |
| PIRA 1000 | Eddy damped pendulum | 5K20.15 | |
| UMN, 5K20.15 | Eddy damped pendulum | 5K20.15 | A magnet pendulum bob is swung over copper, aluminum, and stainless plate. |
| F&A, El-2 | Eddy damped pendulum | 5K20.15 | A bar magnet suspended as a pendulum is damped as it swings over a copper plate. |
| PIRA 1000 | falling aluminum sheet | 5K20.20 | |
| UMN, 5K20.20 | falling aluminum sheet | 5K20.20 | An aluminum sheet is dropped through the poles of a large horseshoe magnet. |
| F&A, El-4 | falling aluminum sheet | 5K20.20 | A strip of aluminum sheet is allowed to fall between the poles of a large Alnico magnet. |
| AJP 35(7),iv | Eddy current brake | 5K20.22 | Fasten a large aluminum disk to a 1/4 hp motor and then bring a magnetron magnet to the edge of the disk to slow the motor down. |
| ref. Doug Osheroff | plates and magnets, the Osheroff demo. | 5K20.24 | Drop a large diameter neodymium magnet on a copper plate.  Then cool the plate with liquid nitrogen and see what happens. |
| Sprott, 5.2 | plates and magnets, the Osheroff demo. | 5K20.24 | A neodymium magnet dropped onto a copper plate cooled in liquid nitrogen bounces upward. |
| TPT 38(1), 48 | plates and magnets | 5K20.24 | Demonstrating Lenz's law with aluminum and wooden plates on an incline with strong cylindrical magnets. |
| TPT 35(4), 212 | plates and magnets | 5K20.24 | Lenz's law with money and a neodymium magnet.  Use aluminum, copper, nickel, silver, and zinc coins. |
| TPT 37(5), 268 | plates and magnets | 5K20.24 | Float an aluminum can in water.  Turn and brake it with a neodymium magnet on a string. |
| TPT 43(4), 248 | plates and magnets | 5K20.24 | Cylindrical neodymium magnets rolling down an aluminum incline. |
| Bil&Mai, p 310 | plates and magnets | 5K20.24 | Cylindrical neodymium magnets and coins are rolled down an aluminum incline at the same time. |
| PIRA 200 | magnets in Eddy tubes | 5K20.25 | Drop a magnet and a dummy in glass and aluminum tubes, then switch. The magnet in aluminum falls slowly. |
| UMN, 5K20.25 | magnets and Eddy tubes | 5K20.25 | |
| D&R, B-280 | Eddy current tubes | 5K20.25 | Drop a powerful magnet through copper and aluminum tubes. |
| AJP 74(9), 815 | Eddy current tubes | 5K20.25 | A calculation is presented that quantitatively accounts for the terminal velocity of a magnet falling through a copper or aluminum tube. |
| AJP 73(1), 37 | Eddy current tubes | 5K20.25 | Dimensional analysis is used to analyze the demonstation of the magnet falling through the copper tube. |
| AJP, 75 (8), 728 | Eddy current tube analysis | 5K20.25 | Revisits a time of fall analysis of a magnet through a conducting tube taking into account the effect of thickness of the tube. |
| Disc 20-26 | Eddy current tubes | 5K20.25 | Drop a magnet and a dummy in glass and aluminum tubes, then switch. |
| PIRA 200 | Faraday repulsion coil | 5K20.26 | |
| PIRA 1000 - Old | Faraday repulsion coil | 5K20.26 | |
| F&A, Ek-1 | forces due to induced current | 5K20.26 | Pull a light bifilar suspended aluminum ring with a magnet. |
| D&R, B-280 | Faraday repulsion coil | 5K20.26 | A magnet is inserted and withdrawn from a solid and split ring on a bifilar suspension.  It is possible to "pump" the solid ring. |
| Disc 20-19 | Faraday repulsion coil | 5K20.26 | Thrust the pole of a magnet in and out of a copper ring of a bifilar suspension. |
| PIRA 200 - Old | jumping ring | 5K20.30 | A solid aluminum ring on the vertical transformer jumps while a split ring does not. |

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| UMN, 5K20.30 | jumping ring | 5K20.30 | Aluminum rings, one slit, the other solid, are placed around the core of a coil and the the coil is energized. |
| F&A, Em-12 | jumping ring | 5K20.30 | An aluminum ring jumps off the iron core of a vertical inductor. |
| Sut, E-236 | jumping ring | 5K20.30 | Solid and split aluminum rings on the vertical transformer. |
| D&R, B-260, B-270 | jumping ring on an Elihu Thompson apparatus | 5K20.30 | Solid, split, and multiple rings on an Elihu Thompson coil. |
| D&R, B-265 | jumping ring on an Elihu Thompson apparatus | 5K20.30 | Multiple rings of various cross sections on an Elihu Thompson coil. |
| Sprott, 5.3 | jumping ring | 5K20.30 | A coil of wire around an iron core is energized to propel a ring of aluminum up to the ceiling. |
| AJP 69(8), 911 | jumping ring analysis | 5K20.30 | A jumping ring apparatus powered by a capacitor bank is needed for a Lenz's law analysis. |
| Disc 20-18 | Thompson's flying ring | 5K20.30 | A copper ring levitates, an aluminum ring flies off, a slit ring does nothing, and a cooled ring flies higher. |
| AJP 39(3),285 | jumping ring analysis | 5K20.31 | An analysis of the role of phase differences in the levitating ring demonstration. |
| AJP 54(9),808 | jumping ring analysis | 5K20.31 | An analysis of the role of phase differences in the levitating ring demonstration. |
| AJP 68(3), 238 | jumping ring analysis | 5K20.31 | Measurements of the phase delay of the current and force on a floating ring were performed for phase angles from 12 degrees to 88 degrees. |
| Mei, 31-2.9 | jumping ring analysis | 5K20.31 | Be careful how you analyze the jumping ring. References. |
| F&A, El-5 | frying egg | 5K20.35 | A copper sheet fitting over the core of a large solenoid gets hot enough to fry an egg. |
| Sut, E-237 | boil water on the vertical transformer | 5K20.36 | Boil water in a ring shaped trough on the vertical transformer. |
| D&R, B-260 | boiling water on a transformer | 5K20.36 | Steam from a water filled ring on an Elihu Thompson coil. |
| PIRA 500 | Eddy current levitator | 5K20.40 | |
| UMN, 5K20.40 | Eddy current levitator | 5K20.40 | |
| F&A, El-1 | Eddy current levitation | 5K20.40 | A strong ceramic magnet is levitated over a spinning aluminum disc. |
| D&R, B-290 | Eddy current levitator | 5K20.40 | A magnet is levitated over a spinning aluminum disk. |
| AJP 31(12),925 | electromagnetic levitator | 5K20.41 | Plans for an electromagnetic levitator that lifts a 18" dia. 1/16" thick aluminum pan. Weighs 100 lbs, requires only 400 W at 110 V. |
| Mei, 31-2.22 | large levitator | 5K20.41 | Directions for building a large levitator. Diagrams, Construction details in appendix, p. 1332. |
| PIRA 1000 | Arago's disk | 5K20.42 | |
| AJP 28(8),748 | Arago's disk | 5K20.42 | Support the horseshoe magnet by a light stranded string and "wind up" the string to get a high spin rate. |
| Sut, E-226 | Arago's disk | 5K20.42 | A magnet suspended above a rotating horizontal copper disk will rotate. |
| Hil, E-8d.1 | rotating magnet | 5K20.42 | A magnet needle over a rotating copper disk. |
| D&R, B-287 | rotating an aluminum plate with a magnet | 5K20.42 | Place an aluminum plate in a pie pan and float in water. Rotate a strong magnet over the plate and the plate will start to spin. Try different magnets and different aluminum plate thicknesses. |
| Disc 20-25 | Arago's disk | 5K20.42 | A bar magnet suspended above a spinning aluminum disc will start to rotate. |
| AJP 47(5),470 | rotating vertical disc | 5K20.43 | A magnet hung by a quadrafilar rolling suspension near a spinning aluminum disk shows both repulsive and retarding forces. |
| PIRA 1000 | rotating ball | 5K20.50 | |
| F&A, Em-13 | rotating ball | 5K20.50 | A hollow aluminum ball rotates in a watch glass atop a shaded pole transformer. |
| Mei, 31-2.18 | spinning ball on a dish | 5K20.50 | A half disc of sheet aluminum placed on an AC excited coil produces a rotating magnetic field that causes a ball to spin. |
| D&R, B-275 | shaded pole induction motor | 5K20.50 | A hollow copper sphere rotates in a beaker atop a shaded pole transformer. |
| AJP 45(11),1020 | magnetic stirrer demonstrations | 5K20.51 | Several eddy current demos including a paradox: place a steel ball on a stirrer and start it up, the ball rolls in one direction, but backwards when placed in while the stirrer is on. |
| Mei, 31-2.19 | Eddy current motor | 5K20.52 | A metal 35 mm film canister spins when mounted to one side of the pole of an electromagnet. |
| Mei, 31-2.8 | rotating aluminum disc | 5K20.55 | An aluminum disc rotates when held asymmetrically over a vertical solenoid powered by line AC unless shielded by an aluminum plate. |
| Mei, 31-2.6 | spinning aluminum discs | 5K20.56 | Two overlapping rotating aluminum discs in parallel planes on the same rigid support rotate in different directions when inserted into a magnetic field. Needs a Diagram. |
| Mei, 31-2.7 | rotating aluminum disc | 5K20.57 | A thin aluminum disc hung vertically between the poles of a vertically mounted horseshoe magnet rotates when the magnet is rotated. |

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| AJP 46(7),729 | one-piece Faraday generator | 5K20.58 | Instead of a conducting disk rotating in an axial magnetic field, the disk is replaced by a cylindrical permanent magnet that supplies its own magnetic field. |
| AJP 40(2),330 | magnetic curl meter | 5K20.59 | Faraday's "electromagnetic rotation apparatus" shows a magnet in a conducting fluid rotating continuously when suspended in a region of distributed current density. This device measures the torque on such a magnet. |
| Sut, E-225 | Eddy currents in Barlow's wheel | 5K20.60 | Attach the Barlow's wheel to a galvanometer and turn by hand. |
| F&A, El-6 | money sorter | 5K20.62 | Silver and ersatz quarters are dropped through a large magnet. |
| Mei, 31-2.5 | rotating cores in magnet | 5K20.63 | A copper loop, solid iron cylinder, and laminated iron cylinder, are each rotated while suspended in a magnetic field. |
| PIRA 1000 | electromagnetic can breaker | 5K20.65 | |
| Sprott, 5.4 | electromagnetic can breaker - can crusher | 5K20.65 | A large capacitor discharged into a low impedance coil of a few turns produces a magnetic field strong enough to crush or break an aluminum soft drink can. |
| Disc 20-27 | electromagnetic can breaker | 5K20.65 | A large pulse of induced current in a soda can blows it apart. |
| | **Transformers** | **5K30.00** | |
| PIRA 500 | wind a transformer | 5K30.10 | |
| PIRA 1000 | salt water string | 5K30.13 | |
| F&A, Em-10 | single turn transformer | 5K30.14 | Probes of an oscilloscope are slid along the ring of a single turn secondary. |
| PIRA 200 | dissectible transformer/light bulb | 5K30.20 | |
| PIRA 500 - Old | dissectible transformer/light bulb | 5K30.20 | |
| F&A, Em-5 | dissectible transformer | 5K30.20 | Various cores are interchangeable with the Leybold transformer. |
| Disc 20-23 | transformers | 5K30.20 | Many variations with the Leybold transformer. |
| Sut, E-240 | toy transformer | 5K30.21 | Place a 110 V lamp in parallel with the input and a 6 V lamp on the output of a step down transformer. Then place an auto taillight lamp in series with the input and a 10 amp fuse wire across the output and increase the voltage with an autotransformer until the fuse melts. |
| Sut, E-246 | telephone and radio transformers | 5K30.22 | Using commercial transformers in demonstrations. |
| AJP 54(6),528 | magnetic losses in transformers | 5K30.24 | Additional cores are placed in the Leybold transformer to demonstrate the magnetic potential drop. |
| Hil, E-11c | transformers | 5K30.25 | High voltage, low voltage, and demonstration transformers are shown. |
| D&R, B-435 | transformers | 5K30.25 | Voltage and current of primary and secondary coils shown with light bulbs in series and as secondary load. |
| PIRA 1000 | vertical transformer | 5K30.30 | |
| UMN, 5K30.30 | vertical transformer | 5K30.30 | Secondary loops attached to light bulbs are placed over the core of a vertical transformer. |
| Sut, E-235 | vertical transformer | 5K30.30 | Directions for making a vertical transformer using 110 V AC in the primary. Includes directions for step up and step down secondaries. |
| Hil, E-11d | Thompson vertical transformer | 5K30.30 | A vertical transformer is shown with a lot of accessories. |
| Disc 20-22 | vertical primary and secondary coils | 5K30.30 | The vertical transformer is used with two coils, one with many turns powers a 110 V lamp, and the other with fewer turns powers a flashlight lamp. |
| Sut, E-238 | autotransformer | 5K30.34 | A variation of the vertical transformer with 400 turns tapped every 50 turns and connected to 110 V AC at 200 turns. Explore with a light bulb. See L-99. |
| PIRA 1000 | light underwater | 5K30.35 | |
| UMN, 5K30.35 | light underwater | 5K30.35 | The secondary coil and light bulb are placed in a beaker of water and held over the core of a vertical transformer. |
| F&A, Em-7 | light under water | 5K30.35 | A waxed coil and light bulb are placed in a beaker of water over a vertical primary. |
| D&R, B-425 | light underwater | 5K30.35 | A secondary coil and light bulb are placed in a beaker of water and held over the core of an Elihu Thompson coil. |
| PIRA 1000 | weld a nail | 5K30.40 | |
| UMN, 5K30.40 | weld a nail | 5K30.40 | Two nails attached to the secondary of a large low voltage transformer are welded together upon contact. |
| F&A, Em-4 | large current transformer | 5K30.40 | Nails connected to the secondary of a large current transformer are welded together. |
| Sut, E-239 | dissectible transformer - welding | 5K30.40 | Two "L" shaped laminated iron cores with interchangeable coils are used to step down 110 V AC to melt an iron wire. |
| D&R, B-445 | weld a nail | 5K30.40 | Nails connected to the secondary of a step-down transformer ( 6.3 volts at 10.6 amps ) are welded together on contact. |
| AJP 36(1),x | simple spotwelder | 5K30.43 | Modify a heavy duty soldering iron to function as a small spotwelder. |
| ref. | Jacob's ladder | 5K30.50 | see 5D40.10 |
| F&A, Em-11 | induced EMF | 5K30.51 | An oscilloscope is connected to a wire in a gap of a transformer. |

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| Sut, E-234 | exploratory coil | 5K30.52 | Explore an alternating magnetic field with an exploratory coil of many turns of No. 30 wire connected to a 6 V lamp. |
| Mei, 31-3.4 | mutual inductance on a scope | 5K30.53 | The relationship between the current in one coil and the voltage in another is shown as a Lissajous figure on an oscilloscope. Diagram. |
| Sut, E-243 | magnetic shunt | 5K30.54 | An "E" core has two windings: 110V primary on one outer, and secondary with a lamp on the middle. Bridge a yoke over the windings and the lamp lights but when put over all three it doesn't. |
| PIRA 1000 | reaction of a secondary on primary | 5K30.60 | |
| F&A, Em-2 | primary current change with secondary load | 5K30.60 | A light bulb in series with the primary brightens as the load on the secondary increases. |
| Sut, E-241 | reaction of secondary on primary | 5K30.60 | Connect a 100 W lamp in series with the primary and increase the load on the secondary to light the lamp. |
| Sut, E-242 | reaction of secondary on primary | 5K30.61 | Vary the load on the secondary and the coupling between the primary while observing the current in the primary. |
| F&A, Em-9 | shocker | 5K30.81 | A vibrator switches the current in a primary and the victim holds onto the leads of the secondary while the coupling is increased. |
| F&A, Em-6 | phony health belt | 5K30.84 | A weird antique health belt. |
| Mei, 33-3.2 | resonant Leyden jar detector | 5K30.90 | One Leyden jar with a loop of wire is driven with a induction coil, another similar arrangement is used as a detector. |
| Hil, A-8a | Leyden jar and loop | 5K30.90 | When a spark jumps from a loop of wire to a Leyden jar, a small spark will jump in a similar device close by. |
| | **Motors and Generators** | **5K40.00** | |
| PIRA 1000 | DC motor | 5K40.10 | |
| UMN, 5K40.10 | DC motor | 5K40.10 | A coil is mounted between two magnetron magnets. |
| F&A, Ei-19 | DC motor | 5K40.10 | A large open coil is mounted between the poles of magnetron magnets to make a DC motor. |
| Sut, E-147 | DC motor | 5K40.10 | A circular loop of heavy wire between two solenoids with iron cores. |
| Sut, E-146 | DC motor | 5K40.10 | A coil in a "U" shaped magnet with a simple commutator. |
| D&R, B-075 | DC motor | 5K40.10 | Simple motor construction using a D battery and single magnet. |
| Bil&Mai, p 308 | DC motor | 5K40.10 | A simple motor construction using D batteries and a single neodymium magnet. |
| Disc 20-09 | DC motor | 5K40.10 | A large model DC motor. |
| F&A, Eq-5 | DC motor and lamp | 5K40.12 | A DC motor has a light bulb in series with the armature to indicate current flow as the motor starts, comes up to speed, and is under load. |
| F&A, Eq-6 | DC series and parallel motors | 5K40.13 | A DC motor on a board allowing armature and field to be connected in series or parallel. |
| PIRA 1000 | Faraday motor | 5K40.15 | |
| AJP 31(1),42 | Faraday motor | 5K40.15 | Apparatus Drawings Project No.33: A rod magnet sticks up through a pool on mercury and a parallel conducting copper wire is free to move in a circle around the magnet. |
| Hil, E-7e | Faraday motor | 5K40.15 | A model of the first electric motor developed by Faraday. |
| Disc 20-14 | Faraday disc | 5K40.15 | Spin a copper disc between the poles of a horseshoe magnet with brushes at the center and edge of the disc connected to a galvanometer. |
| Hil, E-8c | simple motor | 5K40.18 | A two coil, two magnet assembly illustrates simple generator principles. |
| Sut, E-232 | simple speed control for DC motor | 5K40.19 | A circuit to change speed and direction of a small DC motor. |
| PIRA 500 | DC & AC generators on a galvanometer | 5K40.20 | |
| UMN, 5K40.20 | DC & AC generators on a galvanometer | 5K40.20 | A coil mounted between two magnetron magnets is equipped with both commutator and slip rings. |
| Sut, E-228 | motor waveform | 5K40.21 | The armature of a generator is rotated 10 degrees at a time to a ballistic galvanometer and the result of 36 observations are plotted. |
| PIRA 500 | DC & AC generators on a scope | 5K40.25 | |
| UMN, 5K40.25 | DC & AC generators on a scope | 5K40.25 | The waveforms from the DC/AC generator are displayed on an oscilloscope. |
| AJP 49(7),701 | AC and DC dynamo demonstration | 5K40.26 | Abstract from the 1981 apparatus competition. |
| Mei, 31-2.15 | model generator | 5K40.27 | A generator built with a small motor spun rotor in a large open solenoid shows operation of an AC generator. |
| Mei, 31-2.10 | light the bulb with a coil | 5K40.28 | A coil connected to a light bulb is mounted on a disk rotating between the poles of an electromagnet. Picture. |
| Mei, 31-2.14 | generator on the overhead | 5K40.29 | A hand crank generator designed for use on the overhead projector. |
| Bil&Mai, p 313 | AC motor | 5K40.35 | A simple AC motor constructed from the simple DC motor in 5K40.10. Completely remove the epoxy coating from the arms of the coil and drive the motor with a square wave generator. |

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| PIRA 200 | motor/generator | 5K40.40 | A large AC/DC motor/generator has both slip and split rings. |
| UMN, 5K40.40 | motor/generator | 5K40.40 | |
| F&A, Eq-4 | motor generator | 5K40.40 | An armature with both slip rings and a commutator allows operation of a coil between two magnets as either a AC or DC motor or generator. |
| Mei, 31-2.13 | motor/generator | 5K40.40 | A coil mounted between the poles of an electromagnet is rotated by hand as a generator or powered by a battery as a motor. |
| Sut, E-229 | AC and DC generators | 5K40.40 | Directions for making a large demonstration motor/generator. Picture. |
| D&R, B-405 | AC and DC generators | 5K40.40 | Homemade and commercial AC and DC generators with split ring. |
| Disc 20-15 | AC/DC generator | 5K40.40 | A large AC/DC generator with slip and split rings. |
| PIRA 1000 | coupled motor/generator | 5K40.45 | |
| Mei, 31-2.16 | coupled motor/generators | 5K40.45 | Two small permanent magnet DC motors are coupled so when one is driven mechanically, the other will spin. Picture. |
| Mei, 31-2.17 | simple induction motor | 5K40.50 | Bring a coffee can on an axle near two coils mounted at 90 degrees carrying AC with a capacitor in one line. |
| AJP 33(12),1082 | induction motor model | 5K40.53 | Suspend a closed copper loop by a thread in the gap of a rotating magnetron magnet and it will remain aligned with the rotating field. |
| Sut, E-233 | synchronous motor | 5K40.55 | Run an AC dynamo as a synchronous motor by supplying AC to the armature coils. |
| Mei, 31-2.20 | synchronous and induction motors | 5K40.56 | Three pairs of coils in a circle produce a rotating magnetic field for use with a permanent magnet or aluminum rotor. Picture, Construction details in appendix, p. 1329. |
| Sut, E-250 | three phase | 5K40.60 | Directions for winding three coils of a three phase rotator. |
| Sut, E-248 | three phase | 5K40.60 | Directions for making a three phase winding and things to spin in it. |
| Sut, E-249 | three phase | 5K40.61 | Remove the rotor from a three phase induction motor and place a steel ball inside. |
| Mei, 31-2.21 | modified Rowland ring | 5K40.64 | An aluminum ring spins in the center of a three phase horizontal toroid. Picture. |
| Sut, E-251 | two phase rotator | 5K40.65 | How to make a two phase rotator get two phase from either three phase or two phase. Diagram. |
| Sut, E-230 | counter EMF in a motor | 5K40.70 | A lamp in series with a motor does not glow unless a load is placed on the motor slowing it down. |
| D&R, B-295 | back EMF in a motor | 5K40.70 | Voltmeter and ammeter connected to a motor show the effect of back EMF on current drawn under different load conditions. |
| Sut, E-231 | counter EMF in a motor | 5K40.71 | Suddenly switch the armature of a shunt wound DC motor to a voltmeter while it is running. |
| Mei, 30-2.10 | back EMF in a motor | 5K40.72 | The circuit that shows the effect of back EMF on current drawn by a motor under various load conditions and after it is turned off. Diagram. |
| Sut, E-247 | speed of AC motors under load | 5K40.73 | Slip speed and phase shift are shown stroboscopically as the load is increased on induction and synchronous motors. |
| Mei, 31-1.12 | motor debunking | 5K40.75 | A copper conductor in an iron tube in a magnetic field shows forces in most motors are not caused by magnetic fields set up in the conductors. |
| PIRA 200 - Old | hand crank generator | 5K40.80 | Use a hand cranked generator to light an ordinary light bulb. |
| UMN, 1M50.30 | hand crank generator | 5K40.80 | Light a bulb with a hand crank generator. |
| UMN, 5K40.80 | hand crank generator | 5K40.80 | A hand crank generator made with a 120 V DC generator is used with light bulbs. |
| F&A, Mv-4 | hand crank generator | 5K40.80 | A hand cranked generator is used to light an ordinary light bulb. |
| F&A, Eq-7 | hand crank generator | 5K40.80 | Students light a bulb with a hand crank generator. |
| Hil, E-8b | telephone generator | 5K40.80 | An AC generator from an early telephone lights a 110 V lamp. Also, a single loop model and another generator. |
| D&R, B-250 | hand crank generator | 5K40.80 | A Genecon generator is used to charge a capacitor, light an incandescent bulb, bi-color LED to show polarity reversal, and show motor operation. |
| Disc 03-16 | hand crank generator | 5K40.80 | A hand cranked generator slows down in five seconds from internal friction or in one second while lighting a lamp. |
| Hil, E-7f | AC and DC generator | 5K40.82 | A small open hand crank generator. |
| PIRA 1000 | bicycle generator | 5K40.83 | |
| UMN, 5K40.83 | bicycle generator | 5K40.83 | A 2KW generator mounted on a bicycle is used with big lamps. |
| PIRA 1000 | generator slowed by load | 5K40.85 | |
| Disc 03-17 | generator driven by falling weight | 5K40.85 | A weight on a string wrapped around the shaft of a generator falls more slowly when there is an electrical load on the generator. |
| AJP 41(2),203 | MHD power generator | 5K40.99 | Discharge a toy rocket motor between the poles of a magnet and attach copper electrodes placed in the gas jet to a voltmeter. |
| | **AC CIRCUITS** | **5L00.00** | |
| | **Impedance** | **5L10.00** | |
| PIRA 500 | inductive choke | 5L10.10 | |
| UMN, 5L10.10 | inductive choke | 5L10.10 | Move a core in and out of a coil in series with a light bulb. |

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| F&A, En-3 | variable inductance | 5L10.10 | An inductor with a movable iron core is connected in series with a light bulb. |
| Sut, E-258 | inductive reactance | 5L10.10 | Pull a core in and out of a solenoid in series with a 200W lamp, then a 10 W lamp. Try with DC. |
| Disc 21-02 | inductor with lamp on AC | 5L10.10 | Place a large coil in series with a light bulb, then insert an iron core in the coil and the light bulb dims. |
| PIRA 1000 | capacitive impedance | 5L10.20 | |
| F&A, En-4 | capacitive impedance | 5L10.20 | A variable capacitor is connected in series with a light bulb. |
| PIRA 1000 | capacitive reactance | 5L10.30 | |
| Mei, 30-2.9 | capacitive reactance | 5L10.30 | A circuit to vary R through the value of the capacitive reactance, among other things. |
| Sut, E-260 | capacitive reactance | 5L10.35 | Measure the voltage and phase across each element in a circuit with a 25W lamp in series with a capacitor. |
| Mei, 33-5.2 | skin effect | 5L10.40 | Conductors of different dimensions are connected to lamp indicators in a high frequency circuit. |
| AJP 44(10),978 | skin effect | 5L10.41 | Stack metal plates between the primary and secondary of a transformer, a bundle of wire is opened up to gain access to any wire for a current measurement. |
| AJP 53(11),1089 | phasemeter | 5L10.50 | Some phasemeter circuits are given suitable for showing current-voltage relationships for reactive elements. |
| Mei, 33-2.2 | I-V curves on a scope | 5L10.51 | A circuit to generate I-V curves of various electrical components. Diagram, Appendix: p. 1337. |
| TPT 28(3),160 | octopus | 5L10.55 | A simple circuit used by technicians to probe the relationship of current and voltage in a circuit. |
| F&A, Eo-9 | impedance bridge | 5L10.55 | Complex impedances are plugged into a Wheatstone bridge board. |
| | **RLC Circuits - AC** | **5L20.00** | |
| TPT 20(3), 187 | demonstration AC circuit board | 5L20.01 | A simple demonstration board with L, R, C, elements and bold schematics that are easily visible in the classroom. |
| PIRA 500 | RLC - phase differences | 5L20.10 | |
| UMN, 5L20.10 | RLC - phase differences | 5L20.10 | Applied voltage, R, L, and C are displayed on a four channel scope while L is changed and the circuit passes through resonance. |
| F&A, En-13 | parallel resonance | 5L20.10 | Transformers permit viewing voltages in all elements of a parallel RLC circuit. |
| F&A, En-2 | phase shift in an RLC circuit | 5L20.10 | The voltages across elements of a RLC circuit are shown as the inductor is varied through resonance. |
| F&A, En-12 | RLC series circuit | 5L20.10 | Isolation transformers permit viewing applied, R, L, and C simultaneously on an oscilloscope as the inductor is varied through resonance. |
| AJP 47(4),337 | series RLC phase shift on scope | 5L20.11 | Simultaneous display of four traces of the RLC circuit on a single channel scope using a multiplexer. Circuit diagrams are given. |
| Mei, 33-2.3 | RLC phase relationships | 5L20.11 | A circuit allows phase relationships between R and L or C of the Cenco 80375 choke coil and resonance apparatus to be displayed on an oscilloscope. |
| D&R, B-415 | RLC phase relationships | 5L20.11 | Voltage and current phase relationships of various components shown on an oscilloscope. |
| AJP 39(10),1133 | RLC waveforms display | 5L20.12 | The Leybold double wire loop oscillograph is modified to project laser beams showing the current and voltage relationships of a RLC (circuit given) circuit. |
| AJP 43(11),1011 | RLC phase relationships | 5L20.13 | Show the input and output of an RLC circuit on a dual trace oscilloscope. |
| AJP 29(8),546 | phase shift in a fluorescent circuit | 5L20.14 | Among other things, demonstrate the phase shift in a fluorescent lamp circuit. |
| AJP 40(4),628 | LC op amp interface | 5L20.14 | OP amps placed across the inductor and capacitor have high impedance and do not perturb the system. |
| Sut, E-269 | RLC - phase differences | 5L20.15 | A neon lamp detector shining on a disk rotated by a synchronous motor shows phase differences in a series RLC circuit driven by 110 V AC. |
| AJP 45(1),97 | RLC vectors on CRO | 5L20.16 | Pulses are generated from an RLC circuit to modulate the Z axis of a CRO. The dots shift as the applied frequency is changed. |
| AJP 40(10),1529 | seconds period RLC | 5L20.17 | Directions for building an underdamped RLC circuit with a period from .5 to 5 seconds. Forced oscillation with a electromechanical generator. |
| PIRA 1000 | driven RLC circuit | 5L20.18 | |
| Disc 21-04 | driven RLC circuit | 5L20.18 | The voltage and current across the capacitor, inductor, resistor, and supply are shown in succession on an oscilloscope. |
| PIRA 200 | RLC - resonance | 5L20.20 | |
| PIRA 500 - Old | RLC - resonance | 5L20.20 | |
| UMN, 5L20.20 | RLC - resonance | 5L20.20 | A large lamp lights in a 60 Hz 120 V RLC circuit when the L is changed and resonance is achieved. |

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| F&A, En-1 | series RLC circuit | 5L20.20 | The light bulb in a RLC circuit glows when the inductor core is moved through resonance. |
| Hil, E-13b | series RLC resonance | 5L20.20 | A 110 VAC lamp, capacitor, and variable inductor form a series circuit. |
| Hil, E-13c | series RLC resonance | 5L20.20 | Short out the capacitor in a RLC circuit with a light bulb resistance. |
| D&R, B-415 | RLC - resonance | 5L20.20 | RLC resonance shown on an oscilloscope |
| F&A, Eo-15 | parallel AC resonance | 5L20.21 | A capacitor and variable inductor tuned to resonate in parallel at 60 Hz have series light bulb current indicators. |
| Hil, E-13d | parallel resonance | 5L20.21 | A RLC series resonant circuit with a variable inductor and light bulb indicators. |
| Sut, E-265 | RLC - resonance | 5L20.22 | A variable inductor and capacitor in series with a lamp driven by 110 VAC. Short inductor or capacitor, vary both. |
| TPT,37(3), 179 | qualitative demonstrations of parallel/series resonance | 5L20.23 | A set-up for a qualitative investigation of both RLC series and parallel resonance is described. |
| Sut, A-26 | resonance at 60 Hertz | 5L20.24 | The product of inductance in henrys and capacitance in microfarads should be 7. |
| Hil, E-13e | LC parallel resonance | 5L20.26 | An LC circuit is driven by coupling a second coil driven by an audio oscillator. Reference: AJP 36(1),x. |
| AJP 36(9),915 | resonance curves on scope | 5L20.30 | A crude but effective spectrum analyzer circuit for generating and displaying frequency response curves on an oscilloscope |
| Mei, 33-3.6 | RLC resonance plot on scope | 5L20.31 | An x-y plot of the resonance curve is generated by mechanically driving a pot controlling the x axis of the scope by a chain to the tuning knob of the signal generator. Diagram, Picture. |
| Mei, 33-3.5 | coupled RLC circuits | 5L20.40 | Two identical RLC circuits and a driving coil are coupled with a common core. The two are shown to resonate at the same frequency, then when both are operated simultaneously, there are two different frequencies at which resonance occurs. Diagram, Picture. |
| AJP 36(1),x | air coupled circuit | 5L20.41 | Two coils are air coupled, one is driven by an audio oscillator and various capacitors are placed across the other coil while the output is monitored on an oscilloscope. |
| Sut, E-268 | high voltage RLC ringing | 5L20.50 | The secondary of a high voltage transformer is shunted across a spark gap, Leyden jars, and an inductor made of several turns of heavy copper all in series. |
| Mei, 33-3.4 | HF RLC resonance | 5L20.51 | A 30 MHz 500W generator is coupled to a loop, light bulb, parallel plate RLC circuit and the capacitance changed to find resonance. Picture. |
| | **Filters and Rectifiers** | **5L30.00** | |
| PIRA 500 | bridge rectifier | 5L30.10 | |
| UMN, 5L30.10 | bridge rectifier | 5L30.10 | Plug in diodes on a Wheatstone bridge circuit board are used to demonstrate unrectified, half wave, and full wave rectification. Show on an oscilloscope. |
| F&A, Eo-10 | bridge rectifier | 5L30.10 | Half and full wave rectification with a plug in Wheatstone bridge board. |
| F&A, Eo-8 | wheatstone bridge | 5L30.10 | A Wheatstone bridge board with plug in elements. |
| Disc 18-11 | rectifier circuit | 5L30.10 | Diodes in a Wheatstone bridge configuration followed by two low pass filters. |
| Mei, 33-2.4 | bridge rectifier | 5L30.11 | A circuit allows switching between unrectified, half, and full wave rectified configurations. A magnet bob pendulum and pickup coil provide a slow AC signal. |
| Sut, A-80 | diode rectifier | 5L30.12 | Use neon lamps to indicate rectification with a diode rectifier tube. |
| Sut, A-79 | thermionic rectifier | 5L30.14 | Kenotron type thermionic rectifier using a switch to change polarity of DC voltage. |
| Sut, A-25 | very low frequency rectification | 5L30.16 | Rectification can be demonstrated with a rotary potential divider and a vacuum tube in one of the standard circuits. Other stuff too. |
| PIRA 500 | blinky whirligig | 5L30.20 | |
| UMN, 5L30.20 | blinky whirligig | 5L30.20 | A small flashing light on the end of a string is whirled around. |
| TPT 22(9),554 | blinky whirlygig | 5L30.20 | An improvement on TPT,22(7),448, "AC made visible". |
| F&A, Mb-9 | blinky whirligig | 5L30.20 | Blinking neon bulb on a cord is swung around in uniform circular motion. |
| Mei, 7-2.4 | blinky whirligig | 5L30.20 | Swing a light bulb around and take a picture of it with a fan strobed Polaroid |
| D&R, B-410, M-198 | blinky whirligig | 5L30.20 | Neon, argon, and bi-color LED's on the end of a whirling AC or DC cord. |
| Bil&Mai, p 284 | blinky whirligig | 5L30.20 | Neon and bi-color LED's on the end of a whirling AC or DC cord. |
| AJP 43(1),112 | glow lamp swinger | 5L30.21 | Swing a GE A9A or Chicago Miniature Ne-23 neon glow lamp in a 3 foot radius circle. Use as a persistence of vision demo by holding it still. |
| Hil, E-13a | whirling glow lamp | 5L30.21 | A two watt neon glow lamp is mounted on a hand rotator. |
| Mei, 30-1.2 | AC and DC with starch and iodine | 5L30.25 | Drawing an electrode across a starch/iodine solution gives a solid line with DC and a dashed line with AC. |

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| TPT 19(8), 551 | AC and RMS voltages | 5L30.25 | Measure across a 120 volt lamp simultaneously with a digital voltmeter and an oscilloscope. The digital voltmeter will read 120 RMS volts while the oscilloscope will show about 170 volts peak to peak. Or compare the DC ignition voltage for a neon lamp to the AC RMS voltage. |
| Mei, 33-2.5 | LC low pass filter | 5L30.30 | Ammeters measure the current before and after a LC filter while an audio amplifier detects AC before and after as the frequency is varied. |
| Mei, 33-3.3 | current in an LC circuit | 5L30.31 | Lamps are in series in each branch of an LC circuit to show current distribution as inductance is changed. |
| AJP 31(2),134 | Fourier zeros LC circuit | 5L30.34 | No energy is deposited in a resonant high Q circuit at f=n/pulse width. Circuit given. |
| Mei, 33-3.1 | mechanical analog of an LC filter | 5L30.35 | A string and pulley arrangement provides an analog of a parallel LC filter. Reference: AJP 14(5),318. |
| Mei, 33-2.6 | RLC filter | 5L30.36 | A RLC parallel filter with each component individually switched is used to show the effect of each component on audio frequencies. |
| AJP 39(3),337 | resonant cavity properties | 5L30.50 | Identical ultrasonic transducers are bonded to opposite parallel faces of a solid medium. One is pulsed with a rf voltage at the transducer resonant frequency and the other is the receiver. The frequency adjusted to a Fabry-Perot resonance. |
| TPT 3(5),199 | many circuits | 5L30.70 | Nine simple circuits using diodes and transistors covering from rectifiers to a linear sweep generator. |
| | **SEMICONDUCTORS & TUBES** | **5M00.00** | |
| | **Semiconductors** | **5M10.00** | |
| PIRA 200 - Old | Hall voltage | 5M10.10 | Measure the transverse potential of a large rectangle of biased N-doped germanium in a magnetic field. |
| UMN, 5M10.10 | Hall effect | 5M10.10 | The transverse potential of a large rectangle of biased N-doped germanium is measured when inserted into a magnetic field. |
| F&A, Ei-16 | Hall voltage | 5M10.10 | Current is passed through a N doped germanium crystal while in a strong magnetic field and the voltage at the sides is monitored. |
| Mei, 40-1.16 | Hall effect | 5M10.10 | Measure a voltage difference in a germanium sample perpendicular to the current flow when placed in a magnetic field. Picture Diagram, Construction details in appendix, p.1367. |
| Disc 20-10 | Hall effect | 5M10.10 | A Hall effect probe in a magnet, animation. |
| AJP 29(1),29 | Hall effect magnet | 5M10.11 | Apparatus Drawings Project No. 12: A small electromagnet for use with an indium-antimonide device. |
| Mei, 40-1.13 | Lorentz force on conduction electron | 5M10.12 | A voltage is induced on a moving metal in a magnetic field. |
| AJP 52(9),807 | an electron in a periodic potential | 5M10.15 | The interaction of an electron with a crystal periodic potential is demonstrated with an air track cart mounted magnet moving past a magnet array. |
| Mei, 40-1.2 | model of a semiconductor | 5M10.19 | A model made of pegboard and balls that shows a hole moving along a preselected path. |
| Mei, 40-1.3 | hot point probe | 5M10.20 | A hot point probe consisting of a soldering iron and a microammeter tests for the two types of conductivity. |
| Mei, 40-1.5 | color centers | 5M10.30 | Electrons or holes are injected into a large transparent alkali halide crystal in an oven resulting in the formation of color centers. Pictures, Diagrams, References: AJP 25,5 ,306. |
| Mei, 40-1.6 | color centers | 5M10.32 | Injection of electrons into a transparent potassium chloride crystal at high temperatures results in the formation of color centers. Pictures. |
| Mei, 40-1.7 | Shockley-Haynes experiment | 5M10.34 | A difficult but worthwhile demonstration illustrates diffusion and drift phenomena. |
| AJP 41(7),878 | Josephson weak link model | 5M10.40 | A rigid pendulum and aluminum disc are mounted on a shaft driven by a weight hanging on a thread wrapped around the shaft and damped by eddy currents. |
| PIRA 1000 | diode | 5M10.50 | |
| Disc 18-10 | diode | 5M10.50 | Positive and negative voltages are applied to a lamp in series with a diode. |
| Mei, 40-1.12 | PN junction | 5M10.60 | Demonstrate a PN junction with a battery. |
| AJP 29(5),287 | transistor curve tracer | 5M10.61 | Circuits for constructing instruments to display transistor curves on an oscilloscope. |
| AJP 78 (12), 1425 | transistor curve tracer | 5M10.61 | A digital oscilloscope that can write to a USB device, combined with open source software is used to analyze transistor curves. |
| AJP 29(8),529 | Fermi level model | 5M10.62 | A model with ball bearings representing electrons and holes in Plexiglas representing states. |
| AJP 53(1),90 | brillouin | 5M10.70 | View a waveform on an oscilloscope through a cardboard with slots cut out. |
| PIRA 1000 | brillouin/compass array | 5M10.71 | |

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| UMN, 5M10.71 | brillouin/compass array | 5M10.71 | |
| PIRA 1000 | transistor amplifier | 5M10.90 | |
| Disc 18-12 | transistor amplifier | 5M10.90 | A transistor circuit board shows simple amplification. |
| Hil, A-10b | integrated circuits | 5M10.92 | Show transistors and integrated circuits including slides of integrated circuit blow ups. |
| TPT 23(7), 448 | operational amplifiers | 5M10.95 | Measurments and demonstrations with operational amplifiers. |
| TPT 25(1), 38 | operational amplifiers | 5M10.95 | Elementary functions involving operational amplifiers. |
| AJP 40(4), 638 | operational amplifiers | 5M10.95 | A circuit for integration with an operational amplifier. |
| AJP 73(9), 856 | operational amplifiers | 5M10.95 | A simple Fermi-Dirac integrating circuit with an op amp to monitor the output voltage. |
| | **Tubes** | **5M20.00** | |
| PIRA 1000 | glow discharge | 5M20.10 | |
| Sut, A-12 | glow discharge | 5M20.10 | Various discharge phenomena are described from atmospheric to high vacuum. |
| Sut, A-11 | glow discharge tube | 5M20.10 | The pressure is reduced on a large tube while high voltage DC is applied to the electrodes. |
| Hil, A-2c | gaseous discharge tube | 5M20.10 | Pump down a long discharge tube to show Crookes' dark space, negative glow, Faraday dark space, striations, etc. |
| Sprott, 4.8 | gas discharge tube | 5M20.10 | A partially evacuated glass tube filled with various gases at low pressure and connected to a high-voltage electrical source. |
| D&R, S-150 | glow discharge tube | 5M20.10 | The pressure is reduced in a long tube while high voltage from an induction coil is applied to the electrodes. |
| Sut, A-14 | potential required for glow discharge | 5M20.12 | Show the minimum voltage for a neon glow tube to discharge. |
| Sut, A-78 | thermionic effect | 5M20.15 | Use a tube to show the thermionic effect in a vacuum. |
| PIRA 1000 | special purpose discharge tubes | 5M20.20 | |
| Sut, A-13 | special purpose discharge tubes | 5M20.20 | Gas discharge tubes for spectra, fluorescence of minerals, line tubes, paddle wheel, etc. are mentioned. |
| Hil, A-2a | five cathode ray tubes | 5M20.20 | Special tubes that demonstrate five properties of cathode rays. |
| Sprott, 4.8 | Geissler tubes | 5M20.20 | A set of special gaseous discharge lamps with different gases, different glowing surfaces, or fluorescent liquids. |
| D&R, S-150 | special purpose discharge tubes | 5M20.20 | Gas discharge tubes to demonstrate fluorescence are mentioned. |
| Sut, A-18 | electron beams | 5M20.25 | A tube with a replaceable lime spot (or barium, strontium, and calcium oxides) hot cathode gives a brilliant beam. Diagram. |
| Sut, A-21 | electron focusing | 5M20.28 | Three types of focusing of the beam: residual gas, electrostatic, and magnetic. |
| Sut, A-87 | gas filled tubes - two element type | 5M20.30 | A circuit for demonstrating the mercury-vapor rectifier tube. |
| Sut, A-16 | hot-cathode discharges | 5M20.31 | The Tungar rectifier bulb and the phanotron mercury-vapor rectifier illustrate the role of cathode emission in discharge. |
| Hil, A-9a | diode tubes | 5M20.32 | The Welch demonstration power supply board is used to explain the theory of the diode tube. |
| Sut, A-17 | thyratron tube | 5M20.35 | The function of the grid in a discharge tube is shown with a thyratron. |
| Sut, A-88 | gas filled tubes - grid controlled | 5M20.36 | A circuit for demonstrating the thyratron tube. |
| Sut, A-81 | three element tube curves | 5M20.40 | A circuit for obtaining the characteristic curves of a triode. |
| Sut, A-82 | "fresh air three electrode tube" | 5M20.41 | Elements of a three electrode tube are placed in a bell jar. |
| Sut, A-83 | three electrode tube model | 5M20.42 | Steel balls represent electrons in a mechanical model of a triode. Picture. |
| Sut, A-84 | three element tube - electrostatic | 5M20.43 | A circuit for controlling the plate current of a three or four element tube. |
| Hil, A-9b | the triode | 5M20.44 | A circuit for demonstration the principles of a triode tube. Reference: AJP 23(9),384. |
| AJP 29(9),640 | triode demonstrator unit | 5M20.46 | Apparatus review of the Modern and Classical Instruments triode demonstrator board. (1961) |
| Mei, 33-2.1 | soap bubble model of tubes | 5M20.50 | Soap bubbles moving through plates connected to a Van de Graaff generator simulate behavior of electron tubes. Picture. |
| | **ELECTROMAGNETIC RADIATION** | **5N00.00** | |
| | **Transmission Lines and Antennas** | **5N10.00** | |
| PIRA 1000 | model transmission line | 5N10.10 | |
| UMN, 5N10.10 | model transmission line - lamps | 5N10.10 | |
| F&A, Eh-4 | transmission of power | 5N10.10 | Five 200 W bulbs connected in series along resistance wire. |
| Sut, E-162 | model transmission line - lamps | 5N10.10 | Six lamps are connected across two thin wires strung along the lecture bench. |
| Hil, E-2c | voltage drop | 5N10.10 | Voltages are measured successively across four 300 W bulbs. |

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| AJP 55(1),22 | drift velocity | 5N10.13 | Move a Hall specimen perpendicular to the magnetic field in the opposite direction to the drift motion of carriers with exactly the drift velocity compensates for the Hall voltage. |
| PIRA 1000 | high voltage line model | 5N10.15 | |
| Sut, E-244 | H.T. transmission | 5N10.15 | A model transmission line with a lamp for a load that shows a loss unless transformers are used to boost voltage up and back. |
| Hil, E-3g | power loss in transmission line | 5N10.16 | A circuit demonstrates that the efficiency of power transmission increases with increased voltage. Variac, light bulb bank, meters, line resistance. Reference: AJP 21(2),110. |
| PIRA 1000 | model transmission line - phases | 5N10.20 | |
| Mei, 33-6.1 | model transmission line - phases | 5N10.20 | A model transmission line is made of a series of sixty series inductors and shunt capacitors. An oscilloscope is used to show delay times and phase relationships. |
| AJP 53(6),563 | wave propagation | 5N10.21 | A demonstration of wave propagation in a toroidal transmission line with periodic variation of the wave phase velocity around the line. |
| AJP 48(5),417 | wave propagation in aluminum | 5N10.22 | Show amplitude decay and change in phase for waves propagating through an aluminum wedge or large sheet. |
| Mei, 33-6.3 | dispersion in non-inductive cable | 5N10.25 | A model cable made of 150 series resistors and parallel capacitors shows delay and dispersion with meters at each end. |
| AJP 47(5),429 | dispersion circuit | 5N10.26 | A set of T filters with the input and output impedances matched are used to show dispersion of a short pulse. |
| AJP 37(8),783 | dispersion of an EM pulse | 5N10.27 | A microwave demonstration where as a sine wave burst is generated and the dispersion is observed in a slotted line waveguide with a sampling scope. |
| PIRA 500 | reflections in a coax | 5N10.30 | |
| UMN, 5N10.30 | reflections in a coax | 5N10.30 | |
| AJP 72(5), 671 | propagation in a coax | 5N10.30 | Measuring the speed of radio waves along a homemade coaxial transmission line. |
| AJP 29(2),123 | propagation in a coax | 5N10.30 | A circuit using a wetted-contact mercury relay gives a pulse with a very fast rise time. |
| AJP 29(2),ix | reflections in a coax | 5N10.30 | Reflections in a coax using the Tektronix 545A delayed trigger. |
| Mei, 33-6.2 | propagation velocity in coax | 5N10.30 | Using a square wave generator and oscilloscope, propagation time in 1', 20', and 40' of coax are compared. Diagrams |
| PIRA 500 | Lecher wires | 5N10.50 | |
| UMN, 5N10.50 | Lecher wires | 5N10.50 | A 80 MHz generator is coupled to a long transmission line and standing waves are demonstrated with neon and filament lamp probes. |
| F&A, Ep-13 | Lecher wires | 5N10.50 | Standing waves are set up on parallel wires from an 80 MHz generator. |
| Sut, A-37 | Lecher wires | 5N10.50 | Standing electromagnetic waves are coupled from an UHF oscillator to parallel wires. |
| Disc 21-13 | Lecher wires | 5N10.50 | Standing waves are generated on parallel wires by a radio transmitter. An incandescent bulb placed across the wires indicates voltage maxima. |
| Hil, S-2e.3 | Lecher bars | 5N10.52 | Two six foot iron rods are used in a Lecher system with a fluorescent lamp detector. |
| PIRA 1000 | microwave standing waves | 5N10.55 | |
| Mei, 33-7.7 | microwave standing waves | 5N10.55 | Measure the wavelength of a microwave transmitter by using a movable mirror to set up standing waves. |
| D&R, W-140, O-030 | microwave standing waves | 5N10.55 | Measure the wavelength of a microwave transmitter by using a movable reflector about 1 m from the transmitter to set up standing waves. |
| Disc 21-15 | microwave standing waves | 5N10.55 | Standing waves are set up between a microwave transmitter and a metal sheet. The receiver is moved between the two and the signal strength is displayed on an LED bar graph. |
| TPT 28(7), 474 | microwave oven standing waves | 5N10.57 | Standing waves in a microwave oven are measured using cobalt chloride paper. |
| TPT 32(4), 199 | microwave oven standing waves | 5N10.57 | Standing waves in a microwave oven by heating Cream of Wheat. |
| AJP, 78 (5), 492 | microwave oven standing waves | 5N10.57 | Three dimensional standing waves formed on cobalt chloride paper are examined. |
| PIRA 500 | radiation from a dipole | 5N10.60 | |
| UMN, 5N10.60 | radiation from a dipole | 5N10.60 | |
| F&A, Ep-12 | radiation from a dipole | 5N10.60 | A flashlight bulb on a dipole detects radiation from an 80Mhz generator. |
| D&R, O-030 | radiation from a dipole | 5N10.60 | The Cenco microwave transmitter is used to show approximate plane waves emitted by a dipole antenna |
| AJP 69(3), 288 | radiation from a dipole | 5N10.60 | Discussion on how to teach about radiation from a dipole antenna. |
| AJP 70(8), 829 | radiation from a dipole | 5N10.60 | The method of AJP 69(3), 288 is extended to treat the reception and scattering of electromagnetic plane waves by simple wire antennas. |
| AJP 70(10), 1056 | radiation from a dipole | 5N10.60 | Corrections to AJP 70(8), 829. |

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| AJP 76 (11), 1048 | radiation from a dipole | 5N10.60 | Derives analytical expressions in terms of elementary functions for the electromagnetic fields of linear antennas of finite length. |
| Disc 21-11 | radio waves | 5N10.60 | Show radiation with a 100 MHz dipole transmitter and hand held dipole receiver with a flashlight bulb detector. |
| Sut, A-38 | radiation and polarization | 5N10.61 | Polarization of radiation from a dipole antenna is checked with a hand-held dipole antenna with lamp indicator. |
| AJP 52(12),1150 | dipole radiation computer simulation | 5N10.63 | R.H Good report on his Apple II dipole radiation simulation. Excellent and free. |
| Sut, A-39 | directional antenna | 5N10.65 | A directional antenna for use with a UHF oscillator. |
| AJP 55(7),662 | waveguide normal modes | 5N10.70 | Morie pattern type demonstration of normal modes in a waveguide. |
| PIRA 200 | EM vectors | 5N10.80 | |
| Mei, 6-4.2 | EM vectors | 5N10.80 | A dynamic model for demonstrating electric and magnetic vectors in an electromagnetic field. Picture, Diagrams. |
| D&R, O-O25 | EM wave models | 5N10.80 | Ping Pong paddles or semi fixed wave models are used to show the relation of E and B in a plane EM wave. |
| | **Tesla Coil** | **5N20.00** | |
| PIRA 200 | induction coil | 5N20.10 | The small handheld induction coil. |
| F&A, Em-8 | induction coil | 5N20.10 | The small handheld induction coil. |
| Disc 20-21 | induction coil | 5N20.10 | A large induction coil, explained with the aid of animation. |
| Hil, E-11a | induction coil | 5N20.12 | A small Cenco induction coil. |
| Sut, E-245 | induction coil | 5N20.13 | All sorts of stuff on induction coils - producing high voltage from a DC source. |
| AJP, 65(8), 744 | A high potential Tesla coil impulse generator for lecture demonstrations and science exhibitions | 5N20.14 | An excellent "how to" guide for building a large Tesla coil. The article contains information on the design of various parts and the mathematics to analyze your work/design. |
| F&A, Em-1 | spark coil | 5N20.15 | A discussion of the construction of a large spark coil and the effects of reversing polarity. |
| PIRA 200 - Old | hand held Tesla and lamp | 5N20.25 | Light a fluorescent lamp by touching with a hand held tesla coil. |
| UMN, 5N20.25 | hand held tesla and lamp | 5N20.25 | |
| PIRA 1000 | Tesla coil | 5N20.40 | |
| UMN, 5N20.40 | Tesla coil | 5N20.40 | |
| F&A, Ep-2 | Tesla coil | 5N20.40 | Description of a 500 KHz tesla coil. |
| Sprott, 4.6 | Tesla coil | 5N20.40 | A Tesla coil is used to demonstrates phenomena associated with very high voltages and currents. |
| Sut, A-35 | continuous wave Tesla coil | 5N20.41 | A tesla coil is coupled to an oscillator coil from A-32 or A-36. |
| Sut, A-31 | Tesla coil | 5N20.42 | Directions for building a Tesla coil and many demonstrations possible with it are described. |
| Mei, 33-3.8 | Tesla coil | 5N20.43 | Directions for building a Tesla coil (Oudin coil when one end is grounded) that will give a thirty inch spark. |
| Hil, E-11e | Tesla coil | 5N20.44 | Pictures of two Tesla coils. References: Popular Science, Jan 1946, pp 191-194; Popular Science, June 1964, pp 169-73. |
| PIRA 500 | glowing fluorescent lamp | 5N20.50 | |
| UMN, 5N20.50 | glowing fluorescent lamp | 5N20.50 | |
| F&A, Ep-5 | fluorescent light in radiation field | 5N20.50 | A fluorescent light bulb is held in the Tesla coil radiation field. |
| D&R, E-195 | glowing fluorescent lamp | 5N20.50 | A 25 W or 40 W fluorescent tube is held in the radiation field of a Tesla coil. |
| Sprott, 4.6 | glowing fluorescent lamp | 5N20.50 | A fluorescent light bulb is held in the radiation field of a Tesla coil. |
| Disc 21-06 | Tesla coil | 5N20.50 | Light a fluorescent tube at a distance, show the skin effect. |
| Sut, A-15 | electrodeless discharge | 5N20.55 | Hold a bulb of a gas at low pressure near a Tesla coil. |
| PIRA 500 | skin effect | 5N20.60 | |
| UMN, 5N20.60 | skin effect | 5N20.60 | |
| F&A, Ep-4 | high frequency currents | 5N20.60 | The skin effect carries enough current to light a bulb held in the hands. |
| F&A, Ep-6 | betatron action | 5N20.70 | An inductive coil replacing the high voltage transformer in the Tesla coil will give a visible beam in a partially evacuated glass bulb. |
| F&A, Ep-3 | space charge from high frequency corona | 5N20.75 | Discharge a negatively charged electroscope with air blown from a Tesla coil corona. |
| PIRA 200 - Old | Tesla coil and pinwheel | 5N20.80 | Place a pinwheel on the secondary of a tesla coil. See 5B30.50. |
| | **Electromagnetic Spectrum** | **5N30.00** | |
| PIRA 200 | project the spectrum | 5N30.10 | Project white light through a high dispersion prism. |
| UMN, 5N30.10 | projected spectrum with prism | 5N30.10 | White light is projected through a high dispersion prism. |
| Sut, L-101 | project the spectrum with prisms | 5N30.10 | The optical path for projecting a spectrum using glass or liquid filled prisms. |
| Sut, L-106 | project the continuous spectrum | 5N30.10 | A carbon arc or concentrated filament lamp is used as a source with prism optics. |

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| Sut, L-42 | white light with prism | 5N30.10 | Project a slit of light through a prism or hollow prism filled with carbon disulfide. |
| D&R, O-270 | white light with prism | 5N30.10 | Project a slit of light from a slide projector through a glass prism or a hollow prism filled with ethyl cinnamate or carbon disulfide. |
| Sprott, 6.1 | project the spectrum with prisms | 5N30.10 | A rainbow produced by passing a collimated beam of white light through a glass prism illustrates that white light is made of many colors. |
| AJP, 75 (1), 35 | white light with prism | 5N30.10 | A short article with picture detailing a hollow prism into which liquids with different refractive indexes may be poured. |
| Sut, L-112 | mapping the spectrum | 5N30.15 | Use a thermopile and galvanometer to show the infrared energy in the continuous spectrum. Insert a water cell. |
| TPT 38(9), 559 | infrared spectrum | 5N30.15 | Reproducing Herschel's experiment and his discovery of infrared radiation. A liquid crystal sheet is used as the detector. |
| TPT 19(7), 483 | ultraviolet spectrum | 5N30.20 | Part 1. A way to demonstrate the presence of characteristic ultraviolet lines of mercury. |
| TPT 19(9), 618 | ultraviolet spectrum | 5N30.20 | Part 2. A way to demonstrate the far ultraviolet line of mercury on fluorescent dyed cloth or paper. |
| Bil&Mai, p 316 | ultraviolet spectrum | 5N30.20 | A phosphorescent sheet is used to detect ultraviolet wavelengths beyond the violet end of the visible spectrum. |
| F&A, Ok-1 | ultraviolet spectrum | 5N30.20 | A carbon arc is projected through quartz optics and prism to a screen of half white paper and half fluorescent paper. |
| PIRA 500 | microwave transmitter & receiver | 5N30.30 | |
| UMN, 5N30.30 | microwave transmitter & receiver | 5N30.30 | A 12 cm transmitter and receiver are demonstrated. |
| AJP 51(10),925 | microwave homebrew - 13 cm | 5N30.30 | Build a high quality source and detector for $25. Explicit instructions. |
| Disc 21-14 | microwave unit | 5N30.30 | An LED bar graph indicates signal strength as a microwave transmitter is rotated around a receiver and as the beam is blocked by a metal sheet. |
| F&A, Ol-1 | microwave wavelength by phase differential | 5N30.31 | Listen for minima as a second transmitter is moved back and forth a wavelength. |
| Mei, 33-7.1 | microwave resonance | 5N30.33 | A modulated signal from a HP 616A generator is passed through a cavity to a detector with provisions to modify the cavity. |
| Mei, 33-7.3 | water attenuation of microwaves | 5N30.35 | A Plexiglas box between the transmitter and receiver has no effect until filled with water. |
| Disc 21-16 | microwave absorption | 5N30.35 | Place dry and wet cloths in the microwave beam. |
| PIRA 1000 | IR camera and projected spectrum | 5N30.45 | |
| AJP 73(10), 986 | IR camera and projected spectrum | 5N30.45 | Looking at different objects and the spectrum with a webcam that has the IR filter removed. |
| PIRA 1000 | IR camera and remote control device | 5N30.50 | |
| UMN, 5N30.50 | IR from remote control device | 5N30.50 | |
| PIRA 1000 | IR camera and soldering iron | 5N30.51 | |
| PIRA LOCAL | hearing infrared | 5N30.55 | Connect a solar cell to a small amplifier / speaker. Point a remote control at the solar cell and press a button. The infrared signal will be heard. |
| Bil&Mai, p 317 | solar cell and remote control device | 5N30.55 | The signals from a remote control is detected with a solar cell connected to a mini amplifier with speaker. Confirm that the remote is emitting in the red-infrared range by using a red and a blue filter. |
| PIRA 1000 | IR control devices | 5N30.60 | |
| Sut, A-106 | penetration of X-rays | 5N30.80 | Use the ionization method with an electroscope to show penetration of X-rays. |
| Sut, A-107 | absorption coefficents | 5N30.81 | Show the thickness of various materials needed to cut the intensity of a beam in half. |

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| | **GEOMETRICAL OPTICS** | **6A00.00** | |
| | **Speed of Light** | **6A01.00** | |
| PIRA 200 | speed of light | 6A01.10 | Demonstrate speed of light by the path difference method with a fast pulser and fast oscilloscope. |
| UMN, 6A01.10 | speed of light | 6A01.10 | A fast pulser is used to demonstrate speed of light by the path difference method. |
| F&A, Oa-4 | velocity of light | 6A01.10 | The displacement of a pulse from a fast pulser is viewed on a sampling oscilloscope as the path length is changed. Insert different media in the path. |
| Mei, 35-1.5 | speed of light - moving reflector | 6A01.10 | Fancy speed of light apparatus fully documented. Diagrams, Pictures. |
| AJP, 65(7), 614-618 | measuring the speed of light using a fibre optic kit | 6A01.10 | This is a nice discussion of the "time delay method" of measuring the speed of light using the fibre optic method, and a good explanation of the equipment needed. |
| AJP 76 (9), 812 | speed of light | 6A01.10 | A tabletop experiment that directly measures the speed of light using a pulsed diode laser, reflecting mirror, photodiode detector, and an oscilloscope. Electric circuit diagrams included. |
| AJP 41(5),722 | pulser circuit | 6A01.11 | A pulser circuit for the moving reflector speed of light apparatus. |
| AJP 34(7),ix | speed of light - fast pulse | 6A01.11 | Use a high repetition rate pulsed light from TRW to demonstrate the speed of light. |
| AJP 55(9),853 | pulser circuit | 6A01.11 | An LED pulser circuit that emits a 20 ns pulse. |
| AJP 37(11),1154 | pulser circuit | 6A01.11 | A light pulser circuit based on the MV 10A LED. |
| AJP 38(11),1353 | speed of light - N2 laser pulser | 6A01.11 | A N2 pulsed laser is used in the moving reflector setup. |
| AJP 40(5),740 | speed of light - spark source | 6A01.12 | Construction and properties of a spark light source. |
| AJP 37(9),939 | microwave moving reflector | 6A01.15 | A small microwave pulse generator gives short pulses. |
| PIRA 1000 | speed of light - two path | 6A01.20 | |
| Mei, 35-1.4 | speed of light - two path | 6A01.20 | Fast flash through two paths to a photomultiplier tube. Diagrams, Pictures. |
| Mei, 35-1.3 | speed of light - two path | 6A01.21 | A spot of the display trace of a fast oscilloscope is passed through two different paths to a photomultiplier tube whose output is displayed on the same trace. Diagram, Picture. |
| AJP 37(11),1163 | errata - corrected diagram | 6A01.25 | Corrected diagram for figure 2 in AJP 37(8),818 (1969). |
| AJP 41(2),272 | speed of light | 6A01.25 | The MV50 LED is pulsed in this simple time of flight measurement. |
| AJP 50(12),1157 | speed of light - minimal apparatus | 6A01.25 | An inexpensive time of flight apparatus using a strobed LED and voltmeter. |
| AJP 59(5),443 | speed of light - time of flight | 6A01.25 | An acoustico-optic modulator chops a laser beam in a time of flight setup. |
| AJP 36(11),1021 | speed of light choppers | 6A01.25 | Use a 250 tooth commercial gear as a light chopper. |
| AJP 37(8),816 | speed of light - phase shift | 6A01.26 | Many circuits are given. Features a solid-state electro-optical light modulator to replace the Kerr cell. |
| AJP 40(11),1705 | optical radar | 6A01.27 | A commercial (Optitron Inc.) speed of light apparatus with an ultraviolet pulser. |
| PIRA 1000 | speed of light - rotating mirror | 6A01.30 | |
| Mei, 35-1.1 | speed of light - rotating mirror | 6A01.30 | The position of the reflected image from a rotating mirror is measured for clockwise and counterclockwise rotations. Diagram, Appendix, p. 1353. |
| AJP 40(6),910 | speed of light - rotating mirror | 6A01.31 | Photodiode detector with the rotating mirror. |
| AJP 39(10),1145 | speed of light - rotating mirror | 6A01.31 | A laser beam is used with the rotating mirror method. Detector circuits given. |
| AJP 46(11),1189 | speed of light - combined method | 6A01.32 | A rotating mirror chops the laser beam and a beam splitter gives near and far paths. |
| AJP 47(3),288 | Leybold speed of light modification | 6A01.36 | When both sides of the rotating mirror are exposed, deflections as large as 2 cm can be observed with the unaided eye. |
| AJP 29(10),711 | Leybold speed of light rotation rate | 6A01.36 | Instead of comparing the motor sound to a tuning fork, use a microphone to pick up the motor sound and display it on an oscilloscope, use Lissajous figures with a reference. |
| AJP 39(12),1537 | more Leybold improvements | 6A01.36 | Use a solar cell with the AJP 32(7),567 technique. |
| AJP 32(7),567 | Leybold speed of light improvements | 6A01.36 | Find the lateral displacement of the returning beam with a photomultiplier on a carriage. |
| Mei, 35-1.2 | Leybold speed of light improvements | 6A01.36 | Use a microphone, oscillator, and oscilloscope to measure the motor frequency of the Leybold speed of light apparatus. Reference: AJP 29(10),711. |
| AJP 44(6),546 | speed of light - microwave interferometer | 6A01.38 | The Doppler beat frequency from the detector is used to drive a spark generator. |

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| TPT 35(4), 231 | speed of light - microwave oven | 6A01.39 | Place a layer of marshmallows in the microwave oven. Heat the marshmallows until hot spots appear. Measure the distance between hot spots to get the wavelength of the microwave. Remember the hot spot separation should be distances of wavelength/2. Calculate the speed of light. |
| TPT 35(6), 323 | speed of light - microwave oven | 6A01.39 | Correction to TPT 35(4), 231. |
| Sut, L-17 | speed of light - models | 6A01.40 | Set up mirrors on the lab bench to help students visualize the standard methods. Do the sound analog (S-81). Set up a rotating mirror. |
| AJP 58(11),1059 | group velocity of light | 6A01.50 | Measure the speed of light to 0.02% and verify the relationship between group and phase velocity. Low cost circuit is given. |
| AJP 69(2), 110 | speed of light - electrical measurement | 6A01.60 | Determination of the speed of light using an LRC circuit. |
| | **Straight Line Propagation** | **6A02.00** | |
| PIRA 1000 | light in a vacuum | 6A02.10 | |
| Disc 21-07 | light in a vacuum | 6A02.10 | Place a flashing light in the bell jar to emphasize the point. |
| PIRA 1000 | straight line propagation - shadows | 6A02.15 | |
| F&A, Oa-1 | straight line propagation of light | 6A02.15 | A good point source shows straight line propagation of light by shadow projection. |
| Disc 21-08 | straight line propagation | 6A02.15 | Cast shadows with a point source. |
| Sut, H-148 | propagation star | 6A02.16 | An intense radiation point source limited by a star shaped aperture melts a star shaped pattern on a paraffin backed black foil. |
| PIRA 1000 | chalk dust | 6A02.35 | |
| | **Reflection from Flat Surfaces** | **6A10.00** | |
| AJP 59(3),242 | optical design software | 6A10.05 | Use commercial optical design software to model and display geometrical optics. |
| TPT 3(5),230 | reflection model | 6A10.09 | A string and pulley arrangement shows the minimum path for reflection from a flat surface. |
| PIRA 500 | blackboard optics - plane mirror | 6A10.10 | |
| F&A, Ob-11 | blackboard optics - plane mirror | 6A10.10 | Blackboard optics - plane mirror. |
| PIRA 1000 | optical disk with flat mirror | 6A10.11 | |
| UMN, 6A10.11 | optical disk with flat mirror | 6A10.11 | Use a single beam with the optical disk and a flat mirror element. |
| Sut, L-22 | optical disk with flat mirror | 6A10.11 | Turn the optical disk with a single beam of light hitting the mirror. |
| Disc 21-20 | angle of incidence, reflection | 6A10.11 | Aim a beam of light at a mirror at the center of a disc, rotate the disc. |
| PIRA 500 | laser and flat mirror | 6A10.15 | |
| UMN, 6A10.15 | laser and flat mirror | 6A10.15 | Shine a laser at a flat mirror on the lecture bench and use chalk dust to make the beam visible. |
| PIRA 1000 | microwave reflection | 6A10.18 | |
| Disc 21-18 | microwave reflection | 6A10.18 | Reflect a microwave beam off a metal plate into a receiver. |
| PIRA 500 | diffuse and specular reflection | 6A10.20 | |
| F&A, Ob-1 | smooth and rough surface reflection | 6A10.20 | Chalk dust sprinkled on a mirror blurs the image of a light reflecting onto the wall. |
| Disc 21-19 | diffuse and specular reflection | 6A10.20 | Show a beam on light reflecting off a mirror on an optics board. Replace the mirror with a sheet of paper. |
| Mei, 34-1.5 | diffuse reflection | 6A10.21 | Hold frosted glass at various angles in a beam of light focused on the wall. |
| PIRA 1000 | aluminum foil reflection | 6A10.22 | |
| UMN, 6A10.22 | aluminum foil reflection | 6A10.22 | Same as AJP 50(5),473. |
| AJP 50(5),473 | scattering with aluminum foil | 6A10.22 | Reflect light off a sheet of aluminum foil, then crumple and flatten it to create many facets. |
| Sut, L-19 | reflection - normal and grazing | 6A10.24 | Place a lantern and piece of clear glass midway between two walls and show the difference between reflecting by grazing on one wall and normal reflection on the other. Also compare glass and silvered at grazing and normal incidence. |
| PIRA 1000 | ripple tank reflection | 6A10.25 | |
| PIRA 500 | corner cube | 6A10.30 | |
| F&A, Ob-6 | corner reflector | 6A10.30 | Three reflectors are placed on the inside corner of a box. |
| Sut, L-21 | corner cube | 6A10.30 | Two mirrors at 90 degrees or three mirrors mutually perpendicular. |
| Disc 21-24 | corner reflection | 6A10.30 | Look at your image in a corner cube. |
| PIRA 1000 | large corner cube | 6A10.31 | |
| UMN, 6A10.31 | large corner cube | 6A10.31 | |
| AJP 50(8),765 | large corner cube | 6A10.31 | Use large mirror wall tiles (12 in sq) to make a large corner reflector. |
| D&R, O-130 | large corner cube | 6A10.31 | Use mirror "tiles" to make a large corner reflector. |
| Mei, 34-1.2 | signaling mirror | 6A10.33 | A plane mirror with a small unsilvered area in the center is used for signaling. Diagram. |

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| F&A, Ob-9 | perversion | 6A10.35 | Perversion can be demonstrated in public with a license plate and a plane mirror. Sorry, no inversion. |
| D&R, O-105 | perversion | 6A10.35 | Perversion is studied with the word "AMBULANCE" arranged such that it can be read correctly in a rear view mirror. |
| PIRA 1000 | parity reversal in a mirror | 6A10.37 | |
| Disc 21-22 | parity reversal in a mirror | 6A10.37 | View a Cartesian coordinate system in a mirror. |
| PIRA 500 | angled mirrors | 6A10.40 | |
| UMN, 6A10.40 | angled mirrors | 6A10.40 | |
| F&A, Ob-4 | mirrors at an angle | 6A10.40 | A candle placed between angled mirrors forms multiple images. |
| Mei, 34-1.1 | angled mirrors | 6A10.40 | Two hinged front surface mirrors show multiple images of an object placed between them. Diagram. |
| D&R, O-125 | angled mirrors | 6A10.40 | An object placed between variable angle mirrors forms multiple images. |
| AJP, 75 (4), 342 | angled mirrors | 6A10.40 | A short article with picture explaining some of the physics of angled mirrors and multiple images. |
| Disc 21-23 | hinged mirrors | 6A10.40 | Mirrors angled at 60 degrees give one object and five images arranged in a hexagon. |
| Sut, L-20 | hinged mirrors | 6A10.41 | Place a light between two mirrors hinged together and standing vertically. Place a sheet of clear glass between the mirrors forming an isosceles triangle. A few more variations are given. |
| Hil, O-1c | hinged mirrors, kaleidoscopes | 6A10.42 | Hinged mirrors are shown at 60 and 30 degrees along with 60 and 30 degree kaleidoscopes. |
| D&R, O-135 | kaleidoscope | 6A10.42 | A simple kaleidoscope constructed from 3 microscope slides and 2 plastic film canisters |
| AJP 58(6),565 | angled mirrors - laser spots | 6A10.43 | The hyperboloid of revolution formed by the successive reflections of a laser beam on two plane angled mirrors is explained by a simple geometrical method. |
| AJP 30(5),380 | hinged mirrors theory | 6A10.44 | The theorem of Rosendahl is applied to the hinged mirror problem to predict the number of images formed at various inclinations. |
| PIRA 500 | parallel mirrors | 6A10.45 | |
| F&A, Ob-5 | parallel mirrors | 6A10.45 | An infinite number of images are formed with a candle between parallel mirrors. |
| D&R, O-120 | parallel mirrors | 6A10.45 | An infinite number of images are formed with an object between parallel mirrors. Best if one mirror has a hole in the center for easy viewing. |
| AJP 72(1), 53 | parallel mirrors | 6A10.45 | The color of the object becomes darker and greener if common second-surface plane mirrors are used. |
| Disc 21-25 | barbershop mirrors | 6A10.45 | Place objects between parallel mirrors and view them over one of the mirrors. |
| PIRA 500 | full view mirror | 6A10.50 | |
| UMN, 6A10.50 | full view mirror | 6A10.50 | |
| F&A, Ob-3 | height of a mirror for full view | 6A10.50 | Shades are pulled up from the bottom and down from the top covering a mirror until a person can just see their entire height. |
| Hil, O-1d | large plane mirror | 6A10.51 | A three foot plane mirror is used to show all of a six foot person. |
| Sprott, 6.9 | talking head | 6A10.55 | Reflections from a mirror mounted beneath a table give the illusion that a disembodied head is sitting on the table. |
| Bil&Mai, p 331 | antigravity mirror | 6A10.57 | Straddle a large mirror so that it is between your legs. Lift the leg that is in front of the mirror and it will appear you are levitating. |
| PIRA 500 | cold candle | 6A10.60 | |
| UMN, 6A10.60 | cold candle | 6A10.60 | |
| F&A, Ob-2 | candle in a glass of water | 6A10.60 | A candle in front of a plate glass forms an image in a glass of water behind. |
| Sut, L-18 | candle in a glass of water | 6A10.60 | A candle is placed in front of a sheet of glass and a beaker of water an equal distance behind. Place the entire apparatus on a rotating table. |
| D&R, O-100 | candle in a glass of water | 6A10.60 | A candle in front of a plate of glass form an image in a battery jar of water. Can also be done with identical light bulbs in identical sockets. |
| Sprott, 6.10 | candle in a glass of water | 6A10.60 | A candle in front of a plate glass forms an image in a glass of water behind the plate glass. |
| Bil&Mai, p 328 | cold candle | 6A10.60 | A candle in front of a plate glass forms an image that appears to be behind the glass. Place a finger in the "flame" of the virtual image. |
| Disc 21-21 | location of image | 6A10.60 | Place a sheet of glass between a burning candle and a glass of water so the image of the candle appears in the glass. |
| PIRA 1000 | half silvered mirror box | 6A10.65 | |
| D&R, O-115 | mirror box | 6A10.65 | Two people look at opposite sides of a large sheet of acrylic or glass. As the light over one subject is dimmed, the light over the other brightens causing metamorphosis. |

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| Sprott, 6.10 | mirror box | 6A10.65 | People look at opposite sides of a large sheet of acrylic or glass. As the light over one subject is dimmed, the light over the other brightens causing metamorphosis. |
| Disc 21-26 | Mirror Box | 6A10.65 | Two people look into opposite ends of a box containing a half silvered mirror in the center. As the light on one end is dimmed, the light on the other brightens, causing metamorphosis. |
| TPT 28(7),468 | sawblade optics | 6A10.76 | Keep the sawblade perpendicular by lining up the reflection of the board in the sawblade. |
| | **Reflection from Curved Surfaces** | **6A20.00** | |
| PIRA 200 | blackboard optics - curved mirrors | 6A20.10 | |
| PIRA 1000 - Old | blackboard optics - curved mirrors | 6A20.10 | |
| F&A, Oc-1 | blackboard optics - concave mirror | 6A20.10 | Blackboard optics - concave mirror. |
| F&A, Oc-2 | blackboard optics - convex mirror | 6A20.10 | Blackboard optics - convex mirror. |
| D&R, O-150, O-155 | blackboard optics - curved mirrors | 6A20.10 | Blackboard optics, concave and convex mirrors |
| Disc 22-01 | concave and convex mirrors | 6A20.10 | Shine parallel beams at convex and concave mirrors. Use a thread screen for display. |
| PIRA 1000 | optical disc with curved mirrors | 6A20.11 | |
| UMN, 6A20.11 | optical disc with curved mirrors | 6A20.11 | Use the optical disc with multiple beams and curved lens elements. |
| F&A, Oc-3 | optical disc with curved mirrors | 6A20.11 | Mount either concave or convex mirrors in the optical disc. |
| Mei, 34-1.18 | large optical disc | 6A20.11 | A large translucent screen and large lens elements scale up the Hartl optical disc. Diagrams. |
| PIRA 500 | parallel lasers and curved mirrors | 6A20.15 | |
| UMN, 6A20.15 | parallel lasers and curved mirrors | 6A20.15 | Shine parallel lasers at converging and diverging mirrors and use chalk dust to make the beams visible. |
| Bil&Mai, p 332 | parallel lasers and curved mirrors | 6A20.15 | Shine parallel lasers at a concave mirror and use a fog machine to make the beams visible. |
| PIRA 1000 | spherical abberation in a mirror | 6A20.20 | |
| Disc 22-02 | spherical abberation in a mirror | 6A20.20 | Shine parallel rays at spherical and parabolic mirror elements, noting the difference in aberration. |
| AJP 36(11),1022 | off focal point source | 6A20.21 | A picture of the caustic formed by parallel laser rays incident on a parabolic mirror at 30 degrees. |
| Sut, L-25 | concave mirrors - caustics | 6A20.24 | Directions for making a large cylindrical or parabolic mirror element. |
| AJP 35(6),534 | variable curved mirrors | 6A20.26 | Aluminized mylar stretched over a coffee can makes a variable positive or negative mirror when the can is pressurized or evacuated. |
| F&A, Ob-10 | elliptical tank | 6A20.27 | A filament lamp is placed at one focus of an elliptically shaped wall of shiny aluminum and chalk dust shows the image at the other focus. |
| Sut, L-26 | ellipsoidal mirror | 6A20.28 | Compare the light intensity from the lamps at the near and far focus of an ellipsoidal mirror. Directions for making the mirror element. Diagram. |
| PIRA 500 | mirror & rose | 6A20.30 | |
| UMN, 6A20.30 | mirror & rose | 6A20.30 | |
| F&A, Oc-10 | flower in a vase | 6A20.30 | A hidden flower at the center of curvature of a parabolic mirror appears in an empty vase. |
| Sut, L-24 | lamp in the socket | 6A20.30 | A 40 W lamp is projected onto an empty socket. |
| Sut, L-23 | mirror and rose | 6A20.30 | Hints for projecting a real image (rose) on an object (vase). |
| D&R, O-160, O-165 | lamp in the socket | 6A20.30 | A lamp image is projected onto an empty socket. |
| F&A, Oc-11 | cold candle | 6A20.31 | Hold your finger in the inverted image of a candle burning at the center of curvature of a parabolic mirror. |
| D&R, O-165 | cold candle | 6A20.31 | Place the candle with axis horizontal at the center of curvature of a large spherical mirror. Candle will appear to burn at both ends with one flame pointed up and the other flame pointed down. |
| Disc 22-05 | large concave mirror | 6A20.31 | Hold a candle and other objects at the center of curvature of a large convex mirror. |
| PIRA 1000 | optic mirage | 6A20.35 | |
| UMN, 6A20.35 | optic mirage | 6A20.35 | Same as Oc-7. |
| TPT 28(8),534 | optic mirage | 6A20.35 | Derivation of additional "magic separations" of the Optic Mirage that give images. |
| F&A, Oc-7 | optic mirage | 6A20.35 | Two concave mirrors face each other. Images of objects resting on the bottom mirror appear at the center hole of the top mirror. |

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| D&R, O-175 | optic mirage | 6A20.35 | Two concave mirrors face each other. Images of objects resting on the bottom mirror appear at the center hole of the top mirror. |
| AJP 46(3),297 | shine an light on the Optic Mirage | 6A20.36 | Shine a light on an shiny object in the Optic Mirage and the reflections will look real. |
| F&A, Oc-6 | red ball in hemisphere | 6A20.37 | Looking at a red ball pendulum suspended from the rim of a hemispherical concave mirror makes one puke. |
| Mei, 34-1.3 | swinging lamp and concave mirror | 6A20.37 | A lamp pendulum is swung between the center of curvature and the principle focus on a concave mirror. |
| D&R, O-160 | red ball in hemisphere | 6A20.37 | An optics toy that has a red ball pendulum suspended from the rim of a hemispherical concave mirror. |
| Bil&Mai, p 334 | bi-colored ball in hemisphere | 6A20.37 | Looking at a bi-colored pendulum suspended from the rim of a hemispherical concave mirror makes one puke. |
| PIRA 500 | projected arrow with mirror | 6A20.40 | |
| UMN, 6A20.40 | projected arrow with mirror | 6A20.40 | A converging mirror is used to project an image of an illuminated arrow onto a screen. |
| PIRA 1000 | projected filament with mirror | 6A20.41 | |
| UMN, 6A20.41 | projected filament with mirror | 6A20.41 | A converging mirror is used to project the image of a light bulb filament onto a screen. Masks can be used to stop down the mirror. |
| F&A, Oc-4 | image with a concave mirror | 6A20.41 | A concave mirror is used to image a lamp filament on a screen or the wall. |
| Bil&Mai, p 329 | image with a concave mirror | 6A20.41 | A concave mirror is used to image a light bulb with the letter "F" drawn on it onto a wall or screen. |
| AJP 58(3),280 | rotating liquid mirror | 6A20.42 | Rotate a pan of glycerine mixed with dark dye, using a lighted object as a source and ground glass screen or TV camera as a detector. |
| PIRA 500 | convex and concave mirrors | 6A20.45 | |
| F&A, Oc-8 | no image with convex mirror | 6A20.45 | Try to project the image of a filament from a convex mirror. |
| Hil, O-1f | convex and concave mirrors | 6A20.45 | Large 16" convex and concave mirrors are shown. |
| D&R, O-150, O-155 | convex and concave mirrors | 6A20.45 | Large concave and convex mirrors are shown. |
| Hil, O-1e | convex and concave mirrors | 6A20.45 | Project a lamp image with a concave mirror, then try convex. |
| F&A, Oc-5 | amusement park mirrors | 6A20.50 | Cylindrical mirrors are made with a ten inch radius of curvature. |
| D&R, O-140 | amusement park mirrors | 6A20.50 | A rectangular flexible mirror is bent to make concave and convex mirrors to view objects in the horizontal and the vertical. |
| Sut, L-27 | convex mirror | 6A20.51 | View the image of your nose in a 1/2" diameter steel ball through a short focal length lens. |
| PIRA 1000 | energy at a focal point | 6A20.60 | |
| F&A, Oc-9 | lighting a cigarette | 6A20.60 | Light a cigarette at the focal point of a parabolic mirror concentrating the beam of an arc light. |
| Disc 22-03 | energy at a focal point | 6A20.60 | Remove the projection head of an overhead projector and hold a piece of paper at the focal point until it bursts into flame. |
| | **Refractive Index** | **6A40.00** | |
| PIRA 500 | apparent depth with TV | 6A40.10 | |
| F&A, Od-7 | apparent depth with TV camera | 6A40.10 | Focus a camera on a spot and then note how far the camera is moved to refocus when a clear plastic block is placed on the spot. |
| F&A, Od-6 | apparent depth | 6A40.11 | Look down into a tall graduate and estimate the distance to a coin at the bottom. |
| D&R, O-220 | apparent depth on the overhead | 6A40.11 | Place a transparent ruler under a beaker of water filled to a measured depth d on the overhead and focus. Raise another transparent ruler up the outside of the beaker until it to is in focus ( d minus h). d/d-h should be the index of refraction of water. |
| Mei, 34-1.8 | focusing telescope method | 6A40.12 | Move a telescope back and forth on a optical bench to focus on the front and then on the back of a block of Plexiglas or container of liquid. |
| Mei, 33-7.8 | microwave index of refraction | 6A40.13 | The index of refraction is determined by measuring the distance between minima with a movable plane mirror in a container of liquid. Diagram. |
| AJP 33(1),62 | refractive index of ice | 6A40.15 | Freeze water by pumping in a hollow acrylic prism and measure the minimum deviation. |
| PIRA 500 | count fringes | 6A40.20 | |
| UMN, 6A40.20 | count fringes | 6A40.20 | |
| AJP 35(5),435 | Michelson index of refraction | 6A40.20 | Place a gas cell in one leg of the Michelson interferometer and evacuate air or let in a gas while counting fringes. |
| AJP 39(2),224 | Michelson index of refraction | 6A40.20 | Count fringes of laser light as air is let into an evacuated chamber in one leg of a Michelson interferometer. |
| Hil, O-2c | Michelson index of refraction | 6A40.20 | A vacuum chamber is put in one leg of a Michelson interferometer and fringes are counted as air or a gas is leaked into the chamber. Reference: TPT 6(4),176. |
| Mei, 34-1.9 | Raleigh refractometer | 6A40.21 | Improvements on the Raleigh refractometer to make the fringes more visible for easier counting as the air is let back in to the tube. |

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| TPT 28(5),323 | index of refraction of He and SF6 | 6A40.25 | In addition to letting air (21 fringes) into one arm of the Michelson interferometer, let in He (3 fringes) and SF6 (55 fringes). |
| PIRA 200 | disappearing beaker | 6A40.30 | |
| PIRA 500 - Old | Cheshire cat | 6A40.30 | A cats face drawn on a beaker appears to float in the middle of a larger beaker filled with baby oil or Wesson oil. |
| D&R, O-215 | disappearing beaker | 6A40.30 | Use Johnson's baby oil or Wesson oil to make a small beaker disappear when immersed. If the beaker has graduations or words they will appear to be floating in the liquid. |
| D&R, O-216 | broken test tube made whole | 6A40.30 | Smash a test tube and place the pieces into a beaker of baby oil. Pull out an unbroken test tube. |
| Bil&Mai, p 336 | disappearing beaker | 6A40.30 | A small beaker inside a larger beaker is made to disappear when vegetable oil is poured in. |
| Disc 22-10 | disappearing eye dropper | 6A40.30 | Place an eyedropper in a liquid with an index of refraction matched to the glass. |
| AJP 28(8),743 | more Christiansen filters | 6A40.31 | A table of Christiansen filter pairs. See AJP 25,440 (1957) |
| Sut, L-33 | Christiansen filters | 6A40.31 | A mixture of crushed glass and a liquid with the same index of refraction as glass is warmed in a container and exhibits colors. Directions for making a permanent display. Reference. |
| Bil&Mai, p 337 | refraction of laser light | 6A40.33 | A small piece of glass protrudes from the corner of a square battery jar at a 45 degree angle. A laser beam is directed through the jar at a right angle to the side so that it passes through the glass and produces two beams. Fill the jar with vegetable oil and one of the beams disappears. |
| TPT, 36(7), 420 | refraction of diffracted light | 6A40.35 | Refraction of light, using diffracted light, through a water and air interface is explored. |
| AJP 47(1),120 | grating pattern shift | 6A40.36 | Shine a laser beam through a grating so the beam splits the air/liquid interface and measure the difference in the diffraction pattern for the light passing through the air and liquid. |
| AJP 54(10),956 | grating in aquarium | 6A40.36 | Mount a transmission grating inside an aquarium and measure the diffracted laser beam on the other end with and without water in the tank. |
| Sut, L-29 | refraction with shadow and cube | 6A40.37 | A shadow projected through a glass cube has a different length than normal. |
| AJP 46(4),426 | refractive index of beer | 6A40.38 | The ratio of the apparent diameter to the actual diameter of a stick of pepperoni in a glass of beer gives the index of refraction. In the classroom, use a mesh projected on the wall and measure offset of a vertical wire. |
| Mei, 34-1.7 | Abbe refractometer | 6A40.39 | A liquid separates the hypotenuses of two right angle prisms. |
| PIRA 1000 | variable index of refraction tank | 6A40.40 | |
| AJP 40(6),913 | variable index of refraction tank | 6A40.40 | Shine a laser beam through an aquarium with an unstirred sugar solution. |
| Mei, 34-1.12 | variable index of refraction tank | 6A40.40 | How to make a tank with varying concentrations of benzol and CS2. |
| AJP 56(12),1099 | gradient index lens | 6A40.42 | A small gradient index lens is passed around the class. It looks like a glass rod but one sees an inverted image when looking along the axis. |
| PIRA 1000 | mirage | 6A40.45 | |
| Sut, L-32 | mirage | 6A40.45 | How to heat a long plate to demonstrate the mirage effect. |
| Mei, 34-1.15 | mirage | 6A40.46 | The image from a slide projector is directed just above a brass plate heated with a burner. |
| AJP 51(3),270 | mirage with a laser | 6A40.47 | A laser beam almost grazing a hot plate will show deflection when the hot plate is turned on. |
| AJP 51(5),475 | laser beam deflection - thermal gradient | 6A40.47 | An apparatus for cooling a plate to deflect a laser beam downward. |
| AJP 37(3),332 | mirage with laser | 6A40.47 | A laser beam is imaged through a keyhole and the beam then passes through a 1 meter oven. |
| AJP 57(10),953 | superior "superior" image | 6A40.47 | A laser beam passing through a tank of water begins to deflect immediately when heat lamps are turned on. Images are also observed. |
| D&R, O-225 | laser beam deflection - twinkling | 6A40.47 | A laser beam close to the top of a hot plate. The laser beam is run through an aperture after the hot plate and before the screen. The spot on the wall will jiggle, twinkle, or even wink out at times when the plate is turned on. |
| D&R, O-226 | laser and hot plate | 6A40.47 | A laser beam almost grazing a hot plate will "dance" when the hot plate is turned on. |
| Sprott, 6.4 | laser beam deflection - twinkling | 6A40.47 | A laser beam passed over the top of a Bunsen burner produces a spot on the wall that twinkles like a star. |
| AJP 48(11),990 | not a mirage with a laser | 6A40.48 | I haven't figured this out and have to go home to eat, so maybe some other time. |
| AJP 42(9),774 | mirage explanation note | 6A40.49 | A note correcting misleading textbook explanations of the mirage. |
| PIRA 1000 | oil, water, laser | 6A40.50 | |
| PIRA 1000 | Schlieren image | 6A40.60 | |

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| AJP 49(2),158 | cheap Schlieren | 6A40.60 | A small, compact, portable, and inexpensive Schlieren instrument using an ordinary lamp and a light source. |
| Mei, 34-1.27 | Schlieren, etc. | 6A40.60 | Show and compare Schlieren, direct shadow, and interferometeric method of detecting small changes in the index of refraction of air. Diagrams, Details in appendix, p. 1352. |
| AJP 29(9),642 | Schlieren image of a candle | 6A40.61 | A simple arrangement with a point source, lens, and candle near the lens, aperture, and screen for lecture demonstration purposes. |
| F&A, Op-1 | Schlieren image of a candle | 6A40.61 | Laser light is used in Schlieren projection of a candle flame. |
| AJP 52(5),467 | single mirror Schlieren system | 6A40.62 | Two Ronchi rulings are placed at the radius of curvature of a spherical mirror. |
| AJP 50(8),764 | Schmidt-Cassegrain Schlieren | 6A40.63 | Two Schmidt-Cassegraion telescopes are used to make a simple inline Schlieren system. |
| Mei, 34-1.26 | Toepler Schlieren apparatus | 6A40.65 | A simpler Schlieren setup with colors indicating amount of deviation. |
| Sut, L-31 | refraction by gases | 6A40.67 | Shadow project the Bunsen burner (H-137), hold a hot object in one arm on the Michelson interferometer. |
| PIRA 1000 | short beer | 6A40.70 | |
| AJP 45(6),582 | tall beer | 6A40.70 | Properly designed glassware makes the beer look taller. |
| AJP 43(8),741 | cylindrical lens and short beers | 6A40.70 | Analysis of the apparent inner diameter thick cylinder of a liquid of different index of refraction. |
| AJP 44(6),601 | short beers | 6A40.70 | Paint the inside of the illusion cylinder, (AJP 43(8),741). |
| AJP 47(8),744 | beer mugs | 6A40.70 | Two beer mugs were found that have the same outer dimensions and both appear to hold the same amount of beer when full, but actually differ in volume by a factor of two. |
| AJP 44(8),799 | short beer comment | 6A40.70 | Easy explanation. |
| AJP 46(11),1197 | plasma laser-beam focusing | 6A40.90 | An expanded laser beam grazing a flat combustion flame from a paint stripper is focused into a line. A second perpendicular flame gives a point. |
| | **Refraction from Flat Surfaces** | **6A42.00** | |
| PIRA 500 | blackboard optics - refraction | 6A42.10 | |
| F&A, Od-2 | blackboard optics - refraction | 6A42.10 | Blackboard optics with a single beam and a large rectangle and prism of Plexiglas. |
| D&R, O-200 | blackboard optics - refraction | 6A42.10 | Blackboard optics with a single beam and a large acrylic rectangular block. Add a plane mirror to the back of the block to reflect internal beam and show it is parallel to the beam reflected from the front surface. |
| PIRA 1000 | optical disk with glass block | 6A42.11 | |
| UMN, 6A42.11 | optical disk with glass block | 6A42.11 | A single beam of light on the optical disc is used to show refraction through a rectangular block of glass. |
| Disc 22-06 | refraction/reflection from plastic | 6A42.12 | Rotate a rectangle of plastic in a single beam of light. |
| F&A, Od-3 | optical disc - semicircle | 6A42.15 | A single beam of light is refracted at the flat but not the curved side if it leaves along a radius. |
| PIRA 200 | refraction tank | 6A42.20 | Rotate a beam of light in a tank of water containing some fluorescein. |
| F&A, Od-1 | refraction tank | 6A42.20 | A rotatable beam of light in a tank of water containing some fluorescein. |
| Bil&Mai, p 339 | refraction tank and lasers | 6A42.20 | Two different colored laser beams enter a tank of water containing a pinch of powdered coffee creamer. One beam enters at a right angle to the surface of the water, and the other enters at an angle. Use a fog machine to made the beams in air visible and observe the refraction. |
| PIRA 1000 | Nakamara refraction tank | 6A42.21 | |
| UMN, 6A42.21 | Nakamara refraction tank | 6A42.21 | |
| UMN, 6A42.22 | big plastic refraction tank | 6A42.22 | |
| TPT 28(6),422 | force table refraction tank | 6A42.24 | A small refraction tank is mounted on a force table. |
| Sut, L-28 | refraction | 6A42.27 | Three refraction demos - optical tank, ripple tank, glass block. |
| PIRA 1000 | refraction model - rolling | 6A42.30 | |
| Sut, L-30 | refraction model | 6A42.30 | An axle with independent 1" wheels rolls down an incline with one wheel on cloth, the other on the plain board. |
| Mei, 34-1.21 | string models of refraction | 6A42.31 | String models of refraction representing a water tank, prism, thin lens, comma aberration, and astigmatism are shown. Pictures, Construction details in appendix, p.1345. |
| AJP 48(4),275 | wavefront strips model | 6A42.32 | |
| PIRA 1000 | ripple tank refraction | 6A42.35 | |
| UMN, 6A42.35 | ripple tank refraction | 6A42.35 | |
| PIRA 500 | penny in a cup | 6A42.40 | |
| UMN, 6A42.40 | penny in a cup | 6A42.40 | |
| F&A, Od-4 | seeing a coin | 6A42.40 | Pour water into a beaker until a coin at the bottom previously hidden by the side is visible. |
| PIRA 1000 | light in a tank | 6A42.43 | |

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| Disc 22-07 | small refraction tank | 6A42.43 | Position a lamp in an opaque tank so the filament cannot be seen, then add water until the light from the filament is seen over the edge of the tank. |
| PIRA 500 | stick in water | 6A42.45 | |
| F&A, Od-5 | stick in water | 6A42.45 | A stick appears bent when inserted into water at an angle. |
| D&R, O-210 | stick in water | 6A42.45 | A stick, ruler, or spoon, appears bent or broken when inserted into water at an angle. |
| AJP 43(1),112 | rugged refraction demonstration | 6A42.46 | Cast a stick in a tumbler filled with clear casting resin. Pass around the class. |
| PIRA 1000 | acrylic/lead glass refraction | 6A42.47 | |
| Disc 22-08 | acrylic/lead glass refraction | 6A42.47 | Hold a stick behind stacked lead glass and acrylic blocks. The image of the stick is shifted when viewed off the normal to the surface of the blocks. |
| PIRA 1000 | minimum angle of deviation | 6A42.50 | |
| F&A, Of-1 | minimum deviation of a prism | 6A42.50 | At minimum deviation light reflected off the base is parallel to that passing through an equilateral prism. |
| Hil, O-2b | minimum angle of deviation | 6A42.50 | Project a line filament through a large prism on a rotating platform with and without monochromatic filters. Reference: TPT 7(9),513. |
| PIRA 1000 | three prism stack | 6A42.51 | |
| Disc 22-09 | three different prisms | 6A42.51 | A stack of three prisms of different glass shows different refraction and dispersion. |
| PIRA 1000 | paraffin prism and microwaves | 6A42.55 | |
| UMN, 6A42.55 | paraffin prism and microwaves | 6A42.55 | |
| Mei, 33-7.10 | microwave paraffin prism | 6A42.55 | Determine the index of refraction of a large paraffin prism with 3.37 cm microwaves. |
| F&A, Oj-6 | dispersion in different media | 6A42.60 | A multiple element prism is made with layers of different plastic and glass. |
| F&A, Oj-5 | dispersion of liquids | 6A42.65 | A hollow prism is filled with a layer of carbon disulfide and a layer of water. |
| D&R, O-272 | oil, syrup, and water prisms with a laser | 6A42.65 | Fill a V-shaped trough with oil, syrup, or water and shine a projector with a narrow slit aperture through it and look at the spectrums and the deviation. Use a laser to compare deviations and relate to index of refraction of the liquids used. |
| | **Total Internal Reflection** | **6A44.00** | |
| PIRA 200 | blackboard optics | 6A44.10 | Multiple beams of light pass through large scale optical elements. |
| D&R, O-205 | blackboard optics - prism, semicircle | 6A44.10 | Single and multiple beams of light pass through large acrylic prisms and semicircles. |
| PIRA 1000 | optical disk with prism, semicircle | 6A44.11 | |
| UMN, 6A44.11 | optical disk with prism, semicircle | 6A44.11 | A single beam of light on the optical disk shows total internal reflection when passed through a prism. |
| Mei, 34-1.6 | semicircular element on disc | 6A44.11 | A beam of light entering a semicircular glass disc normal to the curved surface is reflected off the flat side. |
| PIRA 500 | big plastic refraction tank | 6A44.20 | |
| F&A, Oe-1 | critical angle in a refraction tank | 6A44.20 | A beam in a tank of water is rotated until there is total internal reflection at the surface. |
| Sut, L-35 | refraction tank | 6A44.20 | Adjust the path of a beam with mirrors in a tank of water with fluorescein to show total internal reflection. |
| Bil&Mai, p 341 | critical angle in a refraction tank | 6A44.20 | Fill a refraction tank with water that contains a pinch of powdered coffee creamer. Direct a laser beam up through one side of the tank towards the top surface of the water. |
| Bil&Mai, p 343 | critical angle / total internal reflection | 6A44.20 | Tape playing cards to the outside walls and bottom of a refraction tank. Fill the tank with water and observe what critical angle and total internal reflection hath wrought. |
| Disc 22-11 | critical angle/ total internal reflection | 6A44.20 | Shine a beam through the side of a tank containing fluorescein. Rotate a mirror in the tank so the beam passes through the critical angle. |
| UMN, 6A44.22 | big plastic refraction tank | 6A44.22 | |
| PIRA 1000 | Snell's wheel | 6A44.25 | |
| PIRA 1000 | ripple tank total internal reflection | 6A44.30 | |
| AJP 45(6),550 | ripple tank total reflection | 6A44.30 | Vary the angle of incidence of ripple tank waves to a boundary with water depths of 13 and 3 mm. |
| ref. | frustrated total internal reflection | 6A44.35 | see 7A50.12 |
| PIRA 200 | laser and fiber optics | 6A44.40 | Shine a laser into a curved plastic rod. |
| UMN, 6A44.40 | laser and fiber optics | 6A44.40 | A laser is used with a bundle of fiber optics, a curled Plexiglas rod, and a 1" square lean rod. |
| F&A, Oe-7 | light pipe - spiral | 6A44.40 | Light is projected down a clear Plexiglas spiral. |
| Sut, L-34 | curved glass tube | 6A44.40 | Shine a bright light source through a curved glass tube. |
| Hil, O-2e | light pipes | 6A44.40 | Several light pipes and fiber optics are shown. |

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| D&R, O-255 | laser and fiber optics | 6A44.40 | Shine a laser through several light pipes. |
| Sprott, 6.5 | light pipe - spiral | 6A44.40 | A long spiral rod illuminated with a low-power laser. |
| Disc 22-13 | light pipes | 6A44.40 | Shine a laser into a curved plastic rod. |
| PIRA 1000 | optical path in fibers | 6A44.41 | |
| Disc 22-14 | optical path in fibers | 6A44.41 | Shine a laser down a bent rectangular bar. |
| PIRA 1000 | steal the signal | 6A44.42 | |
| UMN, 6A44.42 | steal the signal | 6A44.42 | |
| D&R, O-258 | steal the signal | 6A44.42 | Shine a laser into a spiral acrylic light pipe. Dip the spiral into baby oil, or coat with vaseline, and note that the light pipe no longer reflects light internally. |
| AJP 53(2),182 | bounce around a tube | 6A44.43 | A laser beam bounces around a thick walled Plexiglas tube due to total internal reflection. |
| D&R, O-255 | bounce around a tube | 6A44.43 | A laser beam follows a helical path around a thick walled acrylic tube. |
| PIRA 1000 | water stream light pipe | 6A44.45 | |
| AJP 44(6),604 | water stream light pipe | 6A44.45 | Shine a laser beam down the water stream issuing from the orifice of a Plexiglas tank of water. |
| Sut, L-36 | illuminated fountain | 6A44.45 | Shine a light down a stream of water. |
| D&R, O-250 | water stream light pipe | 6A44.45 | Shine a laser beam down the center of an orifice issuing from a large plastic soda bottle. A Florence flask with a two hole stopper may also be used. |
| Sprott, 6.6 | water stream light pipe | 6A44.45 | A stream of water illuminated with a laser or high-intensity white light act as a light guide. |
| Bil&Mai, p 342 | water stream light pipe | 6A44.45 | Shine a laser beam down the center of an orifice issuing water from a large plastic bottle. |
| Disc 22-15 | laser waterfall | 6A44.45 | Shine a laser down the center of a nozzle and it follows the water stream. |
| PIRA 200 - Old | light below surface | 6A44.50 | An underwater light illuminates powder on the surface of water to form a central spot of light. |
| UMN, 6A44.50 | ring of light | 6A44.50 | Same as Oe-2. |
| F&A, Oe-2 | light below surface | 6A44.50 | An underwater light illuminates powder on the surface of water to form a central spot of light. |
| AJP 51(5),469 | ring of light index of refraction | 6A44.51 | Find the index of refraction of transparent plates by wetting a filter paper on one side, shining the laser in that side, and measuring the diameter of the light circle. |
| AJP 49(8),794 | ring of darkness | 6A44.52 | Shine a laser through a sample to a white diffusely reflecting surface and measure the darkened circle on the top surface. |
| F&A, Oe-5 | water/benzol surface | 6A44.53 | Total internal reflection from a water/benzol surface. |
| F&A, Oe-4 | hidden mercury in a test tube | 6A44.54 | Mercury in a partially filled test tube cannot be seen from above when immersed in water. |
| Sut, L-40 | total internal and metallic reflection | 6A44.54 | View a test tube half full of mercury half in water from an angle of 100 degrees to the incident beam. The glass-air interface is brighter. |
| PIRA 1000 | black ball turns silver | 6A44.55 | |
| F&A, Oe-3 | black ball turns silver | 6A44.55 | A soot covered ball appears silver under water due to reflected light from air trapped on the surface of the ball. |
| Sut, L-39 | soot ball | 6A44.55 | A ball covered with soot appears silvery in water due to the air trapped on the soot forming an air-water interface. |
| Disc 22-12 | silver soot ball | 6A44.55 | A ball coated with soot appears silver in water. |
| Sut, L-37 | glass-air interface | 6A44.56 | Two thin strips of glass are sealed with an air barrier and immersed in water. Turned to the proper angle to the incident beam it will exhibit total internal reflection. |
| Sut, L-38 | near critical angle | 6A44.56 | Use the entrapped air slide in a water bath or air between right angle prisms to show the colors of the transmitted and reflected light near the critical angle. Dispersing the two beams will show complementary spectra. |
| F&A, Oe-6 | add water to snow | 6A44.59 | Project light through snow or chopped ice and add water. |
| Sut, L-41 | diamond | 6A44.60 | A thin beam of light is directed on a diamond and the reflections are projected onto a cardboard. |
| F&A, Of-2 | inversion with a right angle prism | 6A44.65 | Project an image upside down and place a right angle prism in the beam to invert the image. |
| F&A, Ob-7 | right angle prism inverter | 6A44.65 | A right angle prism placed in a projected beam inverts the image. |
| F&A, Of-3 | right angle prism - double reflection | 6A44.66 | A beam entering the hypotenuse of a right angle prism is inverted and reversed. |
| F&A, Of-4 | two right angle prisms - inversion | 6A44.67 | Two right angle prisms are arranged to invert and pervert the image. |
| Hil, O-2d | prisms | 6A44.68 | Several prisms demonstrate total internal reflection. |
| AJP 59(5),477 | Goos-Haenchen shift | 6A44.70 | The sideways displacement of a beam at total internal reflection is shown with 3 cm microwaves. |

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| | **Rainbow** | **6A46.00** | |
| PIRA 500 | rainbow | 6A46.10 | |
| UMN, 6A46.10 | rainbow | 6A46.10 | |
| F&A, Oj-10 | rainbow | 6A46.10 | An arc lamp directed at a sphere of water forms a rainbow on a screen. |
| Sut, L-43 | rainbow | 6A46.10 | Project a beam through a spherical flask of water and view the rainbow on a screen placed between the light and the flask. |
| D&R, O-275 | rainbow | 6A46.10 | A slit of light from a slide projector grazes a beaker or square plastic container filled with water producing a rainbow. |
| D&R, O-275 | rainbow | 6A46.10 | A clear plastic cup filled with water is placed on the overhead. A dispersed circular rainbow will be seen on the ceiling. |
| D&R, O-280 | rainbow | 6A46.10 | Project a beam through a spherical flask of water and view the rainbow on a screen with center hole placed between the light source and the flask. |
| AJP 77 (9), 795 | rainbow | 6A46.10 | A project in which students use numerical methods to analyze the physics of the rainbow. |
| Sut, L-45 | artificial rainbow | 6A46.11 | Form a vertical circle "rainbow" by placing a tube of water between a prism and screen. |
| AJP 58(6),593 | secondary rainbow | 6A46.12 | Use a single sphere with the back surface coated with a reflecting material to show both primary and secondary bows with increased intensity. |
| Sut, L-44 | rainbow droplets | 6A46.15 | Small droplets formed by spraying an atomizer on a soot covered glass plate glisten like colored jewels when viewed at 41 degrees. |
| AJP 56(11),1006 | rainbow dust | 6A46.16 | On using small glass spheres to generate bows and halos. |
| PIRA 1000 | rainbow model | 6A46.20 | |
| Mei, 34-1.16 | rainbow model | 6A46.20 | Depict a three dimensional model of the rainbow with strings representing light rays. |
| Mei, 34-1.17 | rainbow | 6A46.25 | A mechanical model for demonstrating rainbow formation shows why the rainbow is produced and why size depends on the time of day. |
| TPT 28(7),509 | rod and dowel raindrop model | 6A46.26 | A rod and dowel raindrop model is used to show why a rainbow is bow-shaped. |
| PIRA 1000 | optical disc with spherical lens | 6A46.30 | |
| UMN, 6A46.30 | optical disc with spherical lens | 6A46.30 | A single beam into a circular glass element is refracted, totally internally reflected, and refracted out again. |
| Disc 23-24 | rainbow disc | 6A46.30 | A single beam is used with a spherical glass element on an optical board to show the path of refracted light that produces a rainbow. |
| | **Thin Lens** | **6A60.00** | |
| PIRA 500 | blackboard optics - thin lens | 6A60.10 | |
| F&A, Og-7 | blackboard optics - thin lens | 6A60.10 | Blackboard optics are used with convex and concave thin lens elements. |
| D&R, O-310 | blackboard optics - thin lenses | 6A60.10 | Blackboard optics are used with convex and concave thin lens elements. |
| PIRA 1000 | optical disk with thin lens | 6A60.11 | |
| UMN, 6A60.11 | optical disk with thin lens | 6A60.11 | The optical disk is used with multiple beams and a thin lens element. |
| F&A, Og-10 | optical disc - lenses | 6A60.11 | Various lens elements are used with the optical disc. |
| F&A, Og-1 | optical disc - refraction at curved surfaces | 6A60.12 | A long plastic slab with a concave surface at one end and a convex surface at the other is used in the optical disc. |
| PIRA 500 | ripple tank convex lens | 6A60.15 | |
| UMN, 6A60.15 | ripple tank convex lens | 6A60.15 | |
| F&A, Sm-6 | ripple tank - lens model | 6A60.15 | Refraction due to depth differences over a lens shaped area in the ripple tank. |
| PIRA 1000 | ripple tank concave lens | 6A60.16 | |
| UMN, 6A60.16 | ripple tank concave lens | 6A60.16 | |
| PIRA 500 | parallel lasers and lenses | 6A60.20 | |
| UMN, 6A60.20 | parallel lasers and lenses | 6A60.20 | Parallel lasers are passed through converging and diverging lenses. Chalk dust illuminates the beams. |
| F&A, Og-9 | parallel lasers and lenses | 6A60.20 | Parallel lasers are used with chalk dust to show the path of rays through a lens and combinations of lenses. |
| AJP 70(12), 1184 | ray tracing with lenses | 6A60.20 | A ray tracing approach to thin lens analysis. This ray tracing approach accommodates skew rays providing a more complete analysis. |
| Disc 22-18 | ray tracing with lenses | 6A60.20 | Show parallel rays passing through a lens element and converging. |
| PIRA 200 | thin lens projection | 6A60.30 | Project the filament of a lamp with a thin lens. |
| UMN, 6A60.30 | projected filament with a lens | 6A60.30 | Project the filament of a light bulb on the wall. The lens can be stopped down. |
| F&A, Og-5 | thin lens projection | 6A60.30 | Project the filament of a lamp with a thin lens. |
| Disc 22-16 | real image formation | 6A60.30 | With a source and screen at the ends of a long optical bench, show the two positions a lens will produce an image. |
| PIRA 1000 | projected arrow with a lens | 6A60.31 | |

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| UMN, 6A60.31 | projected arrow with a lens | 6A60.31 | Use an illuminated arrow with a converging lens to project an image on a screen. |
| D&R, 0-315 | projected arrow with a lens | 6A60.31 | Use an illuminated arrow with a converging lens to project an image on a screen. Two such commercial light sources are shown. |
| D&R, O-320 | project arrow with lens - cover half lens | 6A60.31 | Use an illuminated arrow with a converging lens to project an image on a screen. Cover the bottom half of the lens and observe the image. |
| Bil&Mai, p 345 | projected arrow with a lens | 6A60.31 | Use an illuminated arrow with a converging lens to project an image on a screen. |
| F&A, Og-6 | thin concave lens | 6A60.32 | Try to project an image with a thin concave lens. |
| Hil, O-4a | image location | 6A60.33 | A set of lenses for demonstrating the six general cases for object and image distances. |
| PIRA 1000 | lens magnification | 6A60.35 | |
| Disc 22-17 | lens magnification | 6A60.35 | Place various lenses between a backlit grid and the class. |
| AJP 76 (9), 856 | submerged light bulb | 6A60.37 | Exploring the unusual optical properties displayed by submerged clear and frosted light bulbs. |
| UMN, 6A60.40 | position of virtual image | 6A60.40 | |
| AJP 48(4),322 | position of a virtual image with a TV | 6A60.40 | Find the virtual image location by focusing on an object through a lens removing the lens, and moving the object to a focused position. Also the apparent depth with a TV method. |
| PIRA 1000 | position of a virtual image | 6A60.45 | |
| F&A, Og-12 | focal length of a lens - mirror | 6A60.45 | When a lamp is at the focal length, the image is at the same place if a mirror is placed directly behind the lens. |
| TPT, 37(2), 94 | how to quickly estimate the focal length of a diverging lens | 6A60.46 | A simple method for finding the focal length is explained. |
| Sut, L-50 | effect of medium on focal length | 6A60.48 | Find the focal length of a lens, then find the focal length of the same lens in water. |
| Sut, L-47 | lenses | 6A60.49 | All sorts of focal length stuff. |
| PIRA 500 | pinholes projected with a lens | 6A60.50 | |
| UMN, 6A60.50 | pinholes projected with a lens | 6A60.50 | |
| F&A, Oa-2 | pinholes projected with a lens | 6A60.50 | Pinholes are pricked in a black paper covering a long filament bulb. Bring the multiple images into one image with a converging lens. |
| Sut, L-48 | action of a lens | 6A60.50 | Project the images of a filament through several pinholes and then add a lens to collect the many into a single image. |
| D&R, O-300 | pinholes projected with a lens | 6A60.50 | Pinholes are pricked in a black paper covering a bulb. Bring the multiple images into one image with a large converging lens. |
| PIRA 1000 | paraffin lens and microwaves | 6A60.60 | |
| UMN, 6A60.60 | paraffin lens and microwaves | 6A60.60 | |
| Mei, 33-7.2 | microwave lens | 6A60.60 | Construct a microwave lens and prisms of stacks of properly contoured aluminum sheets separated by just over one half the wavelength. |
| | **Pinhole** | **6A61.00** | |
| PIRA 1000 | pinhole projection | 6A61.10 | |
| Sut, L-15 | pinhole projection | 6A61.10 | Place a lamp in a box covered with heavy paper and poke a hole in the paper with a wire 1-2 mm in diameter. Poke more holes for more images. Try different size holes. |
| Hil, O-1a | pinhole projection | 6A61.10 | Interpose a metal plate with two holes between a lamp and a screen on an optical bench. |
| ref. | pinholes projected with a lens | 6A61.15 | see 6A60.50 |
| PIRA 500 | pinhole camera | 6A61.20 | |
| UMN, 6A61.20 | pinhole camera | 6A61.20 | |
| F&A, Oa-3 | pinhole camera | 6A61.20 | Place film at the back of a box with a hole. |
| D&R, O-350 | pinhole camera | 6A61.20 | Construction of a simple pinhole camera from a shoe box. |
| Disc 21-09 | pinhole camera | 6A61.20 | Project a lamp filament onto a screen. Vary the distance of the screen and the size of the pinhole. Includes animation. |
| Sut, L-16 | pinhole camera | 6A61.21 | A sliding box with has pinhole at one end and a frosted glass at the other. Try a 1" diameter hole in the shutter of a window in a darkened room. Directions on making a pinhole camera. |
| AJP 49(5),715 | pinhole imagery | 6A61.22 | A complete discussion of pinhole imagery. |
| D&R, O-350, O-590 | pinhole imagery | 6A61.22 | A pinhole will allow a person to focus clearly on an object at 5 cm. Approximate 5X magnification will also result. |
| Mei, 34-1.10 | pinhole camera | 6A61.23 | A small tube covered with tin foil with a small hole replaces the lens of a TV camera. |
| Mei, 34-1.11 | fish-eye camera | 6A61.30 | A pinhole camera filled with water or solid Lucite gives a fish-eye view. Diagram, Pictures. |
| | **Thick Lens** | **6A65.00** | |
| AJP 55(12),1128 | computer assisted optics | 6A65.09 | The authors describe a program that covers spherical and chromatic aberration in addition to other topics. BASIC, PC, available from authors. |

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| PIRA 500 | improving an image with a stop | 6A65.10 | |
| F&A, Oh-2 | improving an image with a stop | 6A65.10 | Use a stop to improve the image through a short focal length lens. |
| D&R, O-370 | improving an image with a stop | 6A65.10 | Use a stop to improve the image through a short focal length lens. |
| F&A, Oh-3 | depth of focus | 6A65.11 | Use a six inch long glowing wire as an extended object for showing the effect of stopping down a lens. |
| PIRA 1000 | optical disc - circular glass plate | 6A65.15 | |
| F&A, Og-4 | optical disc - circular glass plate | 6A65.15 | Use a circular plate of glass with the optical disc as an example of a thick lens. |
| PIRA 500 | chromatic aberration | 6A65.20 | |
| UMN, 6A65.20 | chromatic aberration | 6A65.20 | |
| AJP 68(9), 869 | chromatic aberration | 6A65.20 | How to project chromatic aberration in a large lecture classroom using an overhead projector and another glass or Fresnel lens. |
| F&A, Oj-9 | chromatic aberration | 6A65.20 | A diaphragm moved near the focus selects red or blue light from beams passing through the edge of a lens. |
| Mei, 34-1.23 | aplanic properties of a sphere | 6A65.21 | Aplanic systems show no spherical aberration or coma for some special position of object and image demonstrated here with a spherical lens. |
| D&R, O-380 | chromatic aberration | 6A65.21 | Show chromatic aberration using a slide projector, large thick lens, and red and blue or violet Kodak filters. |
| Disc 22-22 | chromatic aberration | 6A65.21 | Project spots of light on a screen from several points on a lens. Note chromatic aberration and then add a second correction lens. |
| Mei, 34-1.22 | chromatic aberration | 6A65.22 | Show the image formation distance for red and UV light using a fluorescent screen to display the UV. |
| Mei, 36-7.2 | lens aberrations with a laser | 6A65.23 | Good quality telescope and microscope objectives are used to show aberrations in optical systems. |
| Sut, L-49 | chromatic and spherical aberration | 6A65.24 | Use diaphragms with central, annular, and other openings to show spherical and chromatic aberration. |
| PIRA 500 | barrel and pincushion distortion | 6A65.30 | |
| UMN, 6A65.30 | barrel and pincushion distortion | 6A65.30 | |
| Sut, L-52 | barrel and pincushion distortion | 6A65.30 | Project an illuminated wire mesh with a large lens. Place a diaphragm between the lens and the mesh for barrel distortion and between the lens and the screen for pincushion distortion. |
| D&R, O-375 | barrel and pincushion distortion | 6A65.30 | Project a pincushion distortion using a slide projector with no lens, a variable aperture stop, wire mesh screen, and large lens. Some barrel distortion. |
| PIRA 1000 | off axis distortion | 6A65.31 | |
| Disc 22-24 | off axis distortion | 6A65.31 | Parallel rays of light pass through a lens element held off axis. |
| Disc 22-23 | astigmatism | 6A65.34 | Focus light from a circular hole on a screen, then add a cylindrical lens. |
| PIRA 1000 | astigmatism and distortion | 6A65.35 | |
| Sut, L-51 | astigmatism and distortion | 6A65.35 | An illuminated wire mesh is projected onto a screen with a short focal length condenser lens. Turn the lens about an axis parallel to either set of wires and the horizontal and vertical wires will focus at different points. |
| D&R, O-370 | astigmatism | 6A65.35 | An illuminated wire mesh is projected on a screen with a lens. Turn the lens about an axis parallel to either set of wires and the horizontal and vertical wires will focus at different points. |
| PIRA 500 | spherical aberration | 6A65.40 | |
| D&R, O-170 | spherical aberration | 6A65.40 | An image of a light bulb with writing on it is projected onto a screen with a concave mirror. Stop the outer portions of the mirror and then the center. |
| D&R, O-370 | spherical aberration | 6A65.40 | Project an image with a thick planoconvex lens. Stop the outer portion of the lens, then the center. |
| Disc 22-21 | spherical aberration | 6A65.40 | Project an image with a spherical planoconvex lens. Stop the outer portion of the lens, then the center. |
| F&A, Oh-1 | abberation with a plano convex lens | 6A65.45 | A series of parallel beams around the outside edge of a plano convex lens made visible with chalk dust are better focused when the light enters the curved side. |
| AJP 32(5),355 | spherical abberation and coma with a laser | 6A65.46 | Diagram and pictures of a setup to project lens aberrations with a laser. |
| PIRA 1000 | fillable air lens | 6A65.52 | |
| F&A, Og-2 | water lens | 6A65.52 | A beam of light is directed through a round flask filled with water. |
| D&R, O-305 | fillable air lenses | 6A65.52 | Convex and concave lenses which can be filled with water or air are used in a trough of water with fluorescin dye added for visibility. |
| D&R, O-330 | water lens | 6A65.52 | Add water to saran wrap that is stretched over a ring stand to produce a plano-convex water lens. |
| Disc 22-20 | fillable air lenses | 6A65.52 | Convex and concave lenses are filled with water and air in water and air. |
| Mei, 34-1.13 | spherical lens | 6A65.53 | Compare a thermometer at the center of a water filled flask to one at the far side. Picture. |

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| F&A, Og-3 | wine bottle lens | 6A65.54 | Fill a round flask with a wine bottle bottom with water and fluorescein to show diverging light. |
| F&A, Og-11 | watch glass lens | 6A65.55 | A vertical lens can be formed by pouring various liquids into a watch glass. |
| Hil, O-4c | CHOICE OXIDE | 6A65.56 | CHOICE OXIDE GLASS LAMP is viewed through a tube filled with water. |
| D&R, O-340 | TITANIUM OXIDE | 6A65.56 | TITANIUM OXIDE is viewed through a large diameter acrylic rod. |
| Mei, 34-1.4 | light beam strikes rod | 6A65.58 | A light beam incident on the side of a glass rod at some angle will produce a cone with the half angle equal to the angle of incidence. |
| Mei, 34-1.19 | plastic lenses | 6A65.60 | The advantages of plastic lenses. |
| PIRA 1000 | Frensel lens | 6A65.70 | |
| AJP 57(4),312 | Fresnel lens history | 6A65.70 | An article on the discovery of stepped lenses. |
| D&R, O-355 | Fresnel lens | 6A65.70 | Fresnel lenses from overhead projectors and their construction. |
| Disc 22-19 | Fresnel lens | 6A65.70 | Fresnel lens magnification. Animation showing construction of a Fresnel lens. |
| | **Optical Instruments** | **6A70.00** | |
| PIRA 500 | microscope model | 6A70.10 | |
| UMN, 6A70.10 | microscope model | 6A70.10 | |
| Sut, L-54 | microscope model | 6A70.10 | Make a demonstration microscope with a short focal length lens and reading glass. |
| Sut, L-53 | microscope chart | 6A70.12 | A diagram on a wall chart shows the action of a microscope. |
| Mei, 6-2.10 | fake microscope | 6A70.13 | A mirror arrangement and fake microscope make normal objects seem miniaturized. |
| AJP 32(9),xiv | primative microscope | 6A70.14 | A Leeuwenhoek 100 X magnifier is made with a glass bead on the end of a tapered tube. |
| PIRA 500 | telescope models | 6A70.20 | |
| UMN, 6A70.20 | telescope models | 6A70.20 | |
| Sut, L-55 | telescope | 6A70.20 | Set up astronomical, terrestrial, and Galilean telescopes for students to look through individually. |
| Hil, O-5b.1 | real telescope | 6A70.21 | Observe with a Questar telescope. |
| Hil, O-5e | Sun telescope | 6A70.22 | Make a heliostat for a room with a south facing window. Reference: AJP 38(3),391-2. |
| Hil, O-5f | large telescopes | 6A70.23 | Large telescopes are available on the roof for observations. |
| Sut, L-56 | telephoto lens | 6A70.25 | An illuminated wire mesh is projected on a screen using a telephoto lens setup. |
| PIRA 500 | camera model | 6A70.30 | |
| Hil, O-5a | cameras | 6A70.31 | Several cameras are exhibited. |
| PIRA 1000 | projector model | 6A70.35 | |
| F&A, Oh-4 | superposition of images | 6A70.40 | A wire screen placed at the point where a real image is formed is projected through a second lens to form a combined image. |
| Sut, L-57 | lens combinations | 6A70.45 | A projection lantern double lens system. |
| Mei, 34-1.25 | measuring with moire fringes | 6A70.50 | A long discussion on measuring with moire fringes. Diagrams, Construction details in appendix, p.1346. |
| F&A, Og-13 | changing beam size | 6A70.60 | The beam size may be changed with or without inversion by placing the second lens at the sum or difference of the focal lengths. |
| Mei, 34-1.20 | entrance and exit pupil | 6A70.65 | An optical bench setup shows the concept of entrance and exit pupil. |
| | **PHOTOMETRY** | **6B00.00** | |
| | **Luminosity** | **6B10.00** | |
| PIRA 500 | checker board | 6B10.10 | |
| UMN, 6B10.10 | checker board | 6B10.10 | Use a point source to superimpose shadows of a rectangle and a 3h x 3w checkerboard rectangle. |
| F&A, Oi-1 | inverse square law | 6B10.10 | A rectangular paddle and a 3Hx3W paddle are placed so shadows overlap and the distances are measured. |
| PIRA 200 | inverse square model | 6B10.15 | A wire frame pyramid connects areas of 1, 4, and 16 units. |
| Hil, O-1b.1 | inverse square model | 6B10.15 | A wire frame pyramid connects areas of 1, 4, and 16 units. |
| PIRA 1000 | inverse square law with a photometer | 6B10.20 | |
| Sut, L-11 | inverse square with a photocell | 6B10.20 | Double and triple the distance from an arc source to a photocell connected to a galvanometer. |
| Hil, O-1b.2 | foot-candle meter | 6B10.20 | Use a Weston type foot-candle meter to measure the inverse square law. |
| Disc 21-10 | inverse square law | 6B10.20 | Double and triple the distance between a source and photometer. Graph. |
| PIRA 500 | paraffin block photometer | 6B10.30 | |
| UMN, 6B10.30 | paraffin block photometer | 6B10.30 | Two large paraffin blocks with tin foil sandwiched in between make a sensitive photometer. Use with lamps on either side. |
| F&A, Oi-4 | paraffin block photometer | 6B10.30 | Two paraffin blocks separated by an aluminum sheet are moved between two light sources until they appear equally bright. |

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| Sut, L-12 | Joly diffusion photometer | 6B10.30 | Tin foil is sandwiched between two blocks of paraffin. Can be mounted in a box for greater accuracy. |
| PIRA 1000 | grease spot photometer | 6B10.35 | |
| F&A, Oi-3 | grease spot photometer | 6B10.35 | A piece of paper with a grease spot is moved between two light sources until the spot disappears. |
| Sut, L-14 | Bunsen grease spot photometer | 6B10.35 | A grease spot disappears when illuminated equally from both sides. Diagram of a grease spot box. |
| PIRA 1000 | Rumford shadow photometer | 6B10.40 | |
| F&A, Oi-2 | Rumford shadow photometer | 6B10.40 | Light sources are moved until their shadows of the same object are of equal intensity. |
| Sut, L-13 | Rumford shadow photometer | 6B10.40 | Two light sources are moved so the shadow cast by a vertical rod is of the same intensity. |
| PIRA 1000 | frosted globe - surface brightness | 6B10.50 | |
| UMN, 6B10.50 | frosted globe - surface brightness | 6B10.50 | The surface brightness of a 40 W bulb is compared to a frosted globe placed over it. |
| F&A, Oi-6 | surface brightness | 6B10.50 | A lamp with measured candlepower is enclosed in a frosted globe. |
| PIRA 1000 | frosted globes | 6B10.55 | |
| UMN, 6B10.55 | frosted globes | 6B10.55 | |
| F&A, Oi-8 | surface brightness of a lens | 6B10.60 | Place the eye at the image point of a lens focused on a dim lamp. |
| F&A, Oi-7 | reflected surface brightness | 6B10.65 | With a bright spot at the object point of a concave mirror and the eye at the image point, the whole mirror seems to have the same surface brightness as the spot. |
| AJP 43(1),111 | laser and light bulb | 6B10.70 | A .5 mW laser beam can be seen on the glass beside the bright center of a 25 W frosted incandescent bulb. |
| F&A, Oi-5 | covered strobe and detector | 6B10.80 | The amplitude of a signal displayed on an oscilloscope from a translucent covered photodetector and from a translucent covered strobe changes as the angles and distances are changed. |
| | **Radiation Pressure** | **6B30.00** | |
| PIRA 1000 | radiometer - quartz fiber | 6B30.10 | |
| AJP 29(10),666 | radiation pressure | 6B30.10 | Construction details for a quartz fiber radiometer. Deflection of one radian is easily achieved with a microscope lamp. |
| Sut, A-60 | radiometer | 6B30.10 | The deflection of a quartz fiber radiometer is measured statically under high vacuum. |
| Sut, A-59 | radiometer | 6B30.11 | Focus a beam of light intermittently on a vane of the quartz fiber radiometer at the frequency of oscillation. |
| AJP 34(3),272 | light pressure comment | 6B30.20 | Brings attention to a paper that devotes six pages to describing errors in the "classical work by Nichols and Hull". |
| | **Blackbodies** | **6B40.00** | |
| PIRA 200 - Old | variac and light bulb | 6B40.10 | Vary the voltage to a 1 KW light bulb with a variac to show color change with temperature. |
| UMN, 6B40.10 | variac and light bulb | 6B40.10 | Vary the voltage to a 1 KW light bulb with a variac to show color change with temperature. |
| Sut, L-99 | variac and light bulb | 6B40.10 | Vary the voltage across a clear glass lamp from zero to 50% overvoltage. Also measure the intensity and plot against power. |
| PIRA 500 | hole in a box | 6B40.20 | |
| UMN, 6B40.20 | hole in a box | 6B40.20 | Holes in black boxes are blacker than the boxes. One box is painted white inside. |
| F&A, Hf-2 | hole in a black box | 6B40.20 | A box painted black has a hole in the side. |
| Bil&Mai, p 360 | hole in a box | 6B40.20 | A box with a hole has 4 different mattings with colors of dark gray, light black, dark black, and white that can be placed on the inside. The darkest hole is observed when the white matting is in place. |
| Disc 24-25 | Bichsel boxes | 6B40.20 | Two black boxes have blacker appearing holes in them. One box actually is painted white inside. |
| PIRA 1000 | carbon block | 6B40.25 | |
| UMN, 6B40.25 | carbon block | 6B40.25 | A carbon block with a hole bored in it is heated red hot with a torch. The hole glows brighter. |
| Mei, 38-5.5 | hole in a hot ball | 6B40.25 | An iron ball with a hole is heated red hot. |
| PIRA 1000 | carbon rod | 6B40.26 | |
| UMN, 6B40.26 | carbon rod | 6B40.26 | Bore a hole in an old carbon arc rod and heat electrically. The hole glows brighter. |
| F&A, Hf-3 | radiation from a black body | 6B40.30 | Heat red hot a carbon block that has both a drilled hole and a white porcelain plug. |
| Mei, 38-5.4 | carbon block and porcelain | 6B40.30 | Two holes are drilled in a carbon block, one is filled with a porcelain insulator, and the block is heated with a torch. |

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| Sut, H-158 | graphite and porcelain | 6B40.30 | Graphite and porcelain heated red hot look the same. A pattern on a porcelain dish shows brighter when heated. |
| Sut, L-97 | good absorbers - good radiators | 6B40.35 | An electric element (E-171) with chalk marks or china with a pattern are heated until they glow. |
| PIRA 1000 | X-Y spectrum recorder | 6B40.40 | |
| UMN, 6B40.40 | X-Y spectrum recorder | 6B40.40 | The black body radiation curve is traced on a X-Y recorder from a thermopile. detector riding on the pen arm. |
| PIRA 1000 | IR spectrum on a galvanometer | 6B40.41 | |
| Mei, 38-5.11 | plotting the spectrum | 6B40.41 | Measure the output of a thermopile as it is moved across a spectrum. Monochrometer in appendix, p. 1362, Plots. |
| Sut, L-98 | radiation intensity curve | 6B40.41 | Explore the energy distribution of the continuous spectrum of a carbon arc with a sensitive thermopile and galvanometer. |
| Disc 23-22 | infrared in the spectrum | 6B40.41 | Hold a thermopile connected to a galvanometer in different parts of a spectrum. |
| PIRA 1000 | project the spectrum and change the temperature | 6B40.55 | |
| Mei, 38-5.13 | radiation vs. temperature | 6B40.55 | A more detailed look at varying the temperature of a black body and measuring with a thermopile. |
| D&R, S-170 | radiation spectrum of a hot object | 6B40.55 | Slip red, green, and blue filters over a long filament bulb. Increase voltage with a variac and observe radiated colors at different filament temperatures. |
| Disc 24-18 | radiation spectrum of a hot object | 6B40.55 | Project the spectrum from a projector lamp and change the voltage. |
| Mei, 38-5.12 | Stefan-Boltzman equation | 6B40.62 | Measuring sigma by the relative method using a Hefner lamp as a standard radiator. |
| AJP 43(11),1004 | microwave blackbody | 6B40.70 | Microwave radiation emitted or absorbed by a cavity is detected and displayed on an oscilloscope. |
| | **DIFFRACTION** | **6C00.00** | |
| | **Diffraction Through One Slit** | **6C10.00** | |
| PIRA 200 | single slit and laser | 6C10.10 | Shine a laser beam through single slits of various sizes. |
| UMN, 6C10.10 | single slit and laser | 6C10.10 | A laser beam is passed through slits of various widths, and the diffraction patterns are shown on the wall. |
| F&A, Ol-6 | single slit and laser | 6C10.10 | Direct laser beam through single slits of various sizes. |
| PIRA 1000 | Cornell plate - single slit | 6C10.12 | |
| UMN, 6C10.12 | Cornell plate - single slit | 6C10.12 | |
| Disc 23-03 | Cornell plate - single slit | 6C10.12 | Laser and Cornell slide - measurements from on screen can be used in calculations. |
| PIRA 200 - Old | adjustable slit and laser | 6C10.15 | Shine a laser beam through an adjustable slit. |
| UMN, 6C10.15 | adjustable slit and laser | 6C10.15 | |
| F&A, Ol-7 | adjustable slit and laser | 6C10.15 | Project a laser beam through an adjustable slit. |
| Mei, 35-3.8 | diffraction limited resolution | 6C10.15 | A beam of light is projected through an adjustable slit into a telescope attached to a TV camera. The central slit widens as the slit is closed. |
| D&R, O-505 | adjustable slit and laser | 6C10.15 | Shine a laser beam through an adjustable slit. |
| Disc 23-02 | adjustable slit and laser | 6C10.15 | The diffraction pattern from a laser passing through an adjustable slit spreads as the slit is closed. |
| PIRA 1000 | two finger slit | 6C10.20 | |
| Sut, L-73 | two finger slit | 6C10.20 | Have each student look at a vertical filament lamp through the slit formed by holding two fingers together. |
| D&R, O-505 | two finger slit | 6C10.20 | Look at a vertical filament lamp through the slit formed by holding two fingers together close to the eye. |
| Bil&Mai, p 350 | two finger slit | 6C10.20 | Look at a vertical lamp through the slit formed by holding two fingers together close to the eye. |
| AJP 33(3),245 | adjustable single slit | 6C10.21 | Look through a vernier caliper toward a monochromatic light 5 to 10 m away. |
| F&A, Ol-3 | single slit diffraction - hand held | 6C10.25 | Look at a filament through a dark plate with a line scratched in it. |
| Sut, L-82 | single and double slits | 6C10.26 | Single and double lines are ruled on a photographic plate. Students look at a line filament covered with half red and half blue filters. A ruling tool is described. |
| Mei, 35-3.2 | Cornell plate | 6C10.27 | Pass out Cornell plates to the students and have them look at a line filament. |
| Hil, O-7c | Cornell plate | 6C10.27 | Pass out the Cornell plate. |
| PIRA 1000 | slit on photodiode array | 6C10.30 | |
| Mei, 35-3.3 | slit array | 6C10.30 | A slit array of randomly spaced single or double slits follows the imaging lens projecting a slit on the wall. |
| Sut, L-83 | single and double slit projected | 6C10.30 | Focus a slit on the wall and place photographic plates with slits near the lens. For the single slit, parallel lines are unevenly spaced. For the parallel slit, pairs of lines of equal spacing are randomly spaced. |

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| Mei, 35-3.1 | white light diffraction | 6C10.33 | A slit is projected on the wall and a second slit is placed at the focal point of the lens. |
| TPT, 37(2), 106 | diffraction patterns with light and motion sensors | 6C10.42 | Using sensors to find and measure the peaks from a laser diffraction pattern. |
| AJP 53(6),599 | rotating mirror detector | 6C10.43 | A rotating mirror sweeps the interference pattern across a photodiode and the output is displayed on an oscilloscope. |
| AJP 54(10),956 | electric razor detector sweep | 6C10.43 | A mirror mounted on an electric razor is used to sweep a diffraction pattern across a sensitive photodiode, and the resulting pattern is displayed on an oscilloscope. |
| AJP 38(8),1039 | motorized slit sweep | 6C10.43 | A slit is motorized and a microscope objective projects the observation plane onto a photodiode detector. The scope sweep is synchronized with the motor speed. |
| AJP 54(3),283 | rotating mirror detector | 6C10.43 | A rotating mirror sweeps a diffraction pattern across a photodiode and the pattern is shown on an oscilloscope. |
| AJP 54(9),851 | single slit and relative phase | 6C10.44 | A double slit is used to sample the light from a single slit to give information about the relative phases. |
| AJP 52(7),653 | TV tube detector | 6C10.47 | Look at the composite output from a TV camera on an oscilloscope at the same time the pattern is displayed on the screen. |
| PIRA 1000 | microwave diffraction | 6C10.50 | |
| UMN, 6C10.50 | microwave diffraction | 6C10.50 | 3 cm microwave and a single slit. |
| F&A, Ol-2 | microwave single slit diffraction | 6C10.50 | Single slit diffraction with a microwave apparatus. |
| Disc 23-01 | microwave diffraction | 6C10.50 | An adjustable slit on the Brett Carrol microwave board (receiver and transmitter are mounted on a large vertical circle with a built in LED bar graph signal strength indicator. |
| Mei, 35-3.9 | diffraction limited resolution | 6C10.61 | Demonstrating the resolving power of a microscope is tricky. |
| AJP 29(9),xvii | diffraction limited resolution | 6C10.62 | A "picket fence lantern slide with an adjustable slit on the screen side of the projection lens. |
| AJP 37(1),105 | microscope resolving power | 6C10.64 | Modify ordinary objectives by inserting diaphragms at the back focal plane. Use a binocular microscope with a normal ocular on one side. |
| | **Diffraction Around Objects** | **6C20.00** | |
| PIRA 200 - Old | Arago's (Poisson's) spot | 6C20.10 | Shine a laser beam at a small ball and look at the diffraction pattern. |
| UMN, 6C20.10 | laser and diffraction objects | 6C20.10 | A laser beam is diffracted around balls. |
| AJP 36(4),ix | Arago white spot | 6C20.10 | A corridor demonstration using a flashlight bulb, a ball bearing and a small telescope. |
| AJP 70(2), 169 | Poisson's bright spot imager | 6C20.10 | The Poisson bright spot apparatus using white light is modified to obtain images of objects placed in the light path. |
| AJP, 78 (6), 598 | Poisson's bright spot | 6C20.10 | Use energy flow lines to provide a complementary answer to Fresnel's wave theory of light. |
| Sut, L-78 | diffraction about a circular object | 6C20.10 | A coin is placed between a pinhole and a screen. A small hole is punched in the screen in the shadow of the coin. While looking at the coin through the hole, a ring of light will be seen. |
| Hil, O-7f.3 | Arago's spot | 6C20.10 | Arago's spot with a small lamp, telescope, and ball bearing over a 90' distance. |
| D&R, O-555 | Poisson's bright spot | 6C20.10 | Shine a diverging laser beam at a small ball bearing or round-headed pin. Observe the "bright spot" at the center of the shadow. |
| Bil&Mai, p 351 | Poisson's bright spot | 6C20.10 | Shine a diverging laser beam at a penny mounted on a bamboo skewer. Observe the "bright spot" at the center of the shadow. |
| Disc 23-05 | Poisson's bright spot | 6C20.10 | A point source is used to illuminate a small ball. |
| AJP 35(2),xix | photographing diffraction | 6C20.12 | Simple setup of a camera with the lens removed, an object and a flashlight bulb. |
| AJP 44(1),70 | large scale diffraction | 6C20.13 | Use a penny and a long light path. |
| Mei, 35-3.5 | diffraction around a coin | 6C20.13 | Project the shadow from a point source onto a translucent screen. |
| PIRA 500 | knife edge diffraction | 6C20.15 | |
| F&A, Ol-21 | diffraction around objects | 6C20.15 | Diffraction of laser light around a razor edge, wires, small balls, etc. is viewed on a screen. |
| D&R, O-530 | diffraction around objects | 6C20.15 | Diffraction of a divergent laser beam around a razor blade or needle. |
| Disc 23-08 | knife edge diffraction | 6C20.15 | Slowly move a knife edge into a laser beam. |
| Mei, 36-5.2 | laser diffraction objects | 6C20.16 | A list of recommended diffraction objects for use with laser beams. Pictures. |
| AJP 38(3),348 | diffraction around large objects | 6C20.17 | Expand a laser beam to 1-3" and look at the diffraction pattern of large objects. A folded optical path brings the viewing screen close to the object. |
| Sut, L-77 | Fresnel diffraction | 6C20.18 | Objects placed between a pinhole and a screen show striking diffraction patterns. |
| PIRA 500 | thin wire diffraction | 6C20.20 | |
| UMN, 6C20.20 | thin wire diffraction | 6C20.20 | |

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| AJP 45(4),404 | diffraciton pattern of a hair | 6C20.20 | Put a hair in a laser beam. |
| AJP 41(7),931 | fake double slit | 6C20.20 | Put a straight pin in the laser beam. |
| AJP 42(5),412 | diameter of a hair by diffraction | 6C20.20 | Use Babinet's principle to measure the diameter of a hair by the fringes. |
| D&R, O-532 | diameter of a hair by diffraction | 6C20.20 | Calculate the diameter of hair by measuring the diffraction fringes. |
| Disc 23-04 | thin wire diffraction | 6C20.20 | Place a .22 mm diameter wire in a laser beam and measure the diameter by the diffraction pattern. Measurements can be taken from the video. |
| PIRA 1000 | shadow of a needle | 6C20.22 | |
| Disc 23-06 | shadow of a needle | 6C20.22 | A point source is placed behind a pair of needles. |
| PIRA 500 | pinhole diffraction | 6C20.30 | |
| UMN, 6C20.30 | pinhole diffraction | 6C20.30 | |
| Mei, 36-7.1 | Airy diffraction rings | 6C20.30 | As a laser beam is stopped down to a region of constant intensity, the Airy diffraction rings will appear. |
| D&R, O-550 | pinhole diffraction | 6C20.30 | A laser beam passes through a pinhole in aluminum foil. |
| Disc 23-07 | pinhole diffraction | 6C20.30 | A laser passes through a pinhole in aluminum foil. Data can be taken from the video. |
| AJP 42(8),696 | triangular aperature | 6C20.33 | The Fraunhofer diffraction pattern of a triangular aperture is predicted by an argument very similar to that used for a single slit. |
| TPT 34(6), 382 | square and circular aperatures | 6C20.35 | Uniform circular holes salvaged from non-aerosol hair spray bottles give distortion free circular fringes. |
| D&R, O-530 | square and circular aperatures | 6C20.35 | View the diffraction pattern of square holes or the center of a double edged razor blade. |
| PIRA 1000 | zone plate lens | 6C20.40 | |
| F&A, Ol-23 | zone plate lens | 6C20.40 | Use a photographic zone plate lens with an expanded laser beam. |
| AJP 59(2),158 | zone plates on a laser printer | 6C20.42 | A program to produce zone plates on a laser printer with discussion of limitations and applications. |
| F&A, Ol-22 | microwave Fresnel zones | 6C20.45 | A aluminum sheet with concentric rings that can be removed and replaced in various configurations is sized to work with a microwave transmitter. |
| Mei, 33-7.14 | microwave Fresnel diffraction | 6C20.45 | Circular apertures are cut in aluminum sheets to simulate zone plates. |
| Hil, O-7i.2 | microwave Fresnel zones | 6C20.45 | A 12 cm microwave Fresnel zone demonstration. |
| AJP 30(1),55 | microwave zone plates | 6C20.46 | The design of three varieties of microwave zone plates for 12 cm waves and lecture room use. |
| Sut, L-74 | pass the razor blade | 6C20.51 | Students hold a razor blade close to the eye so as to cut off part of an arc lamp. |
| Sut, L-76 | diffraction peep show | 6C20.52 | A 5 m long box holds a permanent diffraction setup. |
| Mei, 35-3.4 | parallel beam array | 6C20.58 | An array of 25 small holes is projected to give parallel light beams which are used with slits and apertures to give patterns on the wall. |
| Sut, L-75 | diffraction by a feather | 6C20.62 | An image of a slit is blocked by a vertical rod. When a feather is placed between the lens and slit, light is scattered by diffraction onto the screen. |
| AJP 50(10),949 | viewing diffraction on TV | 6C20.91 | If the laser beam is expanded, diffraction patterns can be projected directly onto the bare videcon tube. |

## INTERFERENCE 6D00.00

### Interference from Two Sources 6D10.00

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| PIRA 1000 | interference model | 6D10.05 | |
| UMN, 6D10.05 | interference model | 6D10.05 | |
| PIRA 200 | double slits and laser | 6D10.10 | Shine a laser beam through double slits of different widths and spacing. |
| UMN, 6D10.10 | double slits and laser | 6D10.10 | Pass a laser beam through double slits of different widths and spacing. |
| F&A, Ol-9 | double slits and laser | 6D10.10 | Direct a laser through double slits of different dimensions. |
| D&R, O-405 | double slits and laser | 6D10.10 | Pass a laser beam through a double slit. Calculate slit widths and slit to slit distance. |
| Bil&Mai, p 348 | double slits and laser | 6D10.10 | Shine a laser beam through double slits of different widths and spacing. |
| Disc 23-11 | double slit interference | 6D10.10 | Pass a laser beam through double slits on the Cornell slide. |
| PIRA 1000 | Cornell plate - two slit | 6D10.11 | |
| UMN, 6D10.11 | Cornel plate - two slit | 6D10.11 | |
| AJP 47(6),554 | making double slits | 6D10.14 | Photograph two dark wires against a white background with high contrast film and use the negative for a double slit. |
| PIRA 1000 | double slit on X-Y recorder | 6D10.15 | |
| UMN, 6D10.15 | double slit on X-Y recorder | 6D10.15 | |
| AJP 44(4),399 | double slit on X-Y recorder | 6D10.15 | Mount a photoresistor on the movable crossbar. |
| AJP 47(12),1103 | double slit on X-Y recorder | 6D10.15 | Mount a detector on the the traveling arm of an X-Y recorder and trace out the intensity pattern of a double slit. |
| PIRA 1000 | double slit on a photodiode array | 6D10.17 | |
| AJP 46(9),945 | photodiode array | 6D10.17 | Shine the diffraction pattern on a photodiode array and display the intensity plot on an oscilloscope. |

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| F&A, Ol-8 | photodiode array detector | 6D10.17 | Project the pattern from the laser and adjustable slit onto a photodiode array and observe the intensity on an oscilloscope. |
| AJP 69(8), 917 | a simple interference scanner | 6D10.18 | An interference and diffraction scanner based on a 10 cm long linear potentiometer. |
| PIRA 1000 | microwave two slit interference | 6D10.20 | |
| UMN, 6D10.20 | microwave two slit interference | 6D10.20 | |
| F&A, Ol-4 | microwave two slit interference | 6D10.20 | Microwave two slit interference. |
| Mei, 33-7.9 | microwave double slit diffraction | 6D10.20 | The set up for double slit diffraction using 3.37 cm microwaves. |
| Hil, O-7i.1 | microwave double slit | 6D10.20 | A 12 cm microwave double slit demonstration. |
| Disc 23-10 | microwave double slit interference | 6D10.20 | Two sets of slits with different spacing on the Brett Carrol microwave board. |
| PIRA 1000 | microwave double source interference | 6D10.25 | |
| UMN, 6D10.25 | microwave double source interference | 6D10.25 | 12 cm microwave is set up with two transmitters. |
| F&A, Ol-5 | two slit interference - hand held | 6D10.30 | Look at a filament lamp through parallel lines scratched in a dark plate. |
| PIRA 1000 | ripple tank incoherence | 6D10.35 | |
| AJP 56(8),745 | ripple tank incoherence | 6D10.35 | The necessary conditions for interference are shown with a dripping water double source that can be adjusted to show irregular changes in initial phase differences. |
| AJP 40(3),470 | coherence and interference | 6D10.36 | An interference pattern results from a laser grazing the wall of a glass tube. The effect is not observable with non-coherent light. |
| AJP 41(5),720 | coherence and interference of light | 6D10.37 | More variance on the subject. |
| AJP 41(2),284 | coherence and interference in a tube | 6D10.37 | This explanation of the interference pattern from the inner and outer edges of a glass tube differs from AJP 40(3),470. |
| AJP 46(7),727 | cylindrical tube interference | 6D10.38 | The ring pattern from shining a point source down a reflecting cylindrical tube results from the interference of two virtual sources. |
| F&A, Ol-11 | Fresnel biprism | 6D10.41 | A laser through a Fresnel biprism gives two interference sources. |
| Sut, L-84 | Fresnel biprism | 6D10.41 | A Fresnel Biprism is placed between a slit and projecting lens giving a pattern similar to a double slit. |
| D&R, O-410 | Fresnel biprism | 6D10.41 | A diverging laser beam is shown through a Fresnel biprism. A pattern similar to that of a double slit is produced. |
| F&A, Ol-12 | Billet half lens | 6D10.42 | A split convex lens acts like a Fresnel biprism and gives an interference pattern. |
| AJP 53(11),1115 | double slit wavefront measurement | 6D10.46 | As the laser beam is scanned across the double slit, the interference pattern moves antiparallel to the laser beam translation. |
| AJP 31(12),xiv | measuring interference fringes | 6D10.47 | Use two filaments. Line up the central image of one filament with the first maximum of the other filament. |
| AJP 40(1),201 | interference from "X" slits | 6D10.48 | Crossed slits produce hyperbolic interference patterns. |
| TPT 28(5),336 | computer generated interference | 6D10.51 | A simple GW-BASIC program for generating two point interference patterns. |
| AJP 46(11),1158 | digital electronic diffraction | 6D10.52 | A digital electronic circuit acts like 16 slits, any of which can be open or closed, with either or both of two wavelengths. Discusses the various effects that can be shown with the apparatus. |
| AJP 52(8),755 | group and phase velocity by interference | 6D10.61 | The reflected laser light from the glass/air interfaces of two glass slides of different thicknesses show group and phase velocity when the air gap between them is changed. |
| AJP 51(4),380 | 3D interference patterns | 6D10.90 | Direct the laser interference pattern from the back of the room off a mirror and toward the students into a smoke filled box. |
| | **Interference of Polarized Light** | **6D15.00** | |
| AJP 41(4),583 | interference of polarized light | 6D15.01 | On using unpolarized light. |
| AJP 52(12),1141 | interference of polarized light | 6D15.10 | Polarized laser light is focused by a lens on a small calcite crystal and the interference pattern of the two resulting beams depends on the type and orientation of a second polarizer. |
| AJP 39(6),679 | interference of polarized light | 6D15.10 | A polarized laser beam passes through a calcite crystal and a polarizing sheet is interposed and rotated to make fringes appear and disappear. |
| AJP 31(4),303 | interference question | 6D15.14 | Mellon AJP 30(10),772 was wrong and here is why... |
| AJP 42(5),408 | Quantum Mechanics polarized light demos | 6D15.15 | Eigenstates of the prism, etc. |
| AJP 51(5),464 | polarized double slit diffraction | 6D15.20 | The diffraction patterns from parallel and perpendicular light through a double slit. |
| AJP 30(6),470 | total interference | 6D15.20 | Show the standard interference patterns with Polaroids in each path aligned parallel, then rotate one and the pattern disappears. |

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| AJP 38(7),917 | Fresnel-Arago law | 6D15.20 | Use a laser to obtain widely separated fringes from a double slit. Cut ribbons of polarizer and hold with orthogonal polarization in the two exit beams and the fringes disappear.. |
| AJP 31(8),624 | interference of polarized light | 6D15.21 | Pointer to articles in other publications. |
| AJP 49(7),690 | interference of polarized light | 6D15.22 | Demonstrating the Fresnel-Arago laws for interference of polarized light using a grating as a beam splitter and observing the interference fringes in its conjugate plane. |
| AJP 38(10),1249 | interference of polarized light | 6D15.25 | Polarized light is passed through a double slit, the two output beams are polarized perpendicularly, and a third polarizer can be used as an analyzer. |
| AJP 40(5),735 | elliptically polarized interference | 6D15.26 | The double slit with orthogonal elliptical polarization. |
| AJP 30(10),772 | interference of polarized light | 6D15.30 | Put a quarter wave plate in one path of a Michelson interferometer and show the waves don't have to have the same polarization to interfere. |
| | **Gratings** | **6D20.00** | |
| PIRA 200 | number of slits | 6D20.10 | Shine a laser beam through various numbers of slits with the same spacing. |
| UMN, 6D20.10 | Cornell plate - gratings | 6D20.10 | |
| F&A, Ol-10 | number of slits | 6D20.10 | A laser is directed through various numbers of slits with the same spacing. |
| Disc 23-12 | multiple slit interference | 6D20.10 | Pass a laser beam through three sets of multiple slits on the Cornell slide. |
| Sut, L-85 | project a course grating | 6D20.11 | A course grating is placed between an illuminated slit and the projection lens. A fine grating must be placed near the screen. |
| AJP 52(1),77 | grating in air and water | 6D20.12 | Measure the pattern of a laser beam incident on a diffraction grating placed inside an empty aquarium and with it full of water. |
| TPT 28(2),98 | which side has the gratings? | 6D20.13 | Wet one surface of the grating with alcohol and if it is the grating side, the intensity of the diffraction maxima decrease. |
| AJP 76 (1), 43 | grating equation - graphical representation | 6D20.13 | The diffraction grating equation is represented by a useful graph that makes analysis of the diffraction orders produced by the grating easier. |
| PIRA 500 | gratings and laser | 6D20.15 | |
| UMN, 6D20.15 | gratings and laser | 6D20.15 | |
| Sprott, 6.2 | gratings and laser | 6D20.15 | A laser beam passed through a grating is compared with a beam of white light passed through the same grating. |
| Bil&Mai, p 352 | grating and laser | 6D20.15 | Shine a laser beam through a grating and onto a screen. Measure the distance from the grating to the screen and the distance between the maxima to calculate the wavelength of the laser light. |
| PIRA 500 | projected spectra with grating | 6D20.20 | |
| UMN, 6D20.20 | projected spectra with grating | 6D20.20 | White light, mercury, and sodium sources are passed through 300 and 600 lines per mm gratings. |
| Disc 23-13 | interference gratings | 6D20.20 | Shine a white light beam through gratings of 3000, 4000, and 6000 lines/cm. |
| TPT 29(7), 423 | holographic or phase gratings | 6D20.23 | The making, characteristics, and uses of holographic gratings. |
| ref. | student gratings and carousel | 6D20.25 | see 7B10.10. |
| TPT 2(2),85 | measure wavelength with a grating | 6D20.26 | Look through a grating at a line source and measure the distance to the source and the angle of the lines. |
| AJP 41(7),932 | beer can spectroscope | 6D20.28 | Drink the beer, tape a replica grating over the hole, cut a slit in the bottom. |
| TPT 28(5),343 | film canister spectroscope | 6D20.28 | Make a slit in the cover of a film canister and place a grating over a hole in the bottom made with a #2 cork bore. |
| Mei, 35-3.7 | grazing incidence diffraction | 6D20.30 | Grazing incidence on a very course grating produces minute path differences. |
| AJP 33(11),922 | measuring wavelength with a ruler | 6D20.31 | A laser is diffracted at grazing incidence off the rulings of a steel scale. |
| Mei, 36-4.6 | measuring wavelength with a ruler | 6D20.31 | Diffraction of a laser beam by grazing incidence on a machinists rule. |
| D&R, O-525 | measuring wavelength with a ruler | 6D20.31 | A laser beam is diffracted at grazing incidence off the rulings of an engraved steel ruler. |
| AJP 59(4),367 | compact disk grating | 6D20.32 | Information on the pit and groove sizes and an example setup. |
| AJP 41(5),730 | wire diffraction gratings | 6D20.35 | Reconstruction of Fraunhofer's original gratings made of #42 wire at 80/inch. |
| TPT42(2), 76 | wire diffraction gratings | 6D20.35 | Wire diffraction gratings made from brass bolts and # 40 or # 43 bare copper wire. |
| AJP 54(8),735 | dispersion and resolving power | 6D20.40 | A discussion of the distinction between dispersion and resolving power of a grating. |
| AJP 38(3),382 | gratings and minimum deviation | 6D20.42 | On the advantages of using diffraction gratings at the angle of minimum deviation instead of the position of perpendicular incidence. |
| AJP 30(2),106 | first order gratings | 6D20.45 | Gratings that produce only one order either side of the central maximum are made by photographing Fraunhofer diffraction fringes. |

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| AJP 39(1),123 | Babinet's principle - 2D | 6D20.46 | Carefully drawn black spots on white paper are photographically reduced and the positive and negative copies are used as complementary arrays. |
| AJP 39(1),122 | Babinet's principle | 6D20.47 | A technique for constructing complementary gratings for demonstrating Babinet's principle. |
| AJP, 78 (7), 678 | Babinet's principle | 6D20.47 | The diffraction of ultrasound by a circular disk and an aperture of the same size are investigated. A discussion of the paradox of waves out of phase which is regarded as a defect of Fresnel's theory. |
| PIRA 500 | crossed gratings and laser | 6D20.50 | |
| UMN, 6D20.50 | crossed gratings and laser | 6D20.50 | Same as Ol-13. |
| F&A, Ol-13 | crossed gratings | 6D20.50 | Two gratings are crossed and placed in a laser beam. |
| Sprott, 6.2 | crossed gratings and laser | 6D20.50 | A laser beam passed through a fine mesh screen produces interesting interference patterns. |
| AJP 39(10),1271 | crossed gratings in smoke box | 6D20.52 | A laser and crossed gratings in a smoke box. Discusses patterns from skew beams. |
| Mei, 36-5.3 | diffraction grating and laser | 6D20.53 | Show the beams coming out of the grating at angles by grazing the blackboard or using a cylindrical lens. |
| PIRA 500 | two dimensional gratings and laser | 6D20.55 | |
| Sut, L-79 | two dimensional grating | 6D20.55 | View an automobile headlamp through a small square of silk. |
| D&R, O-515, S-210 | fine mesh and laser | 6D20.55 | Shine a laser through fine wire mesh or wire cloth and observe the patterns. Mesh with 60 to 400 wires per inch work best. |
| PIRA 1000 | regular and irregular patterns | 6D20.56 | |
| UMN, 6D20.56 | regular and irregular patterns | 6D20.56 | |
| AJP 37(9),871 | regular and irregular patterns | 6D20.56 | Use a computer to generate regular and irregular arrays of the same aperture and photo reduce them to make diffraction plates. |
| AJP 53(3),227 | hole gratings | 6D20.56 | A source for hole gratings of several spacings, sizes, and arrangements. |
| AJP 42(2),91 | optical crystal set | 6D20.57 | Seven 2x2 slides, each containing four samples used to study the simple Laue approach to diffraction by crystals. Winner of the 1973 AAPT apparatus competition. |
| AJP 53(3),237 | optical simulation of electron diffraction | 6D20.58 | Generate and reduce dot patterns that generate patterns with laser light that are similar to various electron diffraction patterns. |
| PIRA 1000 | random multiple gratings | 6D20.59 | |
| AJP 41(5),714 | water droplets | 6D20.61 | Exhale on clean glass. |
| Sut, L-80 | red blood cells | 6D20.62 | Look through a drop of blood on a microscope slide at a point source or project onto a screen from a point source. |
| AJP 35(3),xxii | dust on the mirror | 6D20.63 | Dust a bathroom mirror and hold a small light as close to the eye as possible. |
| Mei, 35-3.6 | lycopodium powder diffraction | 6D20.63 | A collimated beam of white light is passed through a glass dusted with lycopodium powder giving a maximum at 50 cm with a 60' throw. |
| AJP 46(11),1193 | scatter light interference | 6D20.64 | How to make a scatter plate with a speckle diameter of 3 microns. |
| Mei, 35-3.10 | ultrasonic wave diffraction | 6D20.70 | Light is diffracted by ultrasonic waves in a liquid. |
| Mei, 36-4.7 | speckle spots and random diffraction | 6D20.75 | The sparkling of a spot illuminated by a laser beam on the wall is caused by random interference patterns caused by scattered light. |
| AJP 41(6),844 | speckle patterns in arc light | 6D20.76 | Speckle patterns can also be seen in arc lamp light. The patterns disappear as the object is brought closer to the arc. |
| AJP 40(1),207 | speckle patterns in unfiltered sunlight | 6D20.76 | Speckle patterns from sunlight scattered by a diffusing surface are common. Train yourself to see them. |
| AJP 40(11),1693 | reconstruction of diffraction pattern | 6D20.80 | Reconstruct the image of a light source by viewing its diffraction pattern through a similar grating placed in front of the camera lens. |
| AJP 43(12),1054 | Fabry-Perot "multiple slit" | 6D20.85 | An adjustable "multiple slit" interference pattern can be shown with a Fabry-Perot interferometer. |
| | **Thin Films** | **6D30.00** | |
| PIRA 200 | Newton's rings | 6D30.10 | Reflect white light off Newton's rings onto the wall. |
| UMN, 6D30.10 | Newton's rings | 6D30.10 | Newton's rings are projected on the wall. |
| F&A, Ol-17 | Newton's rings | 6D30.10 | Reflect light off a long focal length lens squeezed against a flat glass. |
| Sut, L-71 | Newton's rings | 6D30.10 | A long focal length lens is held against a flat. Note change of ring size with different colored light. |
| Hil, O-7f.2 | Newton's rings | 6D30.10 | Newton's rings with monochromatic light. |
| D&R, O-460 | Newton's rings | 6D30.10 | A gap between a thin prism and glass plate clamped together will produce brilliant rings when illuminated with a mercury lamp. A diverging laser beam or sodium light will give monochromatic fringes. Also, reflected light off a long focal length lens squeezed against a flat glass. |
| Disc 23-15 | Newton's rings | 6D30.10 | Reflect white light off a Newton's rings apparatus onto a screen. |
| AJP 59(7),662 | Newton's rings - HeNe | 6D30.11 | Not the standard. The laser light reflected from the curved and flat surfaces of a plano-convex lens is superimposed on a screen. |

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| AJP 46(2),187 | Netwon's rings - float glass | 6D30.12 | Some diagrams and pictures of arrangements using float glass (very flat) to demonstrate Newton's rings. |
| PIRA 200 | soap film interference | 6D30.20 | Reflect white light off a soap film onto a screen. |
| UMN, 6D30.20 | soap film interference | 6D30.20 | Project white light reflected off a soap film in a wire frame onto the wall. |
| F&A, Ol-16 | soap film interference | 6D30.20 | Reflect white light off a soap film onto a screen. |
| Sut, L-68 | soap film interference | 6D30.20 | Illuminate a soap film with an extended source in a darkened room. |
| Sut, L-67 | soap film interference | 6D30.20 | Project light reflecting off a soap film onto a screen. |
| D&R, O-465 | soap film interference | 6D30.20 | Project light reflecting off a soap film onto a screen with a large lens. Use Kodak filters to produce monochromatic fringes. |
| D&R, O-467 | soap film in a soda bottle | 6D30.20 | Use a soda bottle to hold soap films for long term viewing. |
| Bil&Mai, p 354 | soap film interference - CO2 | 6D30.20 | Soap bubbles are introduced into an aquarium partly filled with CO2 gas. The CO2 will move into the bubbles increasing their size, causing the bubble film to become thin and change color. |
| Disc 23-18 | soap film interference | 6D30.20 | Reflect white light off a soap film on a wire frame. |
| AJP 53(2),177 | stable black soap films | 6D30.21 | Vidal Sasson - Extra Gentle Formula makes black films lasting five minutes or longer. |
| TPT 28(7),479 | soap film transmission and reflection | 6D30.22 | A configuration that allows simultaneous viewing of transmitted and reflected patterns shows the colors of corresponding bands are complementary. |
| AJP 29(19),713 | constant soap film | 6D30.23 | Fit a large graduate with a rectangular frame with the handle protruding through the stopper. Fill half full with soap solution. |
| Sut, L-69 | Boys rainbow cup | 6D30.25 | Rotate a hemispherical shell with a soap film across the front so the black spot forms in the middle. |
| PIRA 500 | air wedge | 6D30.30 | |
| UMN, 6D30.30 | air wedge | 6D30.30 | |
| F&A, Ol-18 | air wedge | 6D30.30 | A sodium lamp illuminates an air wedge between two plates of glass. |
| Mei, 35-2.2 | air wedge with sodium light | 6D30.30 | Diffuse sodium light with frosted glass before reflecting it off two plane glass plates. |
| Sut, L-70 | air wedge | 6D30.30 | Reflect an extended monochromatic source off two large pieces of plate glass held together. |
| AJP 72(2), 279 | air wedge | 6D30.30 | The visibility of the interference fringes can be increased by replacing the glass plates with one-way mirrors. Measurements done with an Ocean Optics spectrometer. |
| D&R, O-455 | air wedge | 6D30.30 | A sodium lamp illuminates an air wedge between two plates of glass. Precise patterns can be obtained using optical flats. |
| Disc 23-14 | glass plates in sodium light | 6D30.30 | The diffused light from a high intensity sodium lamp is viewed by reflection off one and two pieces of plate glass. |
| | air wedge and expanded laser beam | 6D30.35 | An expanded laser beam is reflected off of two pieces of plate glass held together. |
| TPT 41(4), 250 | mirror and expanded laser beam | 6D30.35 | An expanded laser beam shines onto a back surface mirror. Reflections off the front glass surface and the silver coated back surface of the mirror produce large interference patterns. |
| PIRA 500 | Pohl's mica sheet | 6D30.40 | |
| UMN, 6D30.40 | Pohl's mica sheet | 6D30.40 | |
| F&A, Ol-15 | mica interference | 6D30.40 | Show interference by reflection of filtered mercury light from a mica sheet onto a screen. |
| Mei, 35-2.3 | Pohl's mica sheet | 6D30.40 | Reflect light from a mercury point source off a thin sheet of mica onto the opposite wall. Derivation. |
| Hil, O-7e | Pohl's mica sheet | 6D30.40 | Mercury light is reflected off a thin mica sheet. Mercury light source reference: AJP 19(4),248. |
| D&R, O-470 | mica interference | 6D30.40 | Show interference by the reflection of mercury light from a mica sheet onto a screen. |
| Disc 23-17 | Pohl's mica sheet | 6D30.40 | Mercury light reflects off a sheet of mica onto a screen. |
| Mei, 35-2.4 | turpentine film | 6D30.45 | White light incident of the surface of turpentine on water at an angle of 45-60 degrees is focused on a screen. |
| TPT 17(6), 392 | evaporating film - alcohol | 6D30.46 | Show an interference pattern by shining an expanded laser beam on an inverted test tube. Pour alcohol over the test tube and watch the fringes shift with a definite velocity as the alcohol evaporates. |
| AJP 44(8),794 | absorption phase shift | 6D30.48 | Cover the back of a microscope slide with streaks of an absorbing dye and observed under monochromatic light. |
| Mei, 35-2.5 | temper colors | 6D30.50 | A thin film of oxide forms on a polished steel sheet when it is heated. |
| PIRA 1000 | interference filters | 6D30.60 | |
| Mei, 35-2.6 | interference filter | 6D30.60 | An interference filter for the mercury green line is used with white, mercury, and neon light at different angles of incidence. |
| Disc 23-16 | interference filters | 6D30.60 | White light is seen in reflection and transmission on a thread screen using three different interference filters. |

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| Hil, O-7f.1 | interference films | 6D30.61 | A broad source (36 sq in) He lamp is used to examine thin metal films. |
| Hil, O-7d | oil film | 6D30.65 | The thickness of a film of oil on a pan of water that can be varied by sliding an iron bar across the surface makes an excellent variable interference filter. |
| Mei, 33-7.13 | microwave thin film interference | 6D30.70 | Show interference by transmission and reflection with two ground glass sheets, one stationary and the other movable on an optical bench. |
| | **Interferometers** | **6D40.00** | |
| PIRA 200 | Michelson interferometer | 6D40.10 | Use a Michelson interferometer with either laser or white light. |
| UMN, 6D40.10 | Michelson interferometer | 6D40.10 | Pass laser light through a commercial interferometer onto the wall. Can also be done with white light. |
| AJP 30(8),604 | Michelson interferometer modified | 6D40.10 | The Cenco M3 interferometer is modified to obtain good results without the clock drive (AJP 27,520 (1959)). |
| AJP, 50 (11), 987 | Michelson interferometer | 6D40.10 | Michelson and Morley published data on their experiment that showed large systematic trends. However, they did not explain how they removed these trends in their analysis. The paper attempts to reconstruct the missing part of the analysis. |
| F&A, Ol-19 | Michelson interferometer | 6D40.10 | Use a Michelson interferometer with either laser or white light. |
| Mei, 35-2.7 | Michelson interferometer | 6D40.10 | The Michelson interferometer. |
| Sut, L-72 | Michelson interferometer | 6D40.10 | Project colored fringes from white light onto a screen, insert a hot object in one path. |
| D&R, O-440, S-050 | Michelson interferometer | 6D40.10 | Use a Michelson interferometer with the expanded beam from a laser. |
| Disc 23-20 | Michelson interferometer - white light | 6D40.10 | A commercial interferometer with white light. Both circular and line fringes are shown. |
| AJP 39(9),1091 | Michelson interferometer - large class | 6D40.11 | Use a laser with the Michelson interferometer and expand the exit beam with a microscope objective. |
| AJP 35(2),161 | Michelson interferometer - power | 6D40.12 | Measure the power of solar cells in the two outputs of the Michelson interferometer. |
| AJP 39(11),1395 | Michelson interferometer alignment | 6D40.13 | Hints on alignment techniques. |
| PIRA 1000 | interference fringes with audio | 6D40.15 | |
| AJP 47(4),378 | interference fringes with audio | 6D40.15 | A photocell detector detects fringes and the output is converted to an audio signal. |
| AJP 39(4),412 | Michelson interferometer - advanced topics | 6D40.16 | Use the Michelson interferometer to demonstrate graphically the Fourier transform nature of Fraunhoffer diffraction and introduce basic concepts of coherent optics. |
| PIRA 500 | microwave interferometer | 6D40.20 | |
| Mei, 33-7.6 | microwave interferometer | 6D40.20 | Thorough discussion of the microwave interferometer including using it to calibrate a meter stick. |
| Disc 23-19 | Michelson interferometer | 6D40.20 | An interferometer constructed with 3 cm microwaves and using a mesh screen that functions as a half silvered mirror. Constructive and destructive interference is heard as the reflector is moved. |
| Mei, 33-7.4 | microwave interferometer | 6D40.21 | Three microwave interferometers: Lloyd's mirror, Michelson's interferometer, grid-detection interferometer, are shown. Pictures. |
| D&R, O-430 | microwave interferometer | 6D40.21 | Use 11cm microwaves and a metal sheet to demonstrate Lloyd's mirror. |
| AJP 33(11),924 | microwave interferometer | 6D40.22 | Use 4 cm microwaves and 10" square platforms of Plexiglas to demonstrate Lloyd's mirror, Michelson's interferometer, and grid-detection interferometers on the overhead. |
| UMN, 6D40.25 | microwave interferometer | 6D40.25 | Demonstrate an interferometer using chicken wire mirrors and a 12 cm microwave. |
| F&A, Ol-20 | microwave Michelson interferometer | 6D40.25 | Make a microwave Michelson interferometer with window screen reflectors and a chicken wire half reflector. |
| D&R, O-410 | Lloyd's mirror | 6D40.27 | A front surface mirror is brought close to an expanded laser beam at a very small grazing angle. Interference lines are formed on a screen. |
| Mei, 35-2.10 | Jamin interferometer | 6D40.30 | The two mirrors are adjustable about mutually perpendicular axes. |
| Mei, 35-2.9 | Jamin interferometer | 6D40.30 | Use second surface mirrors at an angle to generate parallel beams in this interferometer. |
| AJP 29(10),669 | Sagnac interferometer - real fringes | 6D40.35 | Real fringes are observed with the Sagnac interferometer with both a point source and an extended source. Virtual fringes require an extended source. Also applies to Michelson interferometer. |
| AJP 30(10),724 | Fabry-Perot interferometer | 6D40.35 | Construction details for a Fabry-Perot interferometer. Applications: optical measurements, index of refraction of a gas, and the Zeeman effect. |
| Mei, 35-2.8 | triangular interferometer | 6D40.40 | The triangular interferometer is explained. Diagrams, Construction details in appendix, p. 1353. |
| AJP 43(11),940 | coupled cavity interferometer | 6D40.42 | A prism mounted on a phonograph turntable is used to rapidly vary the path length of the external cavity. |

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| AJP 33(6),487 | coherence length | 6D40.45 | Use a long path interferometer to demonstrate the coherence length is at least 12 m. Also transverse coherence. |
| Mei, 36-4.1 | long path interferometer | 6D40.45 | The movable mirror can be at least 6 m away giving a coherence length of 12 m. |
| Mei, 36-4.2 | long path interferometer | 6D40.46 | A long path interferometer uses corner reflectors instead of mirrors and the output beam is directed onto a photodetector feeding an audio oscillator. |
| Mei, 36-4.3 | double ended interferometer | 6D40.47 | Demonstrates the coherence of beams emitted from opposite ends of the laser tube. |
| Mei, 36-4.4 | transverse coherence | 6D40.48 | Misaligning the mirrors still gives fringes. |
| Mei, 36-4.5 | thick reflecting plate | 6D40.49 | Interference from waves reflected off two sides of a plate, limited to thin films in ordinary light, works in thick glass with lasers. |
| Mei, 35-2.11 | Fresnel interferometers | 6D40.50 | Two different setups of Fresnel interferometers are discussed. |
| AJP 73(12), 1135 | low cost Fabry-Perot cavity | 6D40.54 | Another low cost scanning Fabry-Perot cavity for laser experiments. |
| AJP 35(3),265 | Mylar Fabry- Perot interferometer | 6D40.54 | Design of an interferometer using metalized mylar as mirrors. |
| AJP 35(3),xxii | inexpensive Fabry-Perot | 6D40.54 | Use standard "one-way" mirrors. |
| AJP 33(7),532 | low cost Fabry-Perot interferometer | 6D40.54 | Construction of Fabry-Perot devices from microscope cover glasses and plate glass. |
| AJP 33(12),1088 | medium cost Fabry-Perot | 6D40.54 | Use Pyrex optical flats. |
| AJP 36(1),ix | low cost Fabry-Perot | 6D40.54 | Use surplus optically flat circular plates. |
| AJP 33(12),1090 | low cost comment | 6D40.54 | Spacings up to 1/4" are possible. |
| AJP 71(2), 184 | low cost Fabry-Perot cavity | 6D40.54 | A low cost scanning Fabry-Perot cavity for laser experiments. |
| Hil, O-10d | Fabry-Perot etalon | 6D40.55 | Directions for construction an inexpensive Fabry-Perot etalon. Reference: AJP 36(1),ix. |
| AJP 59(11),992 | Fabry-Perot interferometer | 6D40.56 | Add some mirrors to a commercially made linear positioning stage. |
| AJP 52(6),563 | simple gauge-length interferometer | 6D40.57 | A simple low-cost interferometer using only manufacturers' stock components. |
| AJP 49(5),477 | listening to the Doppler shift of light | 6D40.60 | Light from a laser beam is reflected off fixed and movable mirrors, mixed on a photodetector, and the resulting signal is amplified and drives a speaker. |
| Mei, 19-6.7 | satellite tracking using Doppler | 6D40.60 | Beats between a generator and Sputnik I are recorded and played back while projecting a spot on a map indicating position. |
| Mei, 35-2.12 | spherical mirror interferometer | 6D40.60 | An interferometer with two spherical mirrors is designed to show wind around objects, heat effects, and strain effects. |
| AJP 44(4),391 | optical Doppler shift | 6D40.61 | Show the frequency shift of a laser beam bouncing off a moving mirror with a spectrum analyzer. |
| AJP 46(7),763 | Doppler effect with light | 6D40.61 | Using a laser beam, retroreflector on a moving air track, beam splitter, and stationary mirror, observe the signal of the beat pattern from a silicon photodiode on an oscilloscope. |
| AJP 37(7),744 | Doppler radar | 6D40.62 | Diagram of apparatus for Doppler radar. The reflector is mounted on a 1/32 scale slot car. |
| AJP 33(6),499 | Doppler shift with microwaves | 6D40.62 | Some of the transmitted signal and the signal received after reflection off a moving object are fed to a mixer. |
| TPT 30(2), 102 | radar gun | 6D40.62 | Testing a radar gun and the tuning fork used to calibrate it for accuracy. |
| TPT 40(2), 94 | radar gun | 6D40.62 | Determining the speed of objects in the classroom with a radar gun. |
| Mei, 19-6.8 | complicated Doppler shift setups | 6D40.70 | Sophisticated Doppler shift experiments with construction details, diagrams, and 7 references. |
| | **COLOR** | **6F00.00** | |
| | **Synthesis and Analysis of Color** | **6F10.00** | |
| PIRA 500 | color box | 6F10.10 | |
| UMN, 6F10.10 | color box | 6F10.10 | A commercial Singerman box projects blue, red, and green light onto a screen with individually variable intensity. |
| F&A, Oj-3 | color box | 6F10.10 | Overlap red, green, and blue light of adjustable intensity on a translucent screen. |
| Hil, O-6a | color box | 6F10.10 | The Welch color box shows the addition of the primary colors. |
| Disc 23-26 | color box - additive color mixing | 6F10.10 | Mix red, green, and blue in a color box. |
| Sut, L-88 | color addition | 6F10.11 | Red, green, and blue lamps shine from the corners of a white triangle. A rod or rods are placed on the screen to show the colors of shadows. |
| Hil, O-6b | Cenco color apparatus | 6F10.12 | The primary colors can be projected onto a screen. |
| Mei, 35-7.6 | color synthesizer | 6F10.13 | A color synthesizer allows demonstration of the significance of dominate wavelength, purity, luminosity, etc. |
| Sut, L-89 | color addition | 6F10.15 | Wratten filters Nos. 19, 47, and 61 are used to make a slide with 1/3 of a circle of each color. A projection arrangement shows the combination of colors and division of light between the separate colors. |
| Mei, 35-7.1 | color projector | 6F10.16 | Adapting a lantern slide projector for mixing primary colors. |

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| D&R, O-720 | color projector or projectors | 6F10.16 | A single slide projector with three mirrors on blocks, or three separate slide projectors are used to overlap or mix the three primary colors on a screen. |
| Mei, 35-7.4 | color projector | 6F10.17 | Many color demonstrations are performed with a slide projector and slides reflected off swivel mirrors. |
| Mei, 35-7.2 | lantern slide colors | 6F10.18 | A diffraction grating is held in front of a lantern projector with seven slits, one side with primary additive colors, the other with subtractive, and the center white. |
| PIRA 500 | color filters | 6F10.20 | |
| UMN, 6F10.20 | color filters | 6F10.20 | Cyan, magenta, and yellow filters are available as loose squares or fixed in a Plexiglas holder for use on the overhead projector. |
| D&R, O-730 | color filters | 6F10.20 | Red, green, blue, cyan, yellow, and magenta filters are used on an overhead. |
| AJP 37(6),662 | dichromatic primary pairs | 6F10.22 | Discussion of the standard light addition, subtraction, as they relate to two color mixing. |
| AJP 47(2),142 | artist's colors | 6F10.23 | On why artists use red, yellow, and blue instead of red, green, and blue. |
| AJP 47(7),573 | artist's colors - letter | 6F10.23 | Hey guys, artists use pigments, not light, and anyway the subtractive primary colors are cyan, magenta, and yellow. Information of 4-color printing and real artist's pigments too. |
| Bil&Mai, p 318 | artist's colors | 6F10.23 | Identify the primary colors of light as red, blue, and green using colored flashlights. Cyan, magenta, and yellow filters are place on top of one another on an overhead projector. Use these demonstrations to help discuss the difference between the primary colors of light and the primary colors of pigments. |
| PIRA 1000 | spinning color disc | 6F10.25 | |
| F&A, Oj-2 | spinning color disc | 6F10.25 | A disc with colored sectors appears white when rotated. |
| Sut, L-93 | spinning color disc | 6F10.25 | Disks with colored sectors are spun until the colors blend together. |
| D&R, O-710 | color fan | 6F10.25 | A three blade fan, each blade painted a primary color appears white when rotated. Difficult to find right color mix for a good white. |
| TPT, 36(6), 347 | as easy as R, G, B | 6F10.25 | Using commercially available light sticks and a variable-speed drill to make white light. |
| Bil&Mai, p 320 | as easy as R, G, B | 6F10.25 | Use red, green, and blue light sticks and a variable speed drill to make white light. |
| Disc 23-25 | Newton's color disc | 6F10.25 | A spinning disc of colored sectors appears white. |
| Mei, 35-7.7 | weird slit with Hg light | 6F10.26 | A slit and "inverted slit" used with Hg and a prism produce the normal line spectra and "inverted spectrum" of complementary colors. |
| PIRA 1000 | recombining the spectrum | 6F10.30 | |
| F&A, Oj-4 | recombining the spectrum | 6F10.30 | Recombine the spectrum after passing through a prism to get white light or remove a color and get the complement. |
| Mei, 35-7.5 | recombining colors | 6F10.30 | Recombining dispersed light after reflecting out various colors, etc. |
| Sut, L-92 | recombining the spectrum | 6F10.30 | Obtain a spectrum with a prism, reflect out a color with a small thin mirror, and recombine the light with a lens. |
| PIRA 1000 | purity of the spectrum | 6F10.33 | |
| F&A, Oj-1 | purity of the spectrum | 6F10.33 | A second prism at right angles bends each color without dispersion. |
| Mei, 35-1.6 | splitting and recombining | 6F10.35 | A half spectrum filter splits out light from a beam which is then recombined at a spot. |
| Mei, 35-5.5 | dispersion and recombination | 6F10.36 | Several variations of recombining dispersed light from a prism. |
| PIRA 1000 | complementary shadow | 6F10.45 | |
| UMN, 6F10.45 | red and green | 6F10.45 | |
| Mei, 35-7.8 | complementary shadow | 6F10.45 | Shadows of red and white lights illuminating the same object from different angles appear to produce green light. |
| D&R, O-750 | complementary shadow | 6F10.45 | Two flashlights, one with red filter, one with green filter, will produce a shadow of an additional color when illuminating the same object. |
| Sut, L-96 | metal films and dyes | 6F10.61 | A thin film of gold transmits green but looks reddish-yellow by reflection. Dyes also transmit and reflect different colors. |
| Sut, L-95 | dichromatism | 6F10.65 | Green cellophane transmits more red light than green. Stack lots of sheets and the color of transmitted light changes from green to red. |
| Sut, L-87 | three conditions for color | 6F10.70 | The three conditions are: Color must be in the source, the object must reflect or transmit the color, the detector must be sensitive to the color. Shine different colored light at different colored objects. |
| Sut, L-91 | color due to absorption | 6F10.71 | Light from a projection lantern reflected off red, green, and blue glass to the ceiling is the same but the transmitted light is colored by absorption. |
| PIRA 1000 | colors in spectral light | 6F10.75 | |
| Mei, 35-7.3 | colored yarn | 6F10.75 | Skeins of colored yarn are illuminated with different colored light. |
| Disc 23-23 | colors in spectral light | 6F10.75 | A rose is viewed in white, red, green, and blue light. |

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| AJP 39(2),201 | complementary color transitions | 6F10.80 | Lecture room experiments are proposed which demonstrate complementary color transitions due to complementary boundary conditions at the aperture. |
| | **Dispersion** | **6F30.00** | |
| PIRA 1000 | dispersion curve of a prism | 6F30.10 | |
| Mei, 35-5.4 | dispersion curve of a prism | 6F30.10 | Light passes through a grating and then through a second slit at right angles and a prism generating a dispersion curve in color on the screen. |
| F&A, Oj-7 | deviation with no dispersion | 6F30.15 | Light passed through oppositely pointed crown and flint glass prisms adjusted to give light deviated in two directions but with no dispersion. |
| F&A, Oj-8 | dispersion with no deviation | 6F30.20 | Light passes through prisms of crown and flint glass adjusted to give two beams of the same dispersion but different deviation. |
| Mei, 35-5.1 | anomalous dispersion of fuchsin | 6F30.30 | Overcoming the difficulties of showing anomalous dispersion with fuchsin. |
| Mei, 35-5.2 | anomalous dispersion of sodium | 6F30.30 | An absorption cell for the anomalous dispersion of sodium is described. Diagrams, Construction details in appendix, p.1354. |
| Mei, 35-5.3 | bending dark absorption line of sodium | 6F30.31 | When salt is heated on a flame in the path of a narrow beam of light before dispersion, the edges of the spectrum close to the dark band bend up or down. |
| AJP 56(10),948 | optical ceramics: dispersion | 6F30.50 | A custom fabricated prism made from LaSFN-9 glass shows a cutoff between transmission and total internal reflection that can be tuned through the visible spectrum by turning the prism. |
| | **Scattering** | **6F40.00** | |
| PIRA 200 | sunset | 6F40.10 | Pass a beam of white light through a tank of water with scattering centers from a solution of oil in alcohol. |
| UMN, 6F40.10 | sunset | 6F40.10 | A beam of white light is passed through a tank of water and a solution of cedarwood oil in alcohol is poured in to create scattering centers. |
| D&R, O-040 | artificial sunset | 6F40.10 | Pass a slide projector beam through a hypo solution and add acid. Lysol will also work. |
| D&R, O-615 | scattering and sunset | 6F40.10 | Add powdered creamer in increments to a beaker of water on the overhead. Observe scattered light with a polarizer. Transmitted light will go from white to yellow-red until extinction occurs. |
| AJP 70(6), 620 | scattering and sunset | 6F40.10 | An absorption spectrophotometer is used to measure the wavelength dependence of light scattering from small spheres suspended in water. Measured values are compared to values predicted by the Rayleigh and Mie theories. |
| AJP 70 (1), 91 | scattering and sunset | 6F40.10 | An observation of Mie scattering by using polystyrene microspheres of different diameters. Different diameters give different colors. |
| AJP 76 (9), 816 | scattering of sky light | 6F40.10 | A model is described for the gas in the atmosphere and used to obtain the irradiance for sunlight scattered by the gas molecules contained in a coherence volume. |
| Sprott, 6.7 | scattering and sunset - Rayleigh scattering | 6F40.10 | A white light passing through a liquid scatters primarily the blue light causing the transmitted light to appear red. |
| Disc 24-08 | artificial sunset | 6F40.10 | Pass a beam through a hypo solution and add acid. |
| F&A, On-1 | sunset | 6F40.11 | Light scattering with a hypo solution. |
| Mei, 35-4.1 | sunset | 6F40.11 | HCl into hypo solution scatters blue light. |
| Sut, L-46 | sunset | 6F40.11 | A beam of light is scattered when passed through water containing hypo and HCl. |
| AJP 53(2),184 | various scattering centers, Mei scattering | 6F40.12 | Alternatives to hypo for the sunset demo including latex spheres that demonstrate Mie scattering. |
| Mei, 35-4.2 | red and blue beam | 6F40.15 | A red beam is passed through a solution of gum mastic but a blue beam is not. Diagram. |
| PIRA 1000 | optical ceramics scattering | 6F40.20 | |
| AJP 56(10),948 | optical ceramics - Rayleigh scattering | 6F40.20 | Type 7070 glass is treated to induce glass-in-glass phase separation used to show Rayleigh scattering. |
| Sut, L-100 | color of smoke | 6F40.30 | Cigarette smoke is blue, but after exhaling is white. |
| AJP 77 (11), 1010 | wavelength selective scattering | 6F40.40 | Structural color caused by wavelength selective scattering of light by microscopic features such as the scales on some insects. Morpho butterfly wings and peacock feathers are examples. |
| PIRA 1000 | microwave scattering | 6F40.50 | |
| Mei, 33-7.17 | microwave scattering | 6F40.50 | Show scattering of microwaves with a dielectric dipole inserted in the beam. Picture. |
| AJP 55(6),524 | multiple scattering | 6F40.60 | Examples of common observations inexplicable by single scattering, e.g., darkening of wet sand, whiteness of milk, etc., are discussed without invoking the complete incoherent scattering theory. |
| AJP 55(1),87 | halos | 6F40.80 | Look at a point source lamp through a fogged microscope slide. |

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| Sut, L-81 | dust halos | 6F40.80 | A glass plate covered with dust is held in a beam that converges into a hole in a screen. Circular halos appear on the screen around the hole. |
| AJP 45(4),331 | lunar halo picture | 6F40.82 | Picture and analysis of an unusual lunar halo. |
| | **POLARIZATION** | **6H00.00** | |
| | **Dichroic Polarization** | **6H10.00** | |
| Mei, 35-6.1 | generating polarized light | 6H10.05 | Lists all methods of generating polarized light. |
| TPT 28(7),464 | many light demonstrations | 6H10.06 | Strain patterns, polarization by reflection, pile of plates, scattering, rotary dispersion, the Faraday effect, interference in polarized white light, double refraction, polarizing microscope, double refraction in sticky tape. |
| PIRA 200 | Polaroids on the overhead | 6H10.10 | Show polarization with two sheets of Polaroid and a pair of sunglasses on an overhead projector. |
| UMN, 6H10.10 | Polaroids on the overhead | 6H10.10 | Two sheets of Polaroid and a pair of sunglasses are provided with an overhead projector. |
| Sut, L-122 | Polaroids on the overhead | 6H10.10 | Commercially available polarizing plates are now available. (1930's) |
| D&R, O-610 | Polaroids on the overhead | 6H10.10 | Two sheets of Polaroids are rotated on an overhead projector. |
| Bil&Mai, p 322 | Polaroids on the overhead | 6H10.10 | Show polarization with two sheets of Polaroid on an overhead projector. |
| Disc 24-01 | Polaroid sheets crossed and uncrossed | 6H10.10 | Two Polaroid sheets are partially overlapped while aligned and at 90 degrees. |
| F&A, Om-9 | Polaroids | 6H10.11 | A beam from an arc lamp is directed through two Polaroid sheets. |
| Hil, O-8b | polarization kit | 6H10.15 | Polaroid sheets for the overhead plus a lot of other stuff. |
| PIRA 200 | microwave polarization | 6H10.20 | Hold a grid of parallel wires in a microwave beam and rotate the grid. |
| UMN, 6H10.20 | microwave polarization | 6H10.20 | A "hamburger grill" filter is used to demonstrate polarization from a 12 cm dipole. |
| F&A, Om-1 | microwave polarization | 6H10.20 | A grid of parallel wires is held in a microwave beam. |
| Mei, 33-7.11 | microwave polarization | 6H10.20 | Microwave polarization is shown by rotating the receiver or using a grating. |
| AJP 71(5), 452 | microwave polarization | 6H10.20 | Construction of a strip grating that can convert a linearly polarized plane wave into one that is circularly polarized. |
| Disc 24-04 | microwave polarization | 6H10.20 | A slotted disc is rotated in the microwave beam. |
| PIRA 500 | polarization - mechanical model | 6H10.30 | |
| Sut, L-116 | polarization - mechanical model | 6H10.30 | Two boxes, one a polarizer and the other an analyzer, are built with a center slot that can be oriented either horizontally or vertically. Use with waves on a rubber hose. |
| D&R, O-605 | polarization - mechanical model | 6H10.30 | Two large wooden slits oriented parallel or perpendicular to one another with a long helical spring passing through both. |
| Sut, L-117 | polarization - mechanical model | 6H10.31 | A pendulum is hung from a long strut restrained by slack cords. Circular motion of the pendulum will be damped into a line by the motion of the strut. |
| PIRA 1000 | Polaroids cut at 45 degrees | 6H10.40 | |
| Disc 24-02 | Polaroids cut at 45 degrees | 6H10.40 | Cut squares of Polaroid so the axes are at 45 degrees. Now turning one upside down causes cancellation. |
| | **Polarization by Reflection** | **6H20.00** | |
| AJP 33(4),xxv | making black glass | 6H20.05 | Eliminate the reflection off the second surface of a glass plate with a Canada balsam and lampblack suspension on the back side. |
| PIRA 200 | Brewster's angle | 6H20.10 | Rotate a Polariod filter in a beam that reflects at Brewster's angle off a glass onto a screen. |
| UMN, 6H20.10 | Brewster's angle | 6H20.10 | A beam of white light is reflected off a sheet of black glass at Brewster's angle onto the wall. A Polaroid is provided to test. |
| D&R, O-620 | Brewster's angle | 6H20.10 | A beam of white light is reflected off a stack of glass plates at Brewster's angle. Rotate a Polaroid in the incoming and reflected beams. |
| AJP 69(11), 1166 | polarization by reflection | 6H20.10 | Measurments of reflected light with an interface and light sensor. |
| Disc 24-05 | polarization by reflection | 6H20.10 | Rotate a Polaroid filter in a beam that reflects off a glass onto a screen. |
| Mei, 35-6.2 | tilt the windowpane | 6H20.11 | Reflect plane polarized light off a window pane and vary the angle of incidence through Brewster's angle. |
| Mei, 36-6.2 | Brewster's angle with a laser | 6H20.12 | Using horizontally polarized laser light, rotate a glass plate through Brewster's angle to observe a null. |
| Mei, 36-6.1 | polarization of the laser beam | 6H20.12 | Rotate a Polaroid in the beam of a laser with Brewster's angle mirrors. |
| PIRA 1000 | microwave Brewster's angle | 6H20.15 | |
| Mei, 33-7.12 | microwave Brewster's angle | 6H20.15 | A block of paraffin is tilted until there is a minimum of transmitted radiation. |
| PIRA 500 | polarization by double reflection | 6H20.20 | |
| UMN, 6H20.20 | polarization by double reflection | 6H20.20 | |
| F&A, Om-16 | polarization from two plates | 6H20.20 | Two black glass mirrors - one fixed and the other rotates. |
| F&A, Om-2 | polarization of double reflection | 6H20.20 | Reflect light off a black mirror onto a second rotating black mirror to produce extinction. |
| Mei, 35-6.3 | double mirror Brewster's angle | 6H20.20 | Two glass plates are mounted in a box at Brewster's angle with the second able to rotate around the axis of the incident light. |

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| Hil, O-8a | double reflection polarization | 6H20.20 | Direct unpolarized light at a glass plate at 57 degrees, then to another plate at the same angle of incidence and perpendicular to the polarized light. |
| Disc 24-06 | polarization by double reflection | 6H20.20 | Offset a beam of light by double reflection off a glass, then rotate the first glass 90 degrees to obtain extinction. Replace the glass with metal mirrors and no polarization takes place. |
| Sut, L-123 | Norrenberg's polariscope | 6H20.21 | Light strikes two black glass plates in succession, each at 57 degrees. Rotate the second glass plate and replace it with a mirror. |
| Sut, L-125 | large scale polarizer | 6H20.25 | A large box with two black glass plates gives an extended source of plane polarized light. |
| PIRA 1000 | Brewster's cone | 6H20.30 | |
| F&A, Om-18 | Brewster's cone | 6H20.30 | A black glass cone at Brewster's angle. |
| Sut, L-124 | pyramid method | 6H20.31 | Illuminate a rotatable pyramid made of four triangles of black glass mounted at 57 degrees with the base with plane polarized light. |
| PIRA 500 | stack of plates | 6H20.40 | |
| Sut, L-126 | stack of plates | 6H20.40 | A stack of glass plates at 57 degrees will transmit and reflect light that is cross polarized. |
| | **Circular Polarization** | **6H30.00** | |
| AJP 51(1),91 | circular polarization model | 6H30.01 | One vector moves along with a fixed orientation in space while five others, at quarter wavelengths, rotate. |
| PIRA 200 | three Polaroids | 6H30.10 | |
| PIRA 500 - Old | three Polaroids | 6H30.10 | |
| UMN, 6H30.10 | three Polaroids | 6H30.10 | Three sheets of Polaroid are provided with an overhead projector. |
| Disc 24-03 | rotation by polarizing filter | 6H30.10 | Stick a third sheet between crossed Polaroids |
| PIRA 500 | barber pole | 6H30.30 | |
| Mei, 35-6.6 | barber pole | 6H30.30 | A beam of polarized light is rotated when directed up a vertical tube filled with sugar solution. |
| Sut, L-129 | barber pole | 6H30.30 | Show a beam of polarized light up through a tube with a sugar solution and scattering centers. The beam rotates and colors are separated. |
| Disc 24-14 | barber pole | 6H30.30 | Illuminate a tube of corn syrup from the bottom. Insert and rotate a Polaroid filter between the light and tube. |
| AJP 39(12),1536 | laser and quinine sulfate | 6H30.35 | Pass a polarized laser beam through a cylinder filled with a quinine sulfate solution. |
| PIRA 200 | Karo syrup | 6H30.40 | Insert a tube of liquid sugar between crossed Polaroids. |
| AJP 43(11),939 | Karo syrup tank | 6H30.40 | Fill an aquarium with Karo syrup and insert glass objects - prism, block, balls. View the collection through motorized crossed Polaroids |
| F&A, Om-16 | Karo syrup | 6H30.40 | Place a bottle of Karo syrup between crossed Polaroids |
| Sut, L-130 | rotation by sugar solution | 6H30.40 | Insert a tube of sugar solution between crossed Polaroids |
| D&R, O-690 | Karo syrup tube | 6H30.40 | Place Karo syrup in a 50 to 60 cm acrylic tube. Shine a beam of light from a projector lengthwise through the tube. A Polaroid placed between the light source and the tube will produce a corkscrew rainbow. Also, a beaker of Karo syrup between crossed Polaroids on the overhead. |
| Disc 24-11 | optical activity in corn syrup | 6H30.40 | A bottle of corn syrup between Polaroids, three overlapping containers of equal thickness between Polaroids |
| F&A, Om-19 | Karo syrup prism | 6H30.41 | Colors change as one Polaroid is rotated in a Karo syrup prism between crossed Polaroids |
| Mei, 35-6.5 | three tanks | 6H30.42 | Compare the rotation of plane polarized light in tanks containing sugar solution, turpentine, and water. |
| D&R, O-685 | three tanks | 6H30.42 | Compare the rotation of plane polarized light in tanks containing sugar solution, turpentine, and water. Karo syrup (dextrose) gives right-handed rotation while levulose gives left-handed rotation. |
| Sut, L-131 | quartz "biplate" | 6H30.45 | A quartz "biplate" is set between two crossed Polaroids at 45 degrees, then a tube of sugar solution is also inserted and rotated. |
| AJP 50(11),1051 | quartz slices | 6H30.60 | ? = More Phil Johnson humor. The paper describes the interference patterns that can be displayed through quartz slices that have been cut perpendicular to the optical axis. |
| PIRA 1000 | microwave optical rotation | 6H30.70 | |
| Mei, 33-7.16 | microwave optical activity | 6H30.70 | A styrofoam box contains 1200 coils of wire aligned in an array and wound in the same sense will rotate microwave radiation. |
| AJP 39(8),920 | microwave optical rotation | 6H30.71 | A microwave analog of optical rotation in cholesteric liquid crystals. Plastic sheets with small parallel wires are stacked so the wires on successive layers vary in a screw type fashion. |
| PIRA 1000 | Faraday rotation | 6H30.80 | |
| Sut, L-132 | Faraday rotation | 6H30.80 | Polarized light is passed through holes in an electromagnet bored parallel with the magnetic field. A specimen is placed in the magnet and the rotation is determined when the magnet is energized. |

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| Sut, L-133 | Faraday rotation | 6H30.81 | Insert a partially filled glass container of Halowax or carbon tetrachloride into the core of a solenoid between crossed Polaroids |
| Mei, 35-6.18 | rotation by magnetic field | 6H30.82 | A CS2 cell placed in a solenoid rotates the plane of polarization of light. |
| | **Birefringence** | **6H35.00** | |
| PIRA 200 - Old | two calcite crystals | 6H35.10 | Use a second calcite crystal to show the polarization of the ordinary and extraordinary rays. |
| F&A, Om-6 | two calcite crystals | 6H35.10 | Use a second calcite crystal to show the polarization of the ordinary and extraordinary rays. |
| PIRA 1000 | calcite and Polaroid on the overhead | 6H35.15 | |
| UMN, 6H35.15 | calcite and Polaroid on the overhead | 6H35.15 | Rotate a calcite crystal on an overhead projector covered except for a small hole. Use a Polaroid sheet to check polarity. |
| F&A, Om-5 | ordinary and extraordinary ray | 6H35.15 | Rotate a calcite crystal with one beam entering and two will emerge, one on axis and the other rotating around. |
| Sut, L-120 | calcite and Polaroid on the overhead | 6H35.15 | Project a hole in a strongly illuminated cardboard onto a screen through a calcite crystal. Interpose and rotate a polarizing plate to make the two images disappear alternately, or use a Wollaston prism. |
| D&R, O-625 | calcite and Polaroid on the overhead | 6H35.15 | Place a mask with 1 - 2 mm dia hole on the overhead. Place a calcite crystal over the hole and rotate until two beams emerge. Check polarization of these beams with a Polaroid. |
| Bil&Mai, p 322 | calcite and Polaroid on the overhead | 6H35.15 | Place a transparency with words on an overhead projector. Place a calcite crystal on a portion of the words and rotate until you see two images of the words. Hold a Polaroid above the crystal and rotate. |
| Disc 24-16 | double refraction in calcite | 6H35.15 | Place a calcite crystal over printed material or a metal plate with a small hole. |
| PIRA 1000 | Plexiglas birefringence | 6H35.17 | |
| UMN, 6H35.17 | Plexiglas birefringence | 6H35.17 | Same as AJP 59, (12), 1086 |
| AJP 73(4), 357 | birefringent filters | 6H35.17 | Low cost birefringent filters constructed from cellophane tape. |
| AJP 59(12),1086 | Plexiglas birefringence | 6H35.17 | Show birefringence of a Plexiglas rod directly with a linearly polarized laser. Also easily construct half and quarter wave plates. |
| AJP, 65(5), 449-450 | Plexiglas birefringence | 6H35.17 | A good guide to building your own Lucite optics for the demonstrations of birefringence in polarized light. |
| AJP, 65(7), 672-674 | Plexiglas birefringence - a modification of Schneider's experiment | 6H35.17 | A macroscopic demo of birefringence in Lucite/Plexiglas. A linearly polarized laser is shone along the axis of the Plexiglas cut with a 45 degree surface so both the direct image and a perpendicular image can be seen at the same time. |
| F&A, Om-3 | birefringence crystal model | 6H35.20 | A flexible crystal model is used to show how the index of refraction can vary in a crystal. |
| Sut, L-118 | pendulum model | 6H35.21 | Strike a pendulum with a blow, then wait 1/4, 1/2, or 3/4 period and strike another equal blow at right angles to the first. |
| Sut, L-119 | model of double refraction | 6H35.21 | A double pendulum displaced in an oblique direction will move in a curved orbit. |
| AJP 53(3),279 | wood stick polarization wave models | 6H35.22 | Stick models of plane and circular polarized light. |
| Hil, O-8c | retardation plate models | 6H35.23 | Fifteen models of retardation plates. Reference: AJP 21(9),466-7. |
| F&A, Om-4 | wavefront models | 6H35.24 | Wire models show spherical and elliptical wavefronts in crystals. |
| Mei, 35-6.11 | birefringent crystal axes | 6H35.25 | Examine calcite crystals cut perpendicular, parallel, and along the cleavage axis under a microscope. |
| F&A, Om-8 | Nichol prism | 6H35.30 | One of a pair of Nichol prisms is rotated as a beam of light from an arc lamp is projected through. |
| F&A, Om-7 | Nichol prism model | 6H35.31 | Construct a wire frame model to show how calcite crystals are cut to form a Nichol prism. |
| Sut, L-121 | polarizing crystals | 6H35.32 | Explain the action of tourmaline crystals and the Nicol prism with models. |
| PIRA 500 | quarter wave plate | 6H35.40 | |
| F&A, Om-11 | quarter-wave plate | 6H35.40 | Insert a quarter-wave plate between Nichol prisms at 45 degrees giving circular polarization. |
| Disc 24-15 | quarter wave plate | 6H35.40 | Place a quarter wave disc between a Polaroid and a mirror. |
| AJP 54(5),455 | mechanical model half wave plate | 6H35.41 | An anisotropic spring and metal ball system is the mechanical analog of a half-wave plate. |
| Mei, 35-6.16 | half and quarter wave plates | 6H35.44 | Use half and quarter wave plates with polarized sodium light. |
| PIRA 1000 | half wave plate | 6H35.45 | |
| F&A, Om-10 | half wave plate | 6H35.45 | Insert a half wave plate between Nichol prisms at 45 degrees giving plane polarized light. |
| Mei, 35-6.15 | half wave plate | 6H35.45 | Use a quartz wedge to show the effect of a half wave plate. |
| PIRA 200 - Old | stress plastic | 6H35.50 | A set of plastic shapes are bent between crossed Polaroids. |
| UMN, 6H35.50 | stress plastic | 6H35.50 | A set of plastic shapes are bent between crossed Polaroids. |

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| UMN, 6H35.50 | stress plastic | 6H35.50 | A commercial squeeze device and little plastic shapes are used between crossed Polaroids. |
| AJP 44(11),1138 | stress plastic | 6H35.50 | Plastic shapes on the overhead between crossed Polaroids |
| F&A, Om-15 | stress plastic | 6H35.50 | Various shapes of plastic fit in a squeezer between crossed Polaroids in a lantern projector. |
| Sut, L-134 | stress plastic | 6H35.50 | Plastic is stressed between crossed Polaroids ALSO - Stroke a strip of glass longitudinally between crossed Polaroids and standing waves are apparent. |
| D&R, O-660 | stress plastic | 6H35.50 | Stressed polyethylene bags or acrylic between crossed Polaroids. |
| Disc 24-13 | stress plastic | 6H35.50 | Stress a plastic bar between crossed Polaroids |
| F&A, Om-12 | crystal structure of ice | 6H35.51 | A thin slab of ice is placed between crossed Polaroids |
| Mei, 35-6.12 | quartz wedge | 6H35.51 | Interference colors are shown with a quartz wedge in red, green and white light polarized light. |
| F&A, Om-14 | color with mica | 6H35.52 | Rotate a mica sheet between crossed Polaroids |
| Mei, 35-6.13 | quartz wedge | 6H35.52 | A setup to show the spectral analysis of the colors of a quartz wedge. |
| PIRA 1000 | butterfly, etc. | 6H35.53 | |
| UMN, 6H35.53 | butterfly, etc. | 6H35.53 | |
| Mei, 35-6.17 | sign on crystals | 6H35.53 | A setup using a quartz wedge or sensitive plate to determine the sign of crystals. |
| Sut, L-136 | butterfly | 6H35.53 | Mica, cellophane, etc. are placed between crossed Polaroids |
| Mei, 35-6.14 | various crystal thicknesses | 6H35.54 | Various crystals are placed between crossed Polaroids including etchings. |
| PIRA 500 | cellophane between polarizers | 6H35.55 | |
| AJP 49(9),881 | cellophane between Polaroids | 6H35.55 | A nice short explanation of interference colors and a kitchen table variation where the polarizer and analyzer are not obvious. |
| Mei, 35-6.4 | cellophane between Polaroids | 6H35.55 | A doubly refraction material between fixed and rotatable Polaroid sheets demonstrates color change with Polaroid rotation. |
| D&R, O-630, O-625 | cellophane between Polaroids | 6H35.55 | Cellophane placed between two sheets of Polaroid. Rotate either the cellophane or the Polaroids. |
| Disc 24-09 | cellophane between Polaroids | 6H35.55 | Interesting designs show up when plates with layered cellophane are placed between crossed Polaroids |
| Disc 24-10 | polarized lion | 6H35.56 | The second polarizer is reflected light from a horizontal plate of glass. |
| Disc 24-12 | polage | 6H35.57 | Optically active art work - metamorphosis of a cocoon into a butterfly as one Polaroid rotates. |
| AJP 54(7),625 | Kerr effect with optical ceramics | 6H35.60 | Replace the nitrobenzene in the Kerr cell with an optical ceramic. An interesting welding goggles application is discussed. |
| Sut, L-135 | Kerr effect - electrostatic shutter | 6H35.61 | Halowax oil is used between the plates of a capacitor set between crossed Polaroids Charge the capacitor with an electrostatic machine and the transmitted light will vary. |
| AJP 41(2),270 | nematic liquid crystals | 6H35.62 | Directions for making cells with thin layers of the liquid crystal MBBA and various optics experiments with the material. |
| PIRA 1000 | LCD element between polaroids | 6H35.65 | |
| Mei, 17-8.3 | flow birefringence | 6H35.80 | A colloidal solution demonstrates birefringence accompanying flow. Preparation instructions. |
| | **Polarization by Scattering** | **6H50.00** | |
| PIRA 500 | sunset with polarizers | 6H50.10 | |
| UMN, 6H50.10 | sunset with polarizers | 6H50.10 | Use a sheet of Polaroid to check the polarization of scattering from a beam of light passing through a tank of water with scattering particles. |
| F&A, On-2 | sunset with polarizers | 6H50.10 | Rotate a Polaroid in the incoming beam or at the top and side of the tank in the sunset demonstration. |
| Mei, 35-6.9 | polarization from a scattering tank | 6H50.10 | A mirror at 45 degrees mounted above the scattering tank reflects light scattered up onto the same Polaroid analyzer as the light scattered to the side. |
| Mei, 35-6.8 | the Tyndall experiment | 6H50.10 | Shine light in one side of a box with a scattering solution and look at the scattered light out in a perpendicular direction. |
| Sut, L-128 | sunset with polarizers | 6H50.10 | Rotate a Polaroid in the incident beam of the sunset experiment with a mirror oriented at 45 degrees above the tank. |
| Bil&Mai, p 324 | sunset with polarizers | 6H50.10 | Use a sheet of Polaroid to check the polarization of scattering from a beam of light passing through a tank of water with scattering particles. Use Pine-Sol. |
| Disc 24-07 | polarization by scattering | 6H50.10 | Add milk to water and show polarization of light scattered from a beam. |
| Mei, 36-6.3 | scattered laser light | 6H50.11 | Rotate a polarized laser about its own axis as it is scattered from a solution. |
| Sut, L-127 | polarized scattering in a beaker | 6H50.20 | A beam of light is directed down into a beaker of water containing scattering centers. Rotate a sheet of Polaroid in front of the beaker or in the beam before it enters the water. |

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| Mei, 35-6.7 | scattering tube | 6H50.21 | Direct polarized or unpolarized light up a vertical tube filled with a solution containing scattering centers. |
| PIRA 1000 | depolarization by diffuse reflection | 6H50.30 | |
| Mei, 35-6.10 | depolarization by diffuse reflection | 6H50.30 | Reflect a beam of polarized light off a chalk surface through a Polaroid analyzer. |
| PIRA 1000 | Haidinger's brush | 6H50.90 | |
| TPT 28(9),598 | Haidinger's brush | 6H50.90 | Train yourself to detect polarized light with the naked eye. Most people can. |
| | **THE EYE** | **6J00.00** | |
| | **The Eye** | **6J10.00** | |
| PIRA 200 | eye model | 6J10.10 | |
| PIRA 500 - Old | eye model | 6J10.10 | |
| UMN, 6J10.10 | eye model | 6J10.10 | |
| F&A, Og-8 | eye model | 6J10.10 | Show a take-apart model of the eye. |
| Hil, O-5b.1 | eye model | 6J10.10 | The standard take-apart eye model. |
| Mei, 34-2.1 | water flask model of the eye | 6J10.21 | A large flask filled with water, a little fluorescein, and some external lenses make a model of the eye in near and far sighted conditions. |
| Sut, L-65 | eye model | 6J10.21 | A spherical lens filled with milky water represents the eyeball. Use a large lens in front of the sphere to show inverted image, near and far sightedness. |
| TPT 46(9),528 | eye model | 6J10.21 | How to construct a small but accurate model of the human eye. |
| PIRA 1000 | blind spot | 6J10.30 | |
| UMN, 6J10.30 | blind spot | 6J10.30 | Same as L-58. |
| Sut, L-58 | blind spot | 6J10.30 | Move a white cross toward a white spot on the blackboard while the students close one eye. |
| D&R, O-580 | blind spot | 6J10.30 | Place a black dot and a black cross about 5 cm apart on a white card. Close one eye and look at cross while moving card away from the eye until the dot disappears. |
| PIRA 1000 | inversion of image on the retina | 6J10.40 | |
| Sut, L-59 | inversion of image on the retina | 6J10.40 | A small tube has three holes in a triangular pattern drilled in one end and a single hole in the other. Hold the triangular end near the eye and the pattern appears inverted. |
| Sut, L-64 | astigmatism | 6J10.50 | Look at a chart of radial black lines. |
| Sut, L-66 | eyeglasses | 6J10.55 | Project an image of concentric circles crossed by radial lines. Place a lens and then a correcting lens over the projection lens. |
| Sut, L-63 | chromatic aberration of the eye | 6J10.60 | A purple filter is mounted in front of a straight filament lamp. |
| PIRA 1000 | resolving power of the eye | 6J10.80 | |
| Sut, L-86 | resolving power of the eye | 6J10.80 | The limit of resolving two filaments of an auto headlamp is 25 - 30 feet. ALSO - show slides of the "Navicula" made with green and UV light. Reference. |
| D&R, O-570 | resolving power of the eye | 6J10.80 | Place two black dots about 2 mm apart on a note card and observe from increasing distances until unable to resolve. Determine the angular resolution. |
| PIRA 1000 | resolving power with TV | 6J10.81 | |
| Disc 23-09 | resolving power with TV | 6J10.81 | The camera zooms in on a vertical series of back illuminated double slits, each separated by half the distance of the preceding pair. |
| AJP 58(6),552 | Computer generated Sayce chart | 6J10.85 | A valuable background discussion on the resolution of the eye and a computer generated Sayce is shown. An external slit is used to stop down the eye pupil. |
| Mei, 34-1.14 | locating images by parallax | 6J10.90 | An arrangement is shown for locating real and virtual images by parallax. |
| | **Physiology** | **6J11.00** | |
| PIRA 1000 | retinal fatigue - color disc | 6J11.10 | |
| F&A, Oi-12 | retinal fatigue - color disc | 6J11.10 | A red light placed behind a rotating disc with a slot at the border of half black and half white appears different colors depending on the direction of rotation. |
| Sut, L-94 | retinal fatigue - color disk | 6J11.10 | A disk with a notch, half black, half white is spun in front of a red lamp. The lamp appears green or red depending on the direction that the disk spins. |
| Mei, 6-2.8 | psychological colors | 6J11.11 | A black and white patterned disc appears colored when rotated. |
| PIRA 1000 | visual fatigue | 6J11.20 | |
| Sut, L-61 | visual fatigue | 6J11.20 | Stare at a bright spot and a complementary color appears when the spot is turned off. |
| D&R, O-770 | visual fatigue | 6J11.20 | Stare at a brightly colored object in good light for about 30 seconds. Look away to a white paper or wall and see the image in complementary color. |

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| Mei, 6-2.2 | after image and judgement of size | 6J11.22 | The retinal fatigue image seems to change size. |
| PIRA 1000 | persistence of vision | 6J11.30 | |
| UMN, 6J11.30 | persistence of vision | 6J11.30 | |
| AJP 71(8), 774 | persistence of vision | 6J11.30 | A mathematical description of the Roget Illusion and anorthoscope. Simple devices are shown. |
| Bil&Mai, p 4 | persistence of vision | 6J11.30 | Use a strobe light to read a phrase written on the blades of a spinning fan. |
| Mei, 6-2.7 | persistence of vision | 6J11.30 | A wheel with circles with phase shifted dots painted on the rim is spun in strobed light. |
| TPT, 36(7), 442 | the time delay in human vision | 6J11.31 | Exploring the time delay in vision by spinning LED's on a turntable |
| AJP 43(1),113 | colored fans | 6J11.32 | Paint a four bladed fan different colors and illuminate with a strobe. |
| Mei, 6-2.9 | tubeless television | 6J11.33 | Wave a wand at the point a projected image is focused. |
| D&R, O-585 | tubeless television | 6J11.33 | Wave a meter stick at the point where a projected image is focused. |
| Sprott, 6.11 | tubeless television | 6J11.33 | A visual image appears in midair when waving a light-colored stick near the focal plane of a slide projector. |
| F&A, Oi-9 | integration of light pulses | 6J11.35 | If light intensity from a strobe that appears continuous at 3000 Hz is cut in half, it will appear continuous at about 1700 Hz. |
| Sut, L-60 | fluorescence of the retina | 6J11.36 | Shine an UV source with a visible filter toward the class and notice the luminous haze that covers the field of view. |
| F&A, Oi-10 | jarring the eye | 6J11.37 | Stamp your foot while watching a free running oscilloscope. |
| Mei, 6-2.4 | subjectivity of colors | 6J11.40 | A red spot projected on the wall looks orange or brown if it is surrounded by white or black. |
| Mei, 6-2.11 | Mach disk | 6J11.42 | A spinning disk appears to have light and dark rings where it should be uniform. |
| Mei, 6-2.1 | relative black and white | 6J11.44 | A bright light shining on a black screen looks the same as a filtered light shining on a white screen. |
| F&A, Oi-11 | most sensitive to green light | 6J11.46 | A stick moved up and down in a projected spectrum will appear to bend at the green light area. |
| PIRA 1000 | impossible triangles | 6J11.50 | |
| Disc 21-12 | impossible triangles | 6J11.50 | An optical illusion that depends on viewing angle. |
| TPT 28(8),562 | the square that ain't there | 6J11.51 | A cutout of a square in black paper has the illusion of being a white square on top of black paper. |
| Mei, 6-2.3 | optical illusions | 6J11.52 | Compare the height to the width of a projected hat. |
| D&R, O-805 | optical illusions | 6J11.52 | Four real optical illusions and explanations. 6 spoofs. |
| Sprott, 6.12 | optical illusions | 6J11.52 | Transparencies containing optical illusions projected on a screen. |
| AJP 42(7),531 | perception | 6J11.55 | Many cases of optical perception are discussed along with some audio and miscellaneous phenomena. |
| TPT 46(2), 121 | perception - shades of gray | 6J11.56 | A gray box placed partially over a black background. The part of the box inside the black background looks darker than that ouside the black background, especially if a pencil is placed across the intersection. |
| AJP 33(12),1085 | depth perception - special case | 6J11.60 | Apparatus for the demonstration of depth perception when due solely to the geometrical disparity of binocular vision. |
| TPT 19(8), 564 | Pulfrich illusion - Pulfrich pendulum | 6J11.65 | A pendulum is swinging in a plane but appears to have an elliptical orbit if viewed with a filter over one eye. |
| TPT 20(2), 72 | Pulfrich illusion - Pulfrich pendulum | 6J11.65 | More comments on TPT 19(8), 564. |
| TPT 33(2), 117 | Pulfrich illusion - Pulfrich pendulum | 6J11.65 | A pendulum is swinging in a plane but appears to have an elliptical orbit if viewed with a filter over one eye. |
| D&R, W-060 | Pulfrich illusion - Pulfrich pendulum | 6J11.65 | A pendulum is swinging in a plane but appears to have an elliptical orbit if viewed with a filter or thin transparent film over one eye. |
| PIRA 1000 | color blindness | 6J11.70 | |
| Sut, L-62 | color blindness | 6J11.70 | Use standard color blindness slides or charts to test the students. |

## MODERN OPTICS 6Q00.00

### Holography 6Q10.00

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| AJP 43(8),714 | geometric model for holography | 6Q10.01 | A geometrical model which, without sacrificing any physical principles, correctly explains all the major characteristics of holograms. |
| AJP 35(11),1056 | introduction to holography | 6Q10.01 | Holography at the level of an undergraduate optics course. |
| AJP 43(11),954 | practial holography | 6Q10.01 | A "from the beginning" article on holography. |
| AJP 71(9), 948 | phase holography | 6Q10.01 | A mathematical description of thick hologram recording and playback is given using a basic wave front representation. |
| Mei, 37-1 | hologram chapter | 6Q10.01 | A chapter on holograms in Meiners by Tung H. Jeong. |
| PIRA 200 | holograms | 6Q10.10 | Show a hologram. |
| AJP 44(10),927 | 360 degree reflection holography | 6Q10.10 | Two methods of making 360 degree reflection holograms. |

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| Hil, O-10a | 360 degree hologram | 6Q10.10 | A 360 degree hologram From Edmund Scientific is observed with a Hg lamp and 5461 Angstrom filter. |
| D&R, O-485 | holograms | 6Q10.10 | Transmission and 120 degree holograms. |
| Disc 23-21 | holograms | 6Q10.10 | A video of a 360 degree transmission hologram. |
| AJP 45(5),493 | single beam 360 degree holograms | 6Q10.11 | A very simple arrangement using only a single lens to diverge a laser beam. |
| AJP 43(4),297 | 360 degree holograms | 6Q10.11 | Simple configuration for a good quality hologram. |
| PIRA 1000 | in class holograms | 6Q10.20 | |
| Hil, O-10b | holographic camera | 6Q10.21 | A Gaertner holographic system on an optical table. |
| AJP 57(6),560 | making holographic interferograms | 6Q10.30 | Directions for making a simple and cheap plate holder. |
| AJP 57(5),439 | thin-transmission holograms | 6Q10.31 | A long article on Abramson ray-tracing holograms. |
| AJP 57(5),445 | thin-transmission holograms | 6Q10.32 | A long article on a simple ray-tracing method for thin-transmission holograms. |
| AJP 57(2),133 | rainbow hologram with beaker of water | 6Q10.40 | Use a beaker of water in making the rainbow hologram. |
| AJP 55(9),823 | real time holograms | 6Q10.42 | How to make real time good quality interferograms. |
| AJP 50(3),281 | single beam holography | 6Q10.45 | Use single beam holography to study mechanical vibrations of an opaque object. |
| AJP 50(3),280 | single beam holography | 6Q10.45 | Demonstrate real time holograms that last several hours without glass plate film, etc. |
| AJP 35(5),ix | vibration testing for holography | 6Q10.50 | A vertical Michelson interferometer is constructed on the optical table with a pool of mercury as one mirror. |
| AJP 40(12),1866 | low cost holography | 6Q10.60 | Diagrams of single and double beam methods for making holographs. |
| AJP 37(4),455 | inexpensive holography table | 6Q10.60 | Four inches of newspapers and twelve tennis balls support a concrete slab. |
| AJP 41(7),932 | inexpensive spatial filter | 6Q10.60 | Substitute a microscope with an x-y stage for a commercial spatial filter. |
| AJP 36(2),ix | inexpensive beam splitters | 6Q10.60 | Use dime-store back silvered mirrors for beam splitters for holography. |
| AJP 35(8),773 | inexpensive holography | 6Q10.60 | A simple method for making holograms. |
| D&R, O-490 | inexpensive holography | 6Q10.60 | Directions and references for making holograms with inexpensive equipment and laser. |
| AJP 38(2),266 | simple hologram arrangement | 6Q10.62 | A simple hologram arrangement using ball bearings as beam expander mirrors. |
| AJP 35(11),1092 | instant holograms | 6Q10.63 | Use Polaroid film for holograms. |
| AJP 36(1),62 | holography for sophmore lab | 6Q10.65 | A simple hologram camera. |
| AJP 44(7),712 | beam splitter for holography | 6Q10.70 | A double front surface mirror splitter, and the Edmond 41 960 variable density beam splitter. |
| AJP 48(5),409 | rear reflections in plates | 6Q10.71 | Put black PVC masking tape on the back of the holographic plate. |
| AJP 36(2),ix | film holder for holography | 6Q10.71 | Use a 35 mm camera (both Kodak 649-F and SO-243 films come in 35mm). |
| AJP 43(2),185 | simple hologram verification | 6Q10.72 | Method for finding the orientation necessary for viewing and the location of the hologram on the film. |
| AJP 39(3),349 | holography without darkroom | 6Q10.72 | Dye the plates with a blue-green attenuator and use laser light in a red poor background. |
| AJP 37(7),748 | diffuser as beam splitter | 6Q10.73 | Get by with a single beam expander by using the polished back of the diffuser as a beam splitter. |
| AJP 39(7),840 | holography with 1 mw laser | 6Q10.74 | A technique for low exposure holography. |
| AJP 38(8),1046 | holography table | 6Q10.75 | Construction of an oscillation damped table for holography. |
| AJP 43(7),652 | axial mode detector | 6Q10.76 | The output of a fast silicon photodiode is mixed with a UHF signal and the oscillator is tuned to give a 0 Hz difference frequency. |
| AJP 45(6),590 | comment on AJP 44(7),712 | 6Q10.77 | Two points of concern. |
| AJP 42(5),425 | Kerr cell driver | 6Q10.78 | Modulate a laser beam with a Kerr cell. A circuit for a driver is given. |
| AJP 44(8),774 | computer holograms | 6Q10.81 | Generate holograms with an HP 9100B desktop calculator and plotter. |
| AJP 38(7),919 | reconstruction of acoustic holograms | 6Q10.82 | A photocopy of a hologram produced from sound waves in air was used to reconstruct an image with laser light and a crude setup. |
| AJP, 45(11), 1027 | holograph of a holograph | 6Q10.85 | A virtual image of a lens appears in front of a plate and images of various objects appear behind. |
| | **Physical Optics** | **6Q20.00** | |
| PIRA 1000 | Abbe demonstrations | 6Q20.10 | |
| AJP 30(5),342 | simple Abbe demonstrations | 6Q20.10 | Techniques of demonstrating Abbe theory of image formation with simple microscope equipment avoiding use of special Abbe diffraction gratings. |
| AJP 46(2),185 | Abbe's theory of imaging | 6Q20.10 | A demonstration to show both image and diffraction pattern formation. |
| AJP 39(10),1164 | optical simulation of the electron microscope | 6Q20.11 | An optical setup simulates an electron microscope imaging a two-dimensional lattice. Demonstrates Abbe's theory of the microscope. |
| AJP 48(8),674 | phase reversal effect - single slit | 6Q20.20 | Illuminate a double slit with the central maximum from a single slit diffraction pattern, then move the double slit so one slit is illuminated by the central maximum and the other by the first sideband. |

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| AJP 40(4),571 | symmetries in Fraunhofer Diffraction | 6Q20.21 | The Fraunhofer diffraction patterns for eight apertures each show a central maximum and interesting symmetries. |
| AJP 39(8),959 | spatial filtering | 6Q20.30 | An optimum lens configuration for optical spatial filtering for use in amplitude modification techniques. |
| AJP 42(7),614 | mapping transform | 6Q20.35 | A distorted image is viewed at 45 degrees to the axes of cylindrical convex and concave mirrors resulting in recognizable mirror images. |

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| | **QUANTUM EFFECTS** | **7A00.00** | |
| | **Photoelectric Effect** | **7A10.00** | |
| PIRA 200 | photoelectric effect in zinc | 7A10.10 | Use UV light to discharge a clean zinc plate mounted on an electroscope. |
| UMN, 7A10.10 | photoelectric effect in zinc | 7A10.10 | Discharge a clean zinc plate mounted on an electroscope with UV light. |
| F&A, Ok-3 | photoelectric effect in zinc | 7A10.10 | Discharge a zinc plate on an electroscope with UV light. |
| Mei, 38-2.1 | photoelectric effect in zinc | 7A10.10 | A clean zinc plate mounted on a charged electroscope, discharges the electroscope when the light source is not covered with glass. |
| Sut, A-89 | surface photoelectric effect | 7A10.10 | UV light shines on a zinc plate on an electroscope. More. |
| Hil, A-4b | photoelectric effect in zinc | 7A10.10 | Discharge a zinc plate on an electroscope. |
| D&R, S-095 | photoelectric effect in zinc | 7A10.10 | Discharge a freshly polished zinc plate on an electroscope with UV light from a carbon arc lamp. Don't use a lens. |
| Bil&Mai, p 356 | photoelectric effect in zinc | 7A10.10 | Discharge a clean zinc plate mounted on an electroscope with UV light. Use a glass plate to block the UV light. |
| Disc 24-19 | photoelectric effect in zinc | 7A10.10 | Zinc plate on an electroscope, charged negative, glass UV barrier. |
| PIRA 1000 | photoelectric charging | 7A10.12 | |
| UMN, 7A10.12 | photoelectric charging | 7A10.12 | Same as AJP 33(9),746. |
| AJP 34(2),172 | photoelectric charging | 7A10.12 | Additions to the AJP 33,746 (1965) article. |
| AJP 33(9),746 | photoelectric charging | 7A10.12 | Hold a positively charged object next to the zinc plate on an uncharged electroscope while illuminating it with an UV light. The electroscope will charge positively. |
| PIRA 1000 | discovery of the photoelectric effect | 7A10.15 | |
| Sut, A-90 | discovery of the photoelectric effect | 7A10.15 | A spark passes between two zinc electrodes attached to a 15 KV transformer when UV light is present. |
| AJP 44(3),305 | photoelectric effect with geiger counter | 7A10.17 | Conversion of photons to electrons in lead foil. |
| F&A, Ok-4 | photoelectric effect with prism | 7A10.20 | Project different parts of the spectra onto a zinc plate on a charged electroscope. |
| AJP 53(9),911 | photoelectric effect circuit | 7A10.23 | A photoelectric effect apparatus based on the AD 515 electrometer op amp allows relatively inexpensive and easy direct measurement of the photopotential between anode and photocathode. |
| TPT 1(5),229 | photoelectric effect circuits | 7A10.24 | Very cheap current detector substitutes. |
| AJP 38(6),767 | photoelectric effect circuit | 7A10.26 | Single transistor circuit for use with RCA 929 phototube. |
| AJP 46(2),133 | photoelectric effect circuit | 7A10.26 | An op-amp circuit for a 1P39 or similar phototube. |
| TPT 3(8),380 | photoelectric effect circuit | 7A10.27 | A helpful article on stopping potential with all the basic vital information, e.g., the wavelengths of the spectral lines of mercury, and featuring a transistorized current amplifier. |
| AJP 39(12),1542 | photoelectric effect circuit | 7A10.28 | Circuit diagram for an amplifier for use with the 1P39 tube. |
| PIRA 500 | stopping potential | 7A10.30 | |
| UMN, 7A10.30 | stopping potential | 7A10.30 | Measure the stopping potential of different colored light with a 1P39 phototube. Use interference filters at 400, 450, 500, 550, and 600 nm. |
| AJP 29(10),706 | stopping potential | 7A10.30 | Equipment and circuit diagrams for stopping potential demonstration. |
| TPT 1(3),183 | stopping potential | 7A10.30 | Simple apparatus based on the 929 phototube. Several demonstrations and discussion sections for studying the photoelectric effect and measuring Planck's constant. |
| F&A, MPb-1 | stopping potential | 7A10.30 | Measure the stopping potential of the lines of the mercury spectrum with a phototube. |
| Mei, 38-2.4 | stopping potential | 7A10.30 | A mercury arc lamp is used with filters giving passbands of one spectral line onto the cathode of a 1P39 phototube. |
| Sut, A-93 | stopping potential | 7A10.30 | The potential in the collector is changed while measuring the current under different colored light. |
| AJP 44(8),796 | stopping potential error | 7A10.31 | A widespread error in elementary texts on the stopping potential. |
| D&R, S-100 | Planck's constant - LED's | 7A10.33 | Plot graphs of voltage vs. frequency for several LED's. Multiply the slope of the graph by the electronic charge to calculate Planck's constant. |
| AJP, 78 (9), 933 | Maxwell-Boltzmann distribution - LED's | 7A10,33 | Observations of the Maxwell-Boltzmann distribution in the emission spectra of six LED's spanning the visible spectrum. |
| PIRA 1000 | photoelectric threshold | 7A10.35 | |
| AJP 43(4),370 | photoelectric threshold | 7A10.35 | Rotate the spectrum across a zinc plate until the current rises sharply. |
| Mei, 40-1.9 | photoelectric threshold | 7A10.35 | The photoelectric threshold demonstrator consists of a projected spectrum, a sample holder, and a translucent screen. |
| Mei, 38-2.3 | phototube and electrometer | 7A10.35 | A 929 phototube is connected to a electrometer and the voltage observed while sweeping the tube across a projected spectrum. |
| Sut, A-92 | photoelectric threshold | 7A10.35 | Measure the current from a photocell exposed to different colored light. |

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| Mei, 40-1.10 | photoconductivity | 7A10.36 | A photocell is passed through the spectrum while resistance is measured. |
| Mei, 38-2.2 | photoelectric charging of a capacitor | 7A10.37 | A double pole, double throw switch connects a vacuum phototube to a capacitor, then a galvanometer while different lamps shine on the phototube. |
| Sut, A-91 | alkali metal photocell | 7A10.38 | A simple circuit for showing photoelectric current. |
| PIRA 1000 | solar cells | 7A10.40 | |
| Sut, A-96 | barrier-layer cells | 7A10.40 | Measure the current from a cell of the type used in foot candle meters. |
| Hil, E-3f | Sun batteries | 7A10.40 | This must be a photocell connected to an ammeter. |
| Disc 24-21 | solar cells | 7A10.40 | Shine a bright light on selenium solar cells and run a small motor. |
| Hil, A-4c | ring a bell | 7A10.41 | Shine a light on a photoelectric cell to ring a bell. |
| Hil, A-4d | photo-voltaic switch | 7A10.42 | Turn on a light using a light beam and photo-voltaic cell. |
| Hil, A-4e | photo detector | 7A10.43 | Modulate a light and use a photo detector and amplifier with a speaker. |
| PIRA 1000 | photo conduction vs. thermopile | 7A10.50 | |
| Mei, 40-1.8 | photoconduction vs. thermopile | 7A10.50 | A CdS photocell and thermopile are moved across a projected spectrum and the outputs compared for frequency response. |
| PIRA 1000 | carrier recombination and lifetime | 7A10.60 | |
| Mei, 40-1.11 | carrier recombination and lifetime | 7A10.65 | A photoconductor is strobed and the output observed on an oscilloscope. |
| Sut, E-212 | sodium photoelectric cell | 7A10.71 | On making a sodium photoelectric cell. |
| Sut, A-94 | commercial vacuum photocells | 7A10.72 | Discussion of low cost ceasium-on-oxidized-silver photocells. |
| Sut, A-95 | commercial gas-filled photocells | 7A10.73 | The characteristics of argon filled photocells. |
| Sut, E-170 | selenium photoconductor | 7A10.74 | Directions for making a selenium photoconductor. |
| AJP 29(5),xi | making photoconductors | 7A10.76 | Directions for preparing cadmium sulfide surfaces. |
| Sut, A-100 | photochemical reaction | 7A10.99 | A mixture of hydrogen and chlorine is set off by a light flash. |
| | **Millikan Oil Drop** | **7A15.00** | |
| PIRA 1000 | Millikan oil drop | 7A15.10 | |
| Sut, A-76 | oil drop experiment | 7A15.10 | The real oil drop experiment. |
| AJP 73(8), 789 | Millikan oil drop | 7A15.10 | Put a flexcam over the eyepiece of the Millikan oil drop apparatus and do video analysis of the experiment results. |
| Hil, A-2b | Millikan oil drop experiment | 7A15.10 | The small Millikan chamber and telescope. |
| Disc 24-24 | Millikan oil drop | 7A15.10 | The real experiment and an animated sequence explaining the apparatus. |
| AJP, 50 (5), 394 | Millikan oil drop | 7A15.10 | A look at Millikan's 1913 data on oil drops to look for evidence of charge quantization and for fractional residual charge. |
| AJP 29(3),xxvi | Millikan oil drop illuminator | 7A15.11 | A microscope lamp makes an excellent illuminator for the oil drop experiment. |
| AJP 40(3),474 | Millikan oil drop - laser illumination | 7A15.11 | Replace the light in the Welch apparatus with a laser. |
| AJP 40(5),768 | Millikan oil drop - Pasco apparatus evaluation | 7A15.12 | Problems with the Pasco apparatus. |
| AJP 36(12),1169 | Millikan oil drop suggestions | 7A15.12 | Three suggestions for the Pasco apparatus. |
| AJP 34(2),xv | Millikan oil drop charge change | 7A15.13 | Put a quartz lamp between the plates. |
| AJP 33(5),411 | Millikan oil drop charge change | 7A15.13 | The spark from a small tesla coil is used to change the charge on the drops. |
| AJP 36(12),1170 | drop discriminator and ionizer | 7A15.14 | Modification to introduce drops into the apparatus. |
| PIRA 1000 | Millikan oil drop model | 7A15.20 | |
| Mei, 29-2.6 | Millikan oil drop with soap bubble | 7A15.20 | Blow a soap bubble on a sleeve attached to an electrostatic generator. |
| Mei, 29-2.5 | Millikan oil drop model with glass beads | 7A15.21 | Tiny glass balls are levitated in this model of Millikan's experiment. |
| F&A, Eb-15 | model of Millikan oil drop experiment | 7A15.25 | Place a balloon between two large metal plates attached to a Wimshurst. |
| Mei, 29-2.7 | Millikan oil drop large version | 7A15.25 | A small light foam plastic ball is the drop between parallel plates in this scaled up oil drop demonstration. |
| Sut, A-75 | model oil drop experiment | 7A15.25 | Balance a ping pong ball between two charged plates. |
| AJP 33(5),406 | air drop in a field | 7A15.40 | An apparent violation of Earnshaw's theorem when a float moves towards a field minimum. |
| | **Compton Effect** | **7A20.00** | |
| PIRA 500 | Compton effect with a multichannel analyzer | 7A20.10 | |
| UMN, 7A20.10 | Compton effect with a multichannel analyzer | 7A20.10 | Same as AJP 52(2)183. |
| AJP 52(2),183 | simple Compton effect | 7A20.10 | Use a multichannel analyzer to observe the normal Compton edge while the source and detector are isolated. Bring aluminum and lead blocks nearby and observe the backscattered peaks. |
| Mei, 38-3.1 | Compton scattering with turntable | 7A20.15 | A shielded source faces a scatterer with a scintillator rotating around at various angles. Pictures. |

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| Mei, 38-3.2 | X-ray Compton scattering | 7A20.20 | An X-ray beam strikes an aluminum plate at 45 degrees and the beam is scattered into an ionization chamber while a copper plate is inserted into the beam before and after scattering. |
| | **Wave Mechanics** | **7A50.00** | |
| PIRA 500 | optical barrier penetration | 7A50.10 | |
| AJP 54(7),601 | frustrated total internal reflection | 7A50.10 | A review of the history and theory. Pellin-Broca prisms eliminate reflection losses when measurements are taken. |
| AJP 33(5),xviii | frustrated total internal reflection | 7A50.10 | Squeeze two right angle prisms together with a "c" clamp while directing a beam of light at the interface. |
| AJP 43(1),107 | optical barrier penetration | 7A50.10 | A laboratory setup of optical barrier penetration. |
| AJP 76 (3), 224 | frustrated total internal reflection | 7A50.10 | A method to demonstrate frustrated total internal reflection in the visible using the 100 nm thick air film near the center of Newton's rings. |
| AJP 76 (8), 746 | frustrated total internal reflection | 7A50.10 | Frustrated total internal reflection using a laser and a wedge shaped air gap between two glass prisms. |
| Mei, 38-6.7 | barrier penetration | 7A50.10 | Frustrated total internal reflection with light and glass prisms demonstrates barrier penetration. |
| AJP 39(10),1141 | almost total reflection | 7A50.11 | Use a plano-convex lens between the prisms and laser beam illumination. |
| AJP 52(4),377 | frustrated total internal reflection | 7A50.12 | A good note on frustrated total internal reflection and other accompanying physics. |
| Mei, 38-6.8 | tunnel effect | 7A50.15 | Rocksalt prisms with gaps of 5 microns and 15 microns show transmission of IR to a thermopile in one case only. |
| PIRA 500 | microwave barrier penetration | 7A50.20 | |
| AJP 31(10),808 | microwave barrier penetration | 7A50.20 | Two right angle paraffin prisms are used with 3 cm microwaves to demonstrate barrier penetration. |
| AJP 39(1),74 | optical and microwave penetration | 7A50.20 | Two detectors are used in both optical and microwave barrier penetration to quantitatively show the reflected and transmitted beams. |
| Mei, 38-6.6 | frustrated total internal reflection | 7A50.20 | Demonstrate frustrated total internal reflection using microwaves and two right angle paraffin prisms. Pictures, Reference: AJP 31(10),808. |
| Disc 24-22 | microwave barrier penetration | 7A50.20 | Microwaves are totally reflected off a plastic prism until another is touching the first. |
| AJP 33(10),xiii | microwave tunnel effect | 7A50.21 | A waveguide transmission line with three dielectric regions driven at 5 GHz. |
| AJP 34(3),260 | microwave tunnel effect | 7A50.21 | A microwave "potential barrier" of three sections of waveguide - with dielectric, air and again dielectric. |
| PIRA 1000 | circular vibrating soap film | 7A50.30 | |
| Mei, 38-6.3 | circular vibrating soap film | 7A50.30 | Soap films are vibrated at audio frequencies to produce standing waves which are projected on a screen. |
| Mei, 38-6.4 | circular Rubens tube | 7A50.35 | A 4' diameter circular Rubens flame tube demonstrates circular standing waves. Picture. |
| PIRA 200 | vibrating circular wire | 7A50.40 | Excite a circular wire at audio frequencies with an electromagnet driver to produce standing waves. |
| UMN, 7A50.40 | vibrating circular wire | 7A50.40 | |
| AJP 33(10),xiv | vibrating circular wire | 7A50.40 | Eigenfrequences of a 2.2" dia. wire circle are obtained by exciting with a 650 ohm relay coil. |
| Mei, 38-6.5 | vibrating circular wire | 7A50.40 | A circular wire is excited at audio frequencies with an electromagnet driver to produce standing waves. Diagram, Pictures, Reference: AJP 33(10),xiv. |
| PIRA 1000 | complementary rule | 7A50.50 | |
| AJP 51(3),239 | uncertainty principle with E&M | 7A50.50 | Interpret the inverse relation between the pulse length of a signal on the oscilloscope and the spectral-energy density on a spectrum analyzer as a demonstration of the uncertainty principle. |
| AJP 39(3),302 | complementarity rule | 7A50.50 | Circuit for a generator that produces 1,2,4,8, or 16 pulses in a packet. Decrease in bandwidth for longer packets is evident when the Fourier power spectrum is viewed. |
| AJP 34(12),1122 | electric analog circuit | 7A50.52 | A three dimensional electrical network of inductors and capacitors models energy density in three dimensions. |
| AJP 50(11),996 | photon counter - correlator | 7A50.60 | A low cost time correlator-photon counter enables demonstrations of intensity correlation function, photon-bunching, coherence time, and related topics. |
| AJP 41(8),990 | Kronig-Penny model analog computer | 7A50.80 | Diagram for an analog computer to simulate the Kronig-Penny model wave functions. |
| PIRA 1000 | Mermin's Bell theorem boxes | 7A50.90 | |
| AJP 53(12),1143 | Mermin's Bell theorem boxes | 7A50.90 | A logic circuit that makes Mermin's gedanken experiment a feasible and instructive lecture demonstration. |
| AJP 41(3),418 | noncommuting operators | 7A50.90 | Use the Abbe theory of image formation in the microscope to demonstrate noncommutativity. |

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| | **Particle/Wave Duality** | **7A55.00** | |
| PIRA 1000 | wave/particle sound analogy | 7A55.10 | |
| AJP 49(4),299 | wave/particle sound analogy | 7A55.10 | A discussion of Henry's "principle of uncertainty": that it seems fundamentally impossible to exactly determine both the pitch and duration of sounds in space |
| PIRA 1000 | wave/particle model with dice | 7A55.15 | |
| AJP 30(1),69 | wave/particle model with dice | 7A55.15 | Dice numbered 1-2-3-6-7-8 are thrown and the results plotted, building a pattern similar to a single slit over many throws. |
| PIRA 1000 | single photon interference | 7A55.20 | |
| AJP 40(7),1003 | single photon interference | 7A55.20 | The source, slit, and viewing screen rotated first towards the viewer, and then towards a phototube where it is shown that the photons are individual pulses. |
| AJP 59(5),458 | wave/particle transition | 7A55.22 | Film detectors are placed very close and then further away from a double slit to show the transition from particle to wave behavior. For d=1mm, the transition occurs at about .1mm. |
| AJP 44(3),306 | electron interference phenomena | 7A55.30 | Electron interference is shown on a Seimens Elmiskop 101 equipped with a TV image intensifier. As the current density is increased, the flashes form a fringe pattern. |
| | **X-ray and Electron Diffraction** | **7A60.00** | |
| PIRA 200 | electron diffraction | 7A60.10 | Rings or spots are shown with the old Welch electron diffraction tube. |
| UMN, 7B60.10 | electron diffraction | 7A60.10 | Rings or spots are shown with the old Welch electron diffraction tube. |
| Mei, 38-7.5 | electron diffraction | 7A60.10 | The Meiners/Welch electron diffraction tube. Pictures, Diagram, Reference: AJP,30, ,549. |
| Hil, A-13b | electron diffraction | 7A60.10 | The Welch electron diffraction apparatus. |
| Disc 24-23 | electron diffraction | 7A60.10 | Rings are obtained from a commercial tube with a graphite target. |
| AJP 42(1),4 | electron diffraction - multiple slits | 7A60.11 | A method for making 3 micron wide slits. A schematic for the electron diffraction apparatus is given. |
| AJP 30(12),891 | TV tube electron diffraction | 7A60.12 | With the cooperation of a TV tube manufacturer, a gold foil was placed in a black and white TV tube. |
| Mei, 38-7.4 | TV tube electron diffraction | 7A60.12 | Work with a local TV tube rebuilder to make an electron diffraction tube from an old TV |
| PIRA 500 | Miller indices | 7A60.15 | |
| UMN, 7B60.15 | Miller indices | 7A60.15 | |
| AJP 37(3),333 | Miller indices | 7A60.15 | A solid model of the cuprite crystal habit with the various Miller indices labels on the faces. |
| PIRA 1000 | diffraction model | 7A60.20 | |
| Sut, A-109 | X-ray and electron diffraction model | 7A60.20 | Generate a ring pattern by rotating fine mesh wire gauze in a point source of light. |
| Mei, 38-7.1 | model Laue diffraction pattern | 7A60.21 | Direct a beam of light off a wood cylinder with radial glass vanes to a screen. |
| D&R, O-515 | model Laue diffraction pattern | 7A60.21 | Direct a laser beam through two mounted meshs in series. Observe pattern of diffraction by two planes of mesh, analogous to Laue pattern in X-rays resulting from diffraction by two planes of atoms. |
| Mei, 38-7.2 | model Laue diffraction pattern | 7A60.22 | Reflect a beam of light off a single polished rod onto a screen to illustrate Laue diffraction. |
| AJP 29(6),341 | optical analog of X-ray diffraction | 7A60.24 | Compare Fraunhofer diffraction patterns from masks containing repeating arrays of holes with X-ray diagrams. |
| D&R, S-225 | optical analog of X-ray diffraction | 7A60.24 | View a 15 - 25 W lamp from several meters through a silk scarf, handkerchief, or panty hose. Optical diffraction pattern is similar to that of X-rays diffracted from fine powder. |
| AJP 31(10),807 | spherical projection model | 7A60.26 | Colored dots on the surface of a Lucite sphere represent the projection of the spots as if a single crystal was irradiated at the center of a spherical film. |
| AJP 47(3),289 | blocking patterns in crystal lattices | 7A60.27 | Take a model of a crystal, replace an atom with a point source such as a flashlight battery, project the shadow pattern on a screen. |
| Mei, 38-7.6 | bent crystal spectrometer model | 7A60.28 | A model of the Caushois bent crystal spectrometer using a beam of light and a stack of microscope slides. |
| PIRA 1000 | electron "Poisson spot" | 7A60.30 | |
| AJP 58(12),1143 | electron "Poisson spot" | 7A60.30 | Fresnel zones and the "Poisson spot" with electrons using an electron microscope with a good deal of historical development. |
| PIRA 1000 | field emmission electron microscope | 7A60.40 | |
| UMN, 7A60.40 | field emission electron microscope | 7A60.40 | Use a simplified high voltage generator with the Leybold field emission electron microscope. |
| Mei, 38-7.7 | simple field emission electron microscope | 7A60.45 | A coin used as an electrode in a highly evacuated tube forms an image on a fluorescent screen when voltage is high enough. |

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| PIRA 500 | microwave Bragg diffraction | 7A60.50 | |
| UMN, 7B60.50 | microwave Bragg diffraction | 7A60.50 | |
| AJP 28(5),415 | microwave Bragg diffraction | 7A60.50 | Apparatus Drawings Project No. 6: Three cm microwaves and a ball bearing array demonstrate crystal diffraction. Klystron source. |
| F&A, Ol-14 | microwave Bragg diffraction model | 7A60.50 | Microwave diffraction is observed from a crystal model made of steel bearings mounted in a styrofoam cube. |
| Mei, 33-7.15 | microwave Bragg diffraction | 7A60.50 | Lattices of steel ball bearings embedded in styrofoam form crystal models for microwave diffraction. |
| AJP 77 (10), 942 | microwave Bragg diffraction - rotating crystal | 7A60.50 | Description of a rotating crystal microwave Bragg diffraction apparatus that can be easily constructed. |
| AJP 72(2), 154 | microwave crystal diffraction models | 7A60.51 | Use rods to make the model crystal lattice.  Use a computer interface to measure the difracted intensities. |
| AJP 37(3),333 | improved Welch-Bragg mount | 7A60.51 | A parallelogram device that sweeps both arms through equal angles and has a direct reading of the sine of the angle. |
| AJP 36(9),920 | microwave crystal diffraction models | 7A60.51 | Use 1/2" brads in place of ball bearings to make the analog of polarized particles. |
| AJP 36(6),559 | microwave crystal diffraction models | 7A60.51 | Make models of crystals for microwave diffraction by inserting a No. 7 lead shot in styrofoam balls and then making models of the crystal structures. |
| PIRA 1000 | ripple tank Bragg diffraction | 7A60.60 | |
| Mei, 18-6.4 | ripple tank Bragg diffraction | 7A60.60 | Floating arrays of pith balls model atoms for ripple tank Bragg diffraction. Also ripple tank construction techniques. Diagrams. |
| Mei, 18-6.6 | ripple tank Bragg reflection | 7A60.61 | An array of rods is used to demonstrate Bragg reflection. Picture. |
| PIRA 1000 | X-ray diffraction | 7A60.90 | |
| Sut, A-108 | X-ray diffraction | 7A60.90 | Use a beam, rock salt, and X-ray photographic paper to show diffraction. |
| AJP, 50 (1), 89 | X-ray diffraction | 7A60.90 | Crystalline powder diffraction patterns with the Tel-X-Ometer 80 apparatus. |
| Mei, 38-7.3 | X-ray diffraction | 7A60.91 | X-ray diffraction of a rock salt crystal mounted on a goniometer with GM tube detector. |
| AJP 30(12),864 | X-ray diffraction model | 7A60.92 | If you need to demonstrate the reciprocal lattice concept in relation to single-crystal X-ray diffraction patterns, this is for you. |
| PIRA 1000 | sample X-ray tube | 7A60.95 | |
| UMN, 7A60.95 | sample X-ray tube | 7A60.95 | Show a large X-ray tube. |
| | **Condensed Matter** | **7A70.00** | |
| PIRA 1000 | Josephson junction analog | 7A70.10 | |
| AJP 49(7),701 | Josephson junction analog | 7A70.10 | Abstract from the 1981 apparatus competition describing an electronic circuit for demonstrating Josephson junction behavior. |
| AJP 39(12),1504 | Josephson junction analog | 7A70.10 | A Pendulum analog of a small-area Josephson junction between two superconductors is coupled to the analogs of other circuit elements to demonstrate a variety of time dependent phenomena observed in actual devices. |
| PIRA 1000 | Josephson effect simple demo | 7A70.20 | |
| AJP 53(5),445 | Josephson effect simple demo | 7A70.20 | Niobium wire is twisted together, varnished and built into a simple stainless tube that can be inserted into a helium dewar. I-V curves are observed on an oscilloscope. |
| AJP 40(6),897 | flux quantization in superconductors | 7A70.20 | A indium film with lots of holes is used with a standard magnetometer. |
| PIRA 1000 | F- center diffusion | 7A70.30 | |
| AJP 35(11),1023 | F- center diffusion | 7A70.30 | Place a small KCl crystal in a tube furnace and project the intense blue color that is injected and diffuses through the crystal when 300 V is applied. |
| | **ATOMIC PHYSICS** | **7B00.00** | |
| | **Spectra** | **7B10.00** | |
| PIRA 200 | line spectra and student gratings | 7B10.10 | Have students view line sources through replica gratings. |
| PIRA 1000 - Old | student gratings and line sources | 7B10.10 | |
| UMN, 7C10.10 | line and continuous spectra with gratings | 7B10.10 | Students look at a carousel of line spectra lamps and a line filament with replica gratings. |
| Sut, L-102 | line spectra and student gratings | 7B10.10 | Replica gratings are passed out, sources can be connected in series with an induction coil. |
| Hil, O-9b | emission spectra | 7B10.10 | Line spectra are viewed through 13,400 lines/inch gratings. |
| D&R, O-510, O-520, & S-220 | emission spectra and holographic grating | 7B10.10 | Observe the emission spectra from different spectral tubes through a holographic grating.  Osram lamps can also be used. |
| AJP 77 (10), 920 | helium spectrum analysis | 7B10.10 | A spreadsheet that introduces students to the analysis of helium atomic spectrum data. |
| Bil&Mai, p 362 | line and continuous spectra with gratings | 7B10.10 | Students look at line sources and a line filament with replica gratings or grating glasses. |

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| Disc 25-01 | emission spectra | 7B10.10 | Four spectral tubes and white light through a grating. |
| PIRA 1000 | flame salts | 7B11.11 | |
| AJP 29(12),857 | discharges in gases | 7B10.11 | Rub various tubes with plastic foil to see spectacular discharges produced by the static electricity. |
| Sut, L-104 | bright line spectrum | 7B10.11 | Sources for bright line spectra: high melting point metals are used as electrodes in an arc lamp, the salts of low melting point metals are burned in a flame, gases are heated in discharge tubes. |
| Disc 25-07 | flame salts | 7B11.11 | The colors of different flame salts are observed. |
| Sut, L-105 | band emission spectra | 7B10.12 | Nitrogen, cyanogen, water vapor, and hydrogen show molecular band spectra. |
| PIRA 1000 | line spectra and large grating | 7B10.15 | |
| Mei, 39-1.1 | line spectra tubes and large grating | 7B10.15 | A box with five Pluecker line spectra tubes are mounted in a box with a replica grating front. |
| Hil, O-9c | prism spectrometer | 7B10.17 | Students can view emission spectra individually with a spectrometer. |
| PIRA 1000 | project spectral lines | 7B10.20 | |
| UMN, 7B10.20 | project spectral lines | 7B10.20 | Project high intensity Na and Hg lamps through 300 or 600 lines/mm gratings. |
| UMN, 7B10.25 | spectral chart | 7B10.25 | Add abstract in Handbook.FM |
| Sut, A-8 | salt electrode arcs | 7B10.30 | Pinhole project a carbon arc onto a screen, pack an electrode with a salt, project a spectrum through a prism. |
| Sut, A-69 | emmision spectra - Balmer series | 7B10.40 | Measure the deviations of the Balmer series of a projected spectrum of hydrogen. |
| AJP 28(1),35 | Balmer series spectrum tube | 7B10.42 | Apparatus Drawing Project No. 1: report on constructing and filling a reliable Balmer series tube with a useful life of greater than 1500 hours. |
| Sut, A-110 | X-ray line spectra model | 7B10.50 | Pour lead shot into a pan. |
| AJP 58(9),893 | Raman effect - simple apparatus | 7B10.60 | A simple double cell apparatus that can be inserted into a 200 mW argon laser for direct observation of the virtual image of the spectra of the scattered light. |
| AJP, 78 (7), 671 | Raman effect - simple apparatus | 7B10.60 | A high performance Raman spectrometer made with simple optical components. |
| | **Absorption** | **7B11.00** | |
| PIRA 500 | sodium absorption/emission | 7B11.10 | |
| UMN, 7C11.10 | sodium absorption/emission | 7B11.10 | A TV camera shows the Na doublet from a spectrometer in both emission and absorption. |
| F&A, Oo-4 | sodium absorption/emission | 7B11.10 | A grating spectrometer that resolves the sodium d lines is used to show emission by a salt flame and absorption of white light by the flame. |
| AJP 35(11),1032 | Monochromator | 7B11.11 | Design of a simple monochromator with folded optics that will resolve 1 angstrom lines. |
| Sut, L-107 | sodium absorption/emission | 7B11.12 | Illuminate half a slit with a sodium flame, half with sunlight from a heliostat. Compare emission and absorption lines. |
| Mei, 39-1.9 | sodium absorption/emission | 7B11.13 | A projection system is aligned so both emission and absorption lines of sodium are visible from an arc with one electrode drilled and filled with anhydrous sodium carbonate. |
| F&A, Oo-3 | dark line sodium spectra | 7B11.15 | White light is passed through a concrete block containing a second arc that vaporizes sodium and the spectrum produced shows the sodium d line. |
| Mei, 39-1.4 | sodium absorption lines | 7B11.15 | White light is passed through sodium flames before being dispersed by a prism. |
| AJP 31(12),945 | sodium flame | 7B11.16 | Place a Pyrex test tube at 45 degrees with the bottom in the hottest part of the flame. |
| Sut, L-108 | sodium absorption lines | 7B11.16 | Three methods of burning sodium in an arc and generating enough sodium vapor to show a strong absorption line. |
| Sut, L-103 | imitation line spectra | 7B11.19 | While projecting a slide of the continuous spectrum, insert another plate with lines drawn on representing the absorption spectrum of a gas. |
| PIRA 500 | spectral absorption by sodium vapor | 7B11.20 | |
| AJP 30(9),654 | sodium absorption cloud | 7B11.20 | A cloud of black smoke seems to form when vapor from flame heated salt is illuminated with a sodium lamp. |
| AJP 36(3),ix | two lamp flame absorption | 7B11.23 | Use two lamps (He and Na) with a single condenser and target to provide a reference with the sodium flame absorption. |
| Sut, A-70 | sodium absorption spectra | 7B11.24 | Several methods for producing sodium vapor and passing white light through. |
| PIRA 1000 | flame absorption projected | 7B11.25 | |
| Mei, 39-1.7 | flame absorption projected | 7B11.25 | The light from an arc lamp is focused on a Bunsen burner flame on the way to being projected on the screen. |

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| Disc 25-02 | spectral absorption by sodium vapor | 7B11.25 | Sodium flame looks dark when illuminated with sodium light. |
| PIRA 1000 | mercury vapor shadow | 7B11.30 | |
| F&A, Oo-2 | mercury vapor shadow | 7B11.30 | Mercury vapor illuminated with a mercury lamp casts a shadow on a Willemite screen. |
| Mei, 39-1.5 | mercury vapor shadow | 7B11.30 | A UV lamp shines on a zinc sulfide screen while mercury vapors waft from a heated watchglass. |
| PIRA 1000 | filtered spectrum | 7B11.40 | |
| Sut, L-90 | filtered spectrum | 7B11.40 | Part of a beam of white light is projected through a prism. When a filter is inserted in the beam, the spectrum and transmitted light are compared. |
| D&R, O-740 | filtered spectrum | 7B11.40 | Filters inserted between light source and grating of a projected spectrum will show narrow or wide absorption bands depending on the filter. |
| Hil, O-6c | filtergraph | 7B11.45 | A slide with four filters and the corresponding spectrographic diagrams. |
| Hil, O-9d | plotting absorption | 7B11.47 | A motor drive is connected to a grating and the output of a lead sulfide detector is plotted on a strip chart recorder as the spectrum is scanned with various filters and intensities. Reference: AJP 35(6),542-3. |
| Sut, L-115 | photocell measurement of absorption | 7B11.47 | Use suitable sources, cells, and filters to measure absorption of substances with a photocell. |
| PIRA 1000 | band absorption spectra | 7B11.60 | |
| UMN, 7B11.60 | Glo-Doodler absorption | 7B11.60 | Use the front sheet of a Glo-Doodler etching toy to show a strong absorption band. |
| TPT 29(7),454 | didymium glass | 7B11.65 | Didymium glass, a mixture of praseodymium and neodymium and used by glass blowers, will produce 5 broad absorption bands. |
| AJP, 65(4), 352- 4 | absorption spectra of rare earths | 7B11.65 | The absorption spectra of rare earths is easily observed in the classroom in this experiment. Praesidymium, Neodymium, and Holmium oxides can be used in solution and displayed to the classroom. An excellent Astronomy class demonstration. |
| Sut, L-109 | band absorption spectrum | 7B11.70 | A flask of nitrous oxide is placed in the beam of white light before dispersion by a prism spectroscope. Didymium glass and dilute blood are also suggested. |
| D&R, O-285 | band absorption spectrum | 7B11.72 | Antifreeze ( ethylene glycol ) in a beaker will produce an absorption band when placed in the beam of white light before dispersion by a holographic grating. |
| Sut, L-110 | absorption spectrum of chlorophyll | 7B11.75 | Show the absorption spectrum of chlorophyll obtained by macerating leaves in methyl alcohol. Red and Green transmit. |
| Mei, 39-1.6 | water absorption bands | 7B11.77 | A monochrometer (38-5.11) is used to demonstrate water absorption bands. |
| Mei, 35-4.3 | liquid cell absorption | 7B11.80 | An absorbing solution is placed in a liquid cell placed in a beam of light before dispersion. |
| Hil, O-9a | spectra and liquid absorption | 7B11.80 | Absorption cells filled with liquids are used with a 35 mm projector and the B & L spectra projection kit. |
| TPT 29(7), 454 | "Vanish" absorption | 7B11.85 | Shine a He-Ne laser and a solid state laser emitting at 670 nm through a solution of Vanish. The He-Ne laser light will be completely absorbed while the solid state laser light will pass through. |
| TPT 44(9), 618 | "Vanish" absorption | 7B11.85 | Shine a He-Ne laser and a solid state laser emitting at 670 nm through a solution of Vanish. The He-Ne laser light will be completely absorbed while the solid state laser light will pass through. |
| | **Resonance Radiation** | **7B13.00** | |
| PIRA 1000 | triboluminescence | 7B13.05 | |
| Disc 25-09 | triboluminescence | 7B13.05 | Crush wintergreen lifesavers and they give off faint flashes of light. |
| PIRA 500 | iodine resonance radiation | 7B13.10 | |
| UMN, 7B13.10 | iodine resonance radiation | 7B13.10 | Same as Oo-1. |
| F&A, Oo-1 | iodine resonance radiation | 7B13.10 | Direct a white light beam through an evacuated flask containing iodine crystals. |
| Mei, 39-4.1 | iodine resonance radiation | 7B13.10 | Focus a carbon arc on a large evacuated Florence flask containing iodine crystals. |
| Sut, A-68 | iodine resonance radiation | 7B13.10 | Pass a cone of white light through an evacuated flask containing heated iodine crystals. |
| Mei, 39-4.2 | potassium resonance radiation | 7B13.15 | Heat a pellet of potassium placed in an evacuated flask while passing white light through the flask |
| PIRA 1000 | sodium vapor beam | 7B13.20 | |
| Mei, 39-4.4 | sodium vapor beam | 7B13.20 | A sodium furnace in an evacuated bell jar produces a sodium vapor beam that forms a "pencil" of resonance reradiation when illuminated with sodium light. |
| Mei, 39-4.3 | resonance radiation - sodium vapor | 7B13.20 | A sodium vapor bulb is prepared and heated in a furnace while sodium and mercury light is passed through. |

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| Mei, 39-1.8 | Hanle effect | 7B13.25 | Measure the resonance polarization of mercury light from a quartz resonance cell of mercury vapor. Diagrams, References. |
| PIRA 1000 | UV spectrum by fluorescence | 7B13.40 | |
| Sut, L-111 | UV spectrum by fluorescence | 7B13.40 | A screen painted with quinine sulfate fluoresces in the UV. Use Quartz optics. |
| Mei, 39-1.2 | projected mercury spectum | 7B13.42 | The weak lines of the projected mercury spectrum are made visible by painting half of a card with fluorescent paint. |
| D&R, S-180 | projected mercury spectrum | 7B13.42 | The weak lines of the projected mercury spectrum are made visible using a fluorescent card. Intensity may be increased by carefully removing the glass envelope of the bulb. |
| Mei, 39-1.3 | ultraviolet lines photographed | 7B13.44 | Ultraviolet lines from a carbon arc or mercury lamp are projected onto ultraviolet sensitive photographic paper. |
| TPT 19(7), 483 | ultraviolet lines | 7B13.44 | Use cloth or stationary treated with laundry detergents or dyes that fluoresce and show the ultraviolet lines of a mercury light source. |
| TPT 19(9), 618 | ultraviolet lines | 7B13.44 | Show the far ultraviolet lines of a quartz enclosed mercury light source using a homemade flexible plastic aluminized reflections grating. |
| PIRA 500 | fluorescence and phosphorescence | 7B13.50 | |
| F&A, Ok-2 | black light | 7B13.50 | Use a black lamp to illuminate fluorescent materials. |
| D&R, O-760 | fluorescence | 7B13.50 | Detergent boxes with fluorescent ink, fluorescent chalk, and antifreeze in black light. |
| Sprott, 6.8 | fluorescence | 7B13.50 | Materials illuminated with ultraviolet light re-emit visible light. |
| Disc 25-11 | flourescence | 7B13.50 | A collection of fluorescent materials in black light. |
| Sut, L-114 | fluorescence and phosphorescence | 7B13.51 | Show many substances that fluoresce and phosphoresce in UV light. |
| Hil, O-11a | fluorescence and phosphorescence | 7B13.52 | Dyes, cloth, paint, etc. and an interesting retardation demonstration with a vibrating meter stick and a thin transparent film over one eye. |
| Bil&Mai, p 358 | fluorescence and phosphorescence | 7B13.53 | Use UV sensitive craft beads and glow in the dark plastic string with a UV light. The craft beads undergo a UV induced color change but are not fluorescent. |
| TPT 48(3), 186 | quantum dots | 7B13.54 | An inquiry on the 4 different colors emitted by vials of the same materials. When illuminated with a black light the color of the emitted light depends on the size of the quantum dots. |
| PIRA 1000 | luminescence | 7B13.55 | |
| Disc 25-10 | luminescence | 7B13.55 | A glow-in-the-dark sword exposed to black light. The covered portion does not glow as brightly. |
| Sut, A-105 | fluorescence by X-rays | 7B13.58 | An X-ray tube in a box in a dark room is used to show fluorescence in many materials. |
| Mei, 39-4.5 | phosphorescence | 7B13.60 | Recipes are given for compounds with different luminescence. Several demonstrations are discussed. |
| AJP 29(3),xxv | phosphorescence decay | 7B13.63 | Illuminate a P7 tube face with UV light, then mask half and expose the other half to red light. The masked side will remain luminous. |
| | **Fine Splitting** | **7B20.00** | |
| PIRA 500 | Zeeman splitting with mercury | 7B20.10 | |
| F&A, MPc-1 | Zeeman splitting with mercury | 7B20.10 | A mercury lamp between the poles of a large electromagnet is focused on a Fabry-Perot interferometer. |
| AJP 41(3),423 | Zeeman splitting - three tubes | 7B20.11 | Sodium, mercury, and neon tubes used in Zeeman splitting. |
| AJP 39(11),1387 | Zeeman effect - sources | 7B20.11 | Sodium, mercury, and neon tubes for the Zeeman effect. |
| AJP 41(2),287 | Zeeman effect - source | 7B20.11 | Use the violet 4046 line from the Cenco 79661 mercury tube. |
| Mei, 39-2.3 | Zeeman effect - mercury vapor | 7B20.14 | The light from a mercury lamp is focused on an air stream containing mercury vapor between the poles of an electromagnet. |
| PIRA 1000 | Zeeman effect - sodium flame | 7B20.15 | |
| Mei, 39-2.2 | Zeeman effect - sodium flame | 7B20.15 | Focus sodium light on a bead of borax heated between the poles of an electromagnet. |
| Mei, 39-2.1 | Zeeman effect - sodium flame | 7B20.15 | Sodium light focused on a sodium flame between the poles of an electromagnet will absorb until the field is turned on. |
| PIRA 500 | Stern-Gerlach experiment | 7B20.20 | |
| AJP, 50 (8), 697 | Stern-Gerlach experiment | 7B20.20 | The paradox in the classical treatment of the Stern-Gerlach experiment can be resolved if the torque on the magnetic moment is taken into account. |
| PIRA 1000 | Stern-Gerlach crystal model | 7B20.25 | |
| UMN, 7B20.25 | Stern-Gerlach crystal model | 7B20.25 | |
| PIRA 500 | ESR - low field | 7B20.30 | |
| AJP 37(2),222 | ESR - simple low field | 7B20.30 | A circuit for showing ESR in DPPH as a lecture demonstration. |
| AJP 30(12),927 | ESR apparatus | 7B20.31 | Simple ESR apparatus. |
| AJP 35(3),xxi | ESR coil | 7B20.32 | A small helix plugs into a waveguide to coax transition. |

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| AJP 33(4),xxvi | ESR mechanical analog | 7B20.33 | The shaft of a gyro is made from a permanent Alnico magnet, the Earth's field represents the DC field in the ESR experiment, two Helmholtz coils are used to model the microwave radiation. |
| AJP 35(7),iii | ESR references | 7B20.34 | References for anyone planning to apply the AJP 35(3) note. |
| PIRA 500 | Mossbauer experiment | 7B20.40 | |
| PIRA 1000 | Mossbauer model | 7B20.45 | |
| AJP 40(9),1336 | Mossbauer effect - air track analog | 7B20.45 | Burn a string constraining spring loaded air carts. Vary the mass of the "nucleus" cart. |
| Mei, 41-2.7 | Mossbauer effect model | 7B20.45 | A suspended gun firing steel balls serves as a gamma ray emitting nucleus in a Mossbauer effect model. Picture, Diagrams, Construction details in appendix, p. 1373. |
| | **Ionization Potential** | **7B30.00** | |
| PIRA 1000 | ionization potential of mercury | 7B30.10 | |
| Sut, A8144A-67 | ionization potential of mercury | 7B30.10 | Measure the ionization potential of mercury vapor in a FG-57 tube at different temperatures. |
| Hil, A-6b | ionization potential | 7B30.11 | Looks like some older commercial apparatus to show the ionization potentials of mercury and xenon. |
| AJP 33(5),xvii | ionization potential of xenon | 7B30.12 | Use the Frank-Hertz principle to show the ionization potential of xenon in a 2D21 Thyratron. |
| AJP 34(4),366 | comparrison of apparatus | 7B30.13 | The Klinger and Leybold apparatus are compared. |
| PIRA 500 | Frank-Hertz experiment | 7B30.20 | |
| Mei, 39-3.1 | Frank-Hertz experiment | 7B30.20 | A qualitative lecture demonstration on the oscilloscope. |
| Disc 25-12 | Frank-Hertz experiment | 7B30.20 | The curve generated by a commercial tube is shown on an oscilloscope. |
| TPT 2(6),282 | Frank-Hertz modification | 7B30.21 | The collector is made very negative to both the grid and cathode. When the accelerating potential is increased, the collector current appears in the opposite sense. |
| AJP 35(6),541 | homemade Frank-Hertz tube | 7B30.22 | Replace the commercial cathode and filament assembly with a piece of 7 mil tungsten wire. |
| AJP 33(10),849 | homemade Frank-Hertz tube | 7B30.22 | Directions for making a solder glass tube. |
| Mei, 39-3.2 | Frank-Hertz experiment | 7B30.23 | An argon filled CTIC thyatron is mounted on a board. The circuit is drawn on the board. |
| AJP 43(2),190 | Frank-Hertz automated on an X-Y recorder | 7B30.24 | Connect the constant current source to the X and the electrometer output to the Y of an X-Y recorder. |
| AJP 74(5), 423 | what really happens? | 7B30.26 | A new look at the Frank-Hertz experiment reveals some surprising data. The results contradict the usual assumption that the spacings between successive minima or maxima are equal. |
| AJP 56(8),696 | what really happens? | 7B30.26 | Gives the standard textbook explanation and then goes beyond. |
| PIRA 1000 | excited states model | 7B30.40 | |
| AJP 36(1),49 | air track model ?????? | 7B30.40 | A small air track is caught by a large one. Models a collision between an "electron" and an "atom" capable of being raised to an excited state. |
| AJP 37(5),562 | collisions and excited states model | 7B30.40 | Expansion on AJP 36(1),49. Slight modification to model inelastic collisions of the second kind. |
| | **Electron Properties** | **7B35.00** | |
| PIRA 1000 | discharge at low pressure | 7B35.10 | |
| TPT 2(4),178 | discharge at low pressure | 7B35.10 | Lower the pressure with a cooling bath while running the discharge tube with a spark coil. |
| F&A, Ep-7 | Crookes tube | 7B35.10 | Evacuate a glass tube while a high voltage is applied to electrodes at the ends of the tube. |
| Disc 25-05 | discharge tube and vacuum pump | 7B35.10 | Pump down a long tube while applying a high voltage across the ends. |
| D&R, S-150 | discharge at low pressure | 7B35.10 | The pressure is reduced in a long tube while high voltage from an induction coil is applied to the electrodes. |
| Mei, 30-4.1 | Paschen's law of gas discharge | 7B35.20 | Pump down a double tube assembly with electrodes at different distances with a constant voltage on each set of electrodes. |
| PIRA 1000 | Maltese cross | 7B35.40 | |
| F&A, Ep-10 | Maltese cross | 7B35.40 | An electron beam produces a shadow of a Maltese cross on a fluorescent screen |
| Disc 25-04 | Maltese cross | 7B35.40 | Show the shadow of a Maltese cross in an electron discharge tube. |
| PIRA 1000 | paddle wheel | 7B35.50 | |
| F&A, Ep-9 | paddle wheel | 7B35.50 | The Phil Johnson humor continues with: "I don't have a category for this". The description is: The commercial Crookes' tube with a paddle wheel. The electron beam transfers its momentum to the paddle wheel and turns it to make it roll on the rails. |
| Disc 17-17 | paddle wheel | 7B35.50 | The commercial Crookes' tube with a paddle wheel. |
| Mei, 30-4.2 | hot and cold cathode discharge | 7B35.70 | Electrodes that can be water cooled are used to strike arcs cooled and uncooled. |

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| Mei, 30-1.5 | arc characteristics | 7B35.71 | An arc struck between a carbon rod and an aluminum plate will go out if the polarity is reversed. |
| PIRA 1000 | plasma tube | 7B35.75 | |
| Sprott, 4.8 | plasma tubes or globes | 7B35.75 | Commercial plasma tubes and globes are discussed. |
| Disc 25-06 | plasma tube | 7B35.75 | Bring the hand near a commercial plasma tube. |
| | **Atomic Models** | **7B50.00** | |
| AJP 49(3),217 | history of the atom - symposium | 7B50.01 | Kinetic atom. |
| AJP 49(3),211 | history of the atom - symposium | 7B50.01 | Atomism from Newton to Dalton. |
| AJP 49(3),223 | history of the atom - symposium | 7B50.01 | Rutherford-Bohr atom. |
| AJP 49(3),206 | history of the atom - symposium | 7B50.01 | Greek atomic theory. |
| AJP 49(3),205 | history of the atom | 7B50.01 | An introduction to a series of four papers presented in a symposium "History of the Atom". |
| PIRA 500 | electron orbital models | 7B50.10 | |
| UMN, 7B50.20 | electron orbital models | 7B50.10 | A set of Klinger electron orbital models. |
| D&R, S-105 | electron orbital models | 7B50.10 | Several models showing integer number of wavelengths as when orbital electrons form standing waves in the hydrogen atom. |
| Hil, A-5b | Bohr model | 7B50.11 | A motorized model with fluorescent electrons and nucleus to be viewed in the dark. |
| AJP 28(7),676 | wave function model | 7B50.15 | Draw dots on glass plates and stack them for a 3-d model of the probability of the electron shell. Example given for hydrogen 3d state. |
| Sut, A-66 | electron shell model | 7B50.16 | Golf tees are inserted into predrilled holes in a plywood sheet to represent electrons in the various shells. |
| Sut, A-62 | equilibrium configurations | 7B50.20 | Steel balls floating in a dish of mercury over an electromagnet assume equilibrium configurations. A dynamic setup is also described. |
| PIRA 500 | periodic charts | 7B50.50 | |
| Hil, A-1a | periodic charts | 7B50.50 | Welch and Cenco periodic charts are displayed on the wall. |
| AJP 33(11),xvii | atomic beam apparatus | 7B50.90 | Determine the diameter of atoms by directing a very low pressure stream at a vane in an evacuated bell jar. |
| | **NUCLEAR PHYSICS** | **7D00.00** | |
| | **Radioactivity** | **7D10.00** | |
| TPT 3(4),158 | radiation saftey | 7D10.09 | Introduction to the handbook "Radiation Protection in Teaching Institutions" with brief presentation of urgently needed information. |
| PIRA 200 | Geiger counter & samples | 7D10.10 | Listen to a Geiger counter when radioactive samples are tested. |
| UMN, 7D10.10 | Geiger counter & samples | 7D10.10 | |
| Bil&Mai, p 366 | Geiger counter & samples | 7D10.10 | Listen to a Geiger counter when radioactive samples are tested. Use index cards, aluminum plates and lead to determine the type of radiation emitted by the samples. |
| Sut, A-111 | sources of radioactivity | 7D10.11 | Obtain radioactive ore or old radon seeds. |
| Hil, A-18d | radioactive plate | 7D10.12 | A red "fiesta" plate is checked for radioactivity. |
| PIRA 1000 | half life with isotope generator | 7D10.20 | |
| AJP 39(2),221 | half life with isotope generator | 7D10.20 | Three isotope generators that can be "milked". |
| Disc 25-16 | half life | 7D10.20 | The half life of a barium 137 sample recorded on a computer based analyzer. |
| AJP 39(10),1274 | isotope generator | 7D10.21 | The commercial Cs/Ba generator. |
| AJP 39(10),1282 | isotope generator | 7D10.21 | On the amount of the longer-lived Sn coming through the generator. |
| AJP 39(10),1282 | reply to comment | 7D10.21 | You idiots. |
| PIRA 1000 | radon in the air | 7D10.25 | |
| Mei, 41-1.6 | radon, thoron in the air | 7D10.25 | Pump air through a filter and measure the decay to get two half lives of 32 min and 10 hr. |
| Hil, A-15d | radon in the air | 7D10.25 | Pump air through a filter and place the filter under a counter attached to a strip chart recorder. Reference: AJP 28(11), 743. |
| D&R, S-252 | radon in the air | 7D10.25 | Electrostatically charge an inflated balloon and allow this to set in the room for an hour. Pop the balloon and measure the counts with a Geiger counter. The balloon should measure about 10 times background. |
| AJP 29(11),789 | emanation electroscope | 7D10.27 | Demonstrate the thorium half life by observing the decay of an emanation electroscope. |
| Hil, A-15e | emanation electroscope | 7D10.27 | The Welch emanation electroscope is used to demonstrate the thorium half life. Reference: AJP 29(11),789. |
| PIRA 1000 | activation by a neutron source | 7D10.30 | |
| Mei, 41-1.1 | activation by a neutron source | 7D10.30 | A coin is placed with a neutron source on a paraffin block for a minute and then tested for radioactivity. |
| AJP 34(3),246 | buildup and decay | 7D10.31 | Aluminum foil on the rim of a wheel rotates between a neutron source and beta detector. |
| Hil, A-15f | half life of silver | 7D10.33 | Measure the half life of silver activated by a neutron source. |
| Hil, A-18c | half life of silver | 7D10.33 | Use a neutron source and silver dollar. |
| AJP 31(9),734 | radioactive iodine source | 7D10.36 | Irradiate the sodium iodide crystal that is in the scintillation spectrometer. |

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| PIRA 500 | secular equilibrium | 7D10.40 | |
| Mei, 41-1.4 | secular and transient equilibrium | 7D10.40 | Water flow models of the half life, the half life of the daughter being much less than the half life of the parent. |
| Sut, A-115 | radioactive decay model | 7D10.40 | Cylindrical vessels placed above each other show a hydraulic model of radioactive decay. |
| D&R, S-250 | radioactive decay model | 7D10.40 | Poker chips are used to simulate radioactive decay. |
| Mei, 41-1.5 | secular equilibruim in series | 7D10.41 | A model of a series of disintegrations with a series of capillary tubes emptying into each other. |
| Mei, 41-1.3 | simultaneous decay model | 7D10.41 | Water from two capillaries starting with water at different heights is collected and the results plotted. |
| Mei, 41-1.2 | water flow model of decay | 7D10.42 | Water drips from a capillary for equal time intervals into a series of test tubes. In another setup, the water drips through wire meshes to a counter. |
| PIRA 1000 | electrical analog of decay | 7D10.45 | |
| AJP 46(2),189 | electrical analog of decay | 7D10.47 | An electrical circuit allows three consecutive first-order rate reactions. |
| AJP 45(3),288 | atomic radiative decay analog | 7D10.47 | The response of an electrical circuit is compared to the decay characteristics of coupled three level atomic systems. |
| AJP 39(11),1408 | analog computer decay model | 7D10.48 | Circuit for an analog computer does a three stage nuclear chain decay. |
| PIRA 1000 | dice on the overhead | 7D10.50 | |
| UMN, 7D10.50 | dice on the overhead | 7D10.50 | |
| AJP 51(2),185 | dice on the overhead | 7D10.50 | Drill a face centered hole through each of twenty dice and roll the bunch on an overhead projector, removing the ones that light shows through. |
| Bil&Mai, p 363 | dice on the overhead | 7D10.50 | Drill a face centered hole through each of 48 dice and roll the bunch on an overhead projector, removing the ones that light shows through. |
| PIRA 1000 | coin toss half life | 7D10.55 | Toss some coins into the air and onto a table. Count and keep those that are heads. Collect the tails and toss again. Count and keep the heads, and again toss the tails. Repeat until all are counted. |
| PIRA 500 | range and absorption | 7D10.60 | |
| UMN, 7D10.50 | range and absorption | 7D10.60 | Different barriers are placed between a gamma source and a detector. |
| Disc 25-14 | nuclear shielding | 7D10.60 | Cardboard, aluminum, and lead sheets shield a detector. |
| Hil, A-16a | alpha, beta, and gamma ray absorption | 7D10.61 | A set of absorbers for showing alpha, beta, and gamma absorption. |
| Mei, 41-1.7 | exponential absorption model | 7D10.65 | A series of neutral density filters are added to a light and photocell arrangement to model absorption. |
| Sut, A-113 | range of alpha particles | 7D10.70 | Bring an alpha source near a grid and plate connected to an electroscope. |
| Sut, A-114 | scattering of alpha particles | 7D10.75 | A thin metal foil placed between an alpha source and a detector shows the intensity of scattering dependent on angle. |
| PIRA 1000 | cosmic rays | 7D10.80 | |
| Sut, A-121 | coincidence counters for cosmic rays | 7D10.80 | A circuit with two Geiger-Muler tubes. |
| AJP 69(8), 896 | cosmic rays | 7D10.80 | Measuring and modeling cosmic ray showers with a microcomputer-based laboratory system. |
| Disc 25-17 | cosmic rays | 7D10.80 | Scintillator paddles are placed on each side of a person and simultaneous events indicate cosmic ray muons passing through the body. |
| | **Nuclear Reactions** | **7D20.00** | |
| PIRA 500 | mousetraps | 7D20.10 | |
| UMN, 7D20.10 | mousetraps | 7D20.10 | 56 mousetraps in a cage are each set with two corks. |
| F&A, MPa-1 | mousetrap chain reaction | 7D20.10 | A large number of mousetraps set with two corks each in a large cage. |
| D&R, S-265 | mousetrap chain reaction | 7D20.10 | A large number of mousetraps set with silicone balls in an acrylic enclosure. Trigger with a single "neutron". |
| Disc 25-15 | mousetrap chain reaction | 7D20.10 | Ping pong balls on mousetraps. |
| AJP 48(1),86 | better mousetrap | 7D20.11 | An electronic mousetrap array that can be used as a single event "bomb" or a continuous self-sustaining nuclear reaction. |
| AJP 31(1),62 | mousetrap improvments | 7D20.11 | Attach groups of six mousetraps to a hardwood block. The spacing between the blocks can be varied to produce subcritical, critical, or supercritical assemblies. Place two wood blocks on each trap. |
| Sut, A-65 | nuclear disintegration model | 7D20.12 | A ball rolls down an incline and hits a group of balls in a small potential well. |
| D&R, S-260 | nuclear disintegration model | 7D20.12 | Ball bearings or marbles roll down and inclined aluminum channel and hit a group of balls in a small potential well. |
| PIRA 1000 | match chain reactions | 7D20.15 | |
| UMN, 7D20.15 | match chain reactions | 7D20.15 | |
| AJP 51(2),185 | match chain reaction | 7D20.15 | Matches are spaced differently in two perpendicular rows. Light the match at the junction and the entire row with the smaller spacing ignites. |
| PIRA 1000 | dominoes chain reaction | 7D20.20 | |

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| UMN, 7D20.16 | dominoes chain reaction | 7D20.20 | Knock down a row of dominoes of ever increasing size. |
| AJP 51(2),182 | dominoes chain reaction | 7D20.20 | A whisp of cotton knocks over a small domino starting a chain reaction in which each succeeding domino is 1 1/2 times larger in all dimensions. |
| Mei, 41-2.12 | uranium model | 7D20.30 | A sphere contains internal mechanisms to eject two balls (electrons) after a ball is dropped in (thermal neutron.) Pictures, Construction details in appendix, p. 1378. |
| Mei, 41-2.13 | uranium fission model - U235 | 7D20.31 | A wooden sphere flies apart and ejects two wood balls and an iron sphere when an iron sphere is dropped in. Pictures, Construction details in appendix, p. 1380. |
| AJP 51(2),185 | fission model - liquid drop | 7D20.35 | Probe a motor oil drop in alcohol/water to induce "fission". |
| Mei, 41-2.6 | moderation of fast neutrons | 7D20.40 | The moderation of fast neutrons in paraffin yields both fast and thermal neutrons shown by shielding the boron counter with a Cd sheet and detecting thermal neutrons from a second paraffin block. |
| Mei, 41-2.11 | water model xenon poisoning reactor | 7D20.41 | A water flow model of the behavior of a thermal neutron reactor with xenon poisoning. |
| Mei, 41-2.8 | resonance absorption of gamma rays | 7D20.60 | Model of resonance absorption of gamma rays consists of an electromagnetically driven tuning fork and audio oscillator. |
| AJP 50(7),586 | nuclear explosion effects | 7D20.90 | An introductory level summary of the physics of a nuclear bomb explosion and the effects on humans. |
| | **Particle Detectors** | **7D30.00** | |
| PIRA 1000 | Ludlum Detectors | 7D30.05 | |
| UMN, 7D30.15 | Ludlum Detectors | 7D30.05 | Ludlum hand held alpha, beta, and gamma detectors are used with a variety of sources. |
| Hil, A-18b | survey meters | 7D30.05 | Alpha, beta, and gamma survey meter and slow neutron monitor. |
| AJP 57(11),1051 | Geiger-Muller tube to Apple circuit | 7D30.06 | A simple complete circuit for biasing a Geiger-Muller tube, pulse shaping, and interfacing to an Apple computer. |
| AJP 46(2),191 | Poisson distribution of counts | 7D30.08 | An electronic circuit provides output pulses when the time interval between pulses is of the preset value. Show the difference between inputs from a scintillation detector and Geiger counter. |
| PIRA 1000 | nixie Geiger counter | 7D30.10 | |
| UMN, 7D30.10 | nixie Geiger counter | 7D30.10 | A Geiger tube in a lead brick is used with a nixie tube counter. |
| F&A, MPa-2 | nixie Geiger counter | 7D30.10 | A Geiger tube in a lead block is attached to a nixie tube counter. |
| Sut, A-118 | Geiger-Muller tube | 7D30.11 | Make a simple tube with a wire down the middle at low pressure. Includes circuits for counters. |
| Sut, A-119 | Geiger point counter | 7D30.12 | A Geiger point counter made with an ordinary steel phonograph needle. |
| Sut, A-120 | water jet counter | 7D30.13 | A fine water jet impinging on a rubber diaphragm is controlled by a metal electrode. |
| Mei, 41-3.7 | ionizaton avalanche model | 7D30.14 | Rows of balls held on an inclined plank at intervals by wires form an avalanche starting with one ball as more balls are knocked out in each interval. |
| PIRA 1000 | thermal neutron detector | 7D30.15 | |
| Mei, 41-2.10 | thermal neutron detector | 7D30.15 | A UO2 detector for fission produced thermal neutrons. |
| AJP 34(12),1182 | neutron howitzer | 7D30.16 | A 55 gal drum filled with paraffin. |
| Hil, A-18a | neutron howitzer | 7D30.16 | A 2 curie neutron source is used with a BF3 detector. |
| PIRA 500 | alpha detector | 7D30.20 | |
| UMN, 7D30.20 | alpha detector | 7D30.20 | The Cenco alpha detector with a high voltage bias between a plate and a wire grid. |
| AJP 30(2),140 | Cenco alpha detector review | 7D30.20 | Long review of the Cenco alpha counter originally developed by Harold Waage. |
| Mei, 41-3.8 | alpha detector | 7D30.20 | A grid over a plate is biased just below sparking and an alpha source is brought near. Cenco photo. |
| AJP 53(12),1212 | simple alpha detector | 7D30.21 | Directions on making a simple homemade single wire spark counter. |
| D&R, S-135 | simple alpha detector | 7D30.21 | Simple alpha detector construction using a single wire and plate with 1kv high voltage supply. |
| AJP 51(5),452 | silicon photodiode alpha detector | 7D30.22 | Use a silicon photodiode as a alpha detector. A charge sensitive preamp design is included. |
| PIRA 1000 | spark chamber | 7D30.25 | |
| AJP 35(7),582 | spark chamber | 7D30.25 | Plans for two types of spark chambers: multiplate and "curtain discharge". |
| AJP 31(8),571 | spark chamber | 7D30.25 | Construction details, driver and power supply circuits for a small spark chamber. |
| Mei, 41-3.9 | spark chamber | 7D30.25 | A small spark chamber is shown. Pictures, Construction details in appendix, p.1390, Reference: AJP 31(8),571. |
| AJP 28(2),163 | ionization chamber | 7D30.28 | A simple parallel plate ionization chamber built in an aluminum roasting chamber with a sensitive volume of 75 cubic inches. |

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| Mei, 41-1.8 | magnetic deflection of beta rays | 7D30.30 | A magnet is used to bend electrons from a beta source past a shield to a detector. |
| Mei, 41-1.9 | beta spectrometer | 7D30.31 | A qualitative beta spectrometer for use as a lecture demonstration. Pictures, Diagrams, Construction details in appendix, p. 1370. |
| AJP 28(2),164 | beta spectrometer | 7D30.32 | A small beta spectrometer with a 4" face. |
| Hil, A-15a | film detection | 7D30.40 | Several samples are placed on a large sheet of film overnight and the film is developed the next day showing which are radioactive. |
| TPT 3(3),125 | film detection | 7D30.41 | On using Polaroid land sheet film packets as a detector for radiation experiments and demonstrations. |
| PIRA 500 | Wilson cloud chamber | 7D30.50 | |
| F&A, Hl-12 | Wilson cloud chamber | 7D30.50 | Squeeze the rubber bulb of the Wilson cloud chamber and watch tracks from an alpha source. |
| Sut, A-116 | Wilson cloud chamber | 7D30.50 | The Knipp type chamber with a rubber bulb and alpha source. |
| D&R, S-140 | Wilson cloud chamber | 7D30.50 | Squeeze the rubber bulb of the cloud chamber and watch tracks from an alpha source. |
| Sut, A-117 | Wilson cloud chamber | 7D30.51 | An expansion cloud chamber mounted in a lantern projector. |
| Mei, 41-3.6 | cycling Wilson cloud chamber | 7D30.55 | An automatically cycling Wilson cloud chamber. Pictures, Construction details in appendix, p.1382, Reference: AJP 18(3),149. |
| PIRA 200 | diffusion cloud chamber | 7D30.60 | Dry ice diffusion cloud chambers. |
| UMN, 7D30.60 | diffusion cloud chamber | 7D30.60 | |
| AJP 35(5),ix | cloud chamber accessories | 7D30.60 | Drawings of a lamp housing and chamber housing. |
| AJP 54(5),473 | small cloud chamber | 7D30.60 | A 10x10x10 cm Plexiglas cube cloud chamber suitable for TV projection. |
| TPT 1(2),80 | small cloud chamber | 7D30.60 | A transparent plastic refrigerator jar on a cake of dry ice serves as a small continuous cloud chamber. |
| TPT 3(6),284 | simple diffusion cloud chamber | 7D30.60 | Using cheap parts to make a dry ice cloud chamber. |
| F&A, Hl-13 | diffusion cloud chamber | 7D30.60 | A large chamber supersaturated with alcohol vapor is cooled with an alcohol/dry ice bath at the bottom. |
| Mei, 41-3.5 | diffusion cloud chamber | 7D30.60 | A large alcohol/dry ice cloud chamber is shown. Pictures. |
| Mei, 41-3.2 | simple diffusion cloud chamber | 7D30.60 | Alcohol in a jar placed on dry ice makes a cheap cloud chamber. |
| Hil, A-15b | diffusion cloud chamber | 7D30.60 | Dry ice diffusion cloud chambers. |
| Mei, 41-3.4 | diffusion cloud chamber | 7D30.62 | A fancier dry ice and alcohol cloud chamber. |
| AJP 59(3),285 | LN2 cooled diffusion cloud chamber | 7D30.63 | The design of a LN2 cooled diffusion cloud chamber with increased sensitivity and quick startup. |
| AJP 29(2),99 | cloud chamber - vacuum jacket | 7D30.64 | Design for a vacuum jacket that increases the sensitive area of the chamber. |
| Mei, 41-3.3 | glycol cloud chamber | 7D30.65 | A glycol cloud chamber is heated at the top and cooled with running water at the bottom. |
| AJP 30(8),602 | photographing tracks | 7D30.68 | Black dye (Nigrosin) in methanol provides a dark nonreflective background, other hints. |
| Mei, 41-3.1 | cloud chamber principles | 7D30.69 | Place a spark gap in the steam coming from a teakettle. |
| AJP 35(11),ix | model cyclotron | 7D30.70 | A conical pendulum is accelerated by periodic electrical forces four times per revolution to model the motion of a charged particle in an isochronous cyclotron with four 90 degree Dees. |
| AJP 42(2),106 | model cyclotron | 7D30.70 | A Ball is gravitationally accelerated along a spiral grove in an apparatus designed to demonstrate the principles of acceleration and phase stability in a cyclotron. |
| Mei, 31-1.15 | model cyclotron | 7D30.70 | |
| Mei, 31-1.14 | model cyclotron | 7D30.70 | |
| AJP 43(3),277 | model linear accelerator | 7D30.71 | A ping pong ball is accelerated in a Plexiglas tube when a series of ring electrodes are charged by a Wimshurst |
| AJP 40(5),761 | linear accelerator - sand model | 7D30.71 | A Wimshurst charges a model linear accelerator that shoots sand out one end. |
| Mei, 31-1.16 | particle focusing in accelerator | 7D30.75 | Inverted pendulum model of focusing in a particle accelerator. |
| AJP 43(4),293 | model synchrotron | 7D30.78 | A steel ball bounces on an oscillating piston with concave surface to provide focusing. At constant amplitude, the ball bounces lower when the period is decreased. |
| PIRA 500 | bubble chamber photographs | 7D30.80 | |
| AJP 35(6),x | bubble chamber photographs | 7D30.80 | Welch. Two slide sets taken at the 20" in chamber at the Brookhaven National Laboratory. |
| AJP 34(10),1005 | bubble chamber photographs | 7D30.80 | Pictures and analysis of bubble chamber pictures. |
| Mei, 41-2.9 | bubble chamber photographs | 7D30.80 | Determination of the rest mass of a hyperon particle from bubble chamber pictures. Pictures. |
| AJP 28(5),418 | mass spectrometer | 7D30.90 | Apparatus Drawings Project No. 7: A mass spectrometer for undergraduate lab with a resolving power of 75. |

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| AJP 28(4),380 | mass spectrometer | 7D30.90 | Apparatus Drawings Project No. 5: Small Mass Spectrometer. Construction plans for a small radius 180 degree mass spectrometer with a salt coated tungsten filament, 1K gauss, 100V, resolving power 33. |
| D&R, S-190 | mass spectrometer model | 7D30.90 | A model mass spectrometer using a magnet, ruler or aluminum angle, and different size ball bearings. |
| Bil&Mai, p 293 | mass spectrometer model | 7D30.90 | A model mass spectrometer is constructed using a magnet, ruler, and different size ball bearings. |
| Mei, 38-4.1 | pair production and annihilation | 7D30.95 | A pair of scintillation counters face each other across an electron beam interrupted by a card with the appropriate equipment to detect coincidences. |
| | **NMR** | **7D40.00** | |
| PIRA 1000 | NMR - gyroscope model | 7D40.10 | |
| Mei, 41-4.1 | NMR - gyroscope model | 7D40.10 | A modified gyroscope model of NMR. Diagram, References, AJP 29(10),709. |
| Mei, 41-4.2 | NMR - gyroscope model | 7D40.11 | A gyroscope with a permanent magnet is placed on like poles of an electromagnet. |
| Mei, 41-4.3 | NMR - gyroscope model | 7D40.12 | A gyroscope model designed to show the magnetic transitions when the field and Larmor frequency are identical. |
| AJP 29(10),709 | NMR - Maxwell top model | 7D40.13 | The top post of the Maxwell top is constrained by rubber bands attached to a frame to demonstrate the "flopping" of the magnetic moment vector which increases or decreases the precession angle. |
| Mei, 41-4.4 | Larmor precession model | 7D40.13 | A spinning gyro over an electromagnet demonstrates Larmor precession. Diagram, Picture, Construction details in appendix, p.1392. |
| AJP 31(6),446 | magnetic resonance | 7D40.15 | A small magnet suspended and driven with Helmholtz coils will oscillate at a particular frequency, but at a different frequency if a static field is applied at right angles. |
| Hil, A-6a | Larmor precession model | 7D40.16 | A bicycle wheel gyro used to show Larmor precession. |
| AJP 33(4),322 | NMR - air bearing gyro model | 7D40.20 | An air bearing gyro with Alnico magnet in the ball and Helmholtz coils. |
| Mei, 41-4.5 | NMR - air bearing gyro model | 7D40.20 | NMR principles are demonstrated with an air gyro mounted between Helmholtz coils. Diagrams, Reference: AJP 33(4),322. |
| Mei, 41-4.6 | Magnetic top in Helmholtz coils | 7D40.22 | An air driven magnetic top mounted between Helmholtz coils demonstrates spinning dipole interaction with external fields. Pictures, Construction details in appendix, p. 1393. |
| PIRA 500 | spin echo spectrometer | 7D40.30 | |
| AJP 42(1),58 | spin echo spectrometer | 7D40.30 | Design and construction of a simple pulsed NMR spectrometer, used first in a high school physics class. |
| Mei, 41-4.7 | spin echo instrument | 7D40.30 | Four demonstrations with a simplified spin echo instrument. |
| AJP 31(1),58 | NMR "grid dip" method with cobalt | 7D40.31 | A bottle of powdered cobalt, a grid current meter, and a tuned oscillator show a small dip in grid current at resonance. |
| AJP 43(8),747 | NMR with fixed field | 7D40.40 | Block diagram of a method to demonstrate NMR in a fixed field by sweeping and modulating the frequency. |
| AJP 42(12),1057 | magnetic resonance demonstration | 7D40.40 | A description of a simple and inexpensive demonstration model of pulsed magnetic resonance effects. |
| AJP 34(4),335 | simple NMR spectrometer | 7D40.40 | Circuits for a simple NMR spectrometer. |
| | **Models of the Nucleus** | **7D50.00** | |
| PIRA 500 | Rutherford scattering | 7D50.10 | |
| UMN, 7D50.10 | Rutherford scattering | 7D50.10 | Balls roll down a ramp onto a potential surface to model Rutherford scattering. |
| AJP 37(2),204 | scattering surface with analyzer | 7D50.10 | Balls roll down an incline onto a scattering surface. Eighteen pockets ring the surface. |
| TPT 2(6),278 | Rutherford scattering on the overhead | 7D50.11 | Ink dipped balls are rolled down an incline toward a clear plastic potential hill on an overhead projector stage. |
| Sut, A-63 | alpha particle scattering model | 7D50.12 | A magnet pendulum is repulsed by the pole of a vertical electromagnet. Orbits can be demonstrated in the attracting case. |
| Mei, 41-2.3 | Rutherford pendulum | 7D50.13 | An electromagnet pendulum suspended from an aluminum rod swings by an electromagnet on the table. |
| AJP 72(2), 237 | Rutherford scattering on an air table | 7D50.14 | Use magnets and a ring of Hall switches to determine the force law from scattering. |
| AJP 29(4),xiii | Rutherford scattering on a table | 7D50.14 | A dry ice puck with a vertically mounted magnet is placed on a glass plate with a second vertically oriented magnet just underneath to give an inverse square force. |
| Sut, A-64 | alpha particle scattering model | 7D50.15 | A ping pong ball pendulum is suspended above a Van de Graaff generator. |
| AJP 29(12),854 | "Welch" scattering apparatus | 7D50.16 | On using the "Welch" ball bearing scattering apparatus to model the conditions of an experiment in nuclear physics as far as possible. |

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| Bil&Mai, p 359 | "Welch" scattering apparatus | 7D50.16 | Construct a "Welch" style scattering apparatus to model the conditions of the Rutherford experiment. |
| AJP 29(6),349 | alpha particle scattering model | 7D50.19 | Apparatus Drawings Project No. 16: Simple Rutherford scattering using an annular ring of scattering material. The distance from the ring to the detector is varied giving scattering angles from 28 to 71 degrees. |
| AJP 33(12),1055 | Rutherford scattering | 7D50.19 | Take data for thirty minutes as a lecture demonstration. |
| PIRA 1000 | Rutherford scattering animation | 7D50.20 | |
| Disc 25-13 | Rutherford scattering animation | 7D50.20 | An animation of alpha particle scattering. |
| PIRA 1000 | Thomson model | 7D50.30 | |
| Mei, 39-5.1 | Thomson model of the atom | 7D50.30 | Vertical needle magnets stuck in corks float in a pan of water surrounded by a coil on the overhead projector. |
| Hil, A-5a | Thomson model | 7D50.30 | Looks like it might be the vertical magnets in a coil apparatus. Reference: H.E.White, Modern College Physics, 5th ed., p 452. |
| Mei, 41-2.2 | Thomson vs. Rutherford model | 7D50.35 | An apparatus to randomly shoot steel balls at models of the Thomson or Rutherford atom. |
| Mei, 41-2.1 | 1/r surface model of the nucleus | 7D50.40 | A Lucite 1/r surface with a well and accelerating ramp for ball bearings is used to show repulsion, capture, and ejection. Picture, Construction details in appendix., p.1372. |
| D&R, S-255 | scattering field of the nucleus | 7D50.40 | A cone made from cardboard or fiberglass. Launch ball bearings to show scattering and capture. |
| AJP 31(11),888 | scattering field of the nucleus | 7D50.42 | Deform a rubber sheet by boiling water in a test tube and holding it against the rubber sheet so it gets sucked down, then lift the test tube to make a potential barrier. |
| Mei, 39-5.2 | electron falls into the nucleus | 7D50.45 | A ball rolling in a funnel falls into the middle. |
| PIRA 1000 | mass defect | 7D50.46 | |
| UMN, 7D50.46 | mass defect | 7D50.46 | |
| AJP 28(6),561 | chemical heart model of the nucleus | 7D50.65 | The chemical heart vibrates in various modes giving a crude model of a nucleus. Recipe included. |
| Mei, 41-2.4 | mercury ameoba model of the nucleus | 7D50.65 | The mercury amoeba is used to demonstrate vibratory motion analogous to oscillations of an excited nucleus. Reference: AJP 28(6),561. |
| Mei, 41-2.5 | scattering x-rays by paraffin | 7D50.90 | A paraffin block is inserted to scatter x-rays into a Geiger counter. |
| | **ELEMENTARY PARTICLES** | **7E00.00** | |
| | **Miscellaneous** | **7E10.00** | |
| PIRA 500 | fundamental particles chart | 7E10.10 | |
| UMN, 7E10.10 | fundamental particles chart | 7E10.10 | |
| PIRA 1000 | fundamental particles software | 7E10.20 | |
| UMN, 7E10.20 | fundamental particles software | 7E10.20 | |
| AJP 49(11),1030 | quark confinement model | 7E10.50 | A Rubik's cube is used as a model of quark confinement. |
| | **RELATIVITY** | **7F00.00** | |
| | **Special Relativity** | **7F10.00** | |
| ref. | gravitational surface | 7F10.05 | see 8C20.20 |
| PIRA 1000 | Lorentz transformation machine | 7F10.10 | |
| AJP 31(10),802 | Lorentz transformation machine | 7F10.10 | A machine shows the behavior of clocks and measuring rods in two reference frames. |
| Mei, 38-1.3 | Lorentz transformation machine | 7F10.10 | A device offers visual representation of the space and time coordinates of two reference frames in uniform relative motion. Picture, Reference: AJP 31(10),802. |
| PIRA 1000 | flow ripple tank - twin source | 7F10.20 | |
| Mei, 38-1.1 | flow ripple tank | 7F10.20 | Wave propagation upstream and downstream is shown with a flow ripple tank. Picture. |
| Mei, 38-1.2 | flow ripple tank - twin source | 7F10.20 | Twin source interference in a moving medium is demonstrated with a flow ripple tank and variable phase generator. |
| PIRA 1000 | foam rubber roller | 7F10.25 | |
| AJP 31(12),913 | Fitzgerald contraction model | 7F10.26 | A stick traveling at constant velocity makes a traveling dimple in an elastic sheet. |
| AJP 73(9), 876 | time dilation - twin paradox | 7F10.31 | An explicit formula for differential aging from acceleration. |
| TPT 3(5),218 | time dilation - high school gedanken | 7F10.31 | Algebra and geometry only covering a gedanken experiment of time dilation and space contraction. |
| AJP, 75 (9), 805 | time dilation - twin paradox | 7F10.31 | How do clocks, initially synched in the laboratory frame, fall out of sync as their speed relative to the lab increases. |
| AJP 76(4 & 5),360 | time dilation - twin paradox | 7F10.31 | Two java applets developed to interactively explore time dilation. |
| AJP 56(10),941 | relativistic length contraction - simple diagrams | 7F10.32 | Simple diagrams for representing relativistic length contraction and time dilation. |

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| AJP, 50 (3), 278 | relativistic length contraction | 7F10.32 | Additional length contraction of an accelerated meter stick when viewed from an inertial system. |
| AJP 48(9),780 | induction coil relativity | 7F10.35 | On using the simple induction coil and galvanometer as a special relativity demonstration. |
| AJP, 58(11), 1066 | computer relativistic phenomena | 7F10.40 | The Edwin F Taylor Spacetime Software is used to generate printouts demonstrating aberration, the Doppler effect, the headlight effect, etc. |
| AJP 57(6),508 | computer software review | 7F10.40 | An evaluation of the Taylor "Space-time" software, used mainly in a homework mode. |
| AJP 56(7),600 | many colored relativity engine | 7F10.41 | The author's review of a simple program about relativistic space and time that requires no knowledge of physics, algebra, or geometry. |
| AJP 47(3),218 | cylindrical relatvity model | 7F10.50 | A spacetime diagram rolled on a cardboard tube is used to demonstrate the nature of simultaneity and the propagation of light in a rotating coordinate system. |
| AJP 38(8),971 | geometrical appearances | 7F10.55 | Some examples are illustrated in detail. |
| ref. | time reversal invariance | 7F10.60 | see 1N30.23 |
| PIRA 200 | Lorentz Transformation | 7F10.60 | |
| PIRA 500 - Old | Lorentz Transformation | 7F10.60 | |
| UMN, 7F10.60 | Lorentz Transformation | 7F10.60 | The Mechanical Universe chapter 42 and the Hewitt film "Relativistic Time Dilation" |
| PIRA 500 | Hewitt Film | 7F10.65 | |
| UMN, 7F10.65 | Hewitt film | 7F10.65 | |
| PIRA 1000 | Majestic clockwork | 7F10.66 | |
| | **General Relativity** | **7F20.00** | |
| AJP 50(4),300 | general relativity primer | 7F20.01 | A tutorial article. |
| AJP 50(3),232 | film loop review article | 7F20.10 | Two film loops, "Uniformly Accelerated Reference Frame", and "Twin Paradox", are thoroughly reviewed. |

## PLANETARY ASTRONOMY 8A00.00

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| | **HISTORICAL ASTRONOMY** | **8A05.00** | |
| TPT 37(8), 476 | calendar wheels | 8A05.10 | Native American celestial calendar wheels and how to construct them. |
| PIRA LOCAL | Stonehenge | 8A05.15 | Many models of this famous megalith are available. |
| AJP 45(2), 125 | megaliths | 8A05.16 | Some historical background on megalighic astronomy. |
| TPT, 31(6), 383 | constellations | 8A05.20 | Constellations used to interpret historical legends. |
| TPT, 29(2), 80 | constellations | 8A05.20 | The Big Dipper used to tell time. |
| TPT 25(8), 500 | Eratosthenes measurment of Earth's radius | 8A05.30 | Eratosthenes determination of the circumference of the Earth updated by doing the experiment from an aircraft. |
| TPT 26(3), 154 | Eratosthenes measurment of Earth's radius | 8A05.30 | Eratosthenes experiment redone using meter sticks instead of wells. |
| TPT 31(7), 440 | Eratosthenes measurment of Earth's radius | 8A05.30 | Trying to calculate the radius of the Earth by watching the Sun set twice, once from the bottom and then from the top of a tall building. |
| TPT 31(9), 519 | measurment of Earth's radius | 8A05.30 | The calculation done using feet and miles. Also several other neat problems using Earth's radius as a starting point. |
| TPT 38(6), 360 | measurment of Earth's diameter | 8A05.30 | A GPS is used to calculate the diameter of the Earth. |
| TPT 38(3), 179 | Eratosthenes - scale of Earth/Moon/Sun system | 8A05.30 | Using Eratosthenes calculation of the diameter of the Earth to calculate the size of the Moon. |
| AJP 31(6),456 | Eudoxus: homocentric spheres models | 8A05.33 | Two homocentric models of Eudoxus: one shows the motion of the Sun, the other shows retrograde motion. |
| AJP 30(9),615 | Ptolemaic and Copernian orbits | 8A05.35 | An analog computer (circuit given) displays orbits and epicycles on an oscilloscope. |
| TPT 25(8), 493 | Kepler and planetary orbits | 8A05.40 | Kepler's third law and the rise time of stars. |
| TPT 34(1), 42 | Kepler and planetary orbits | 8A05.40 | Applying Kepler's third law to elliptical orbits. |
| TPT 36(1), 40 | Kepler and planetary orbits | 8A05.40 | Measuring an asteroids orbit to test Kepler's first and second law. |
| TPT 36(4), 212 | Kepler and planetary orbits | 8A05.40 | A graphical representation of Kepler's third law. |
| TPT 42(9), 530 | Kepler and planetary orbits | 8A05.40 | Kepler's third law calculations without a calculator. |
| AJP, 69(4), 481 | Kepler and planetary orbits | 8A05.40 | A hodographic solution to Kepler's laws. |
| AJP, 69(10), 1036 | Kepler and planetary orbits | 8A05.40 | An unusual verification of Kepler's first law. |
| AJP 52(2),185 | sundial | 8A05.50 | A Plexiglas model of a sundial. |
| TPT 10(3), 117 | sundial | 8A05.50 | Detailed descriptions, pictures, and how to time correct a sundial. |
| TPT 37(2), 113 | sundial | 8A05.50 | Constructing a portable sundial. |
| TPT 41(5), 268 | sundial, solar pocket watch | 8A05.50 | Picture of a portable sundial ( solar pocket watch ) dated 1573. |
| TPT 41(8), 380 | sundial, solar pocket watch | 8A05.50 | Additional observations on TPT 41(5), 268. |
| AJP 42(5),372 | horizontal sundial | 8A05.55 | An analytic solution for determining the markings on a sundial and a description of construction. |
| AJP 33(2),165 | cross-staff | 8A05.60 | Cut a meter stick into 57 1/3 cm and 42 2/3 cm. (At 57 1/3 cm one degree equals one cm.) Some refinements. |
| PIRA LOCAL | sextant | 8A05.70 | Pictures of and directions for sextants. |
| TPT 38(4), 238 | sextant | 8A05.70 | An easily constructed mini-sextant and directions for it's use. |
| PIRA LOCAL | artificial horizon | 8A05.80 | A mercury filled dish that is used for an artificial horizon when taking measurments with a sextant during times when the real horizon is obscured. |
| PIRA LOCAL | chronometer | 8A05.85 | An accurate ships time piece used in conjunction with the sextant to determine longitude and latitude. |
| AJP 38(3),391 | heliostat | 8A05.90 | Picture of a heliostat |
| | **SOLAR SYSTEM MECHANICS** | **8A10.00** | |
| | origin of the Solar System | 8A10.05 | |
| TPT 5(8), 363 | origin of the Solar System | 8A10.05 | Discussion on how the Solar System was formed. |
| TPT 29(5), 268 | planetary nebula | 8A10.06 | On the formation of planetary nebula. |
| PIRA 200 | Orrery model | 8A10.10 | A mechanical model of the inner planets. |
| UMN, 8A10.10 | Orrery model | 8A10.10 | |
| F&A, Ma-3 | Orrery model | 8A10.10 | A motor driven model of the Sun, Moon, Earth system. |
| D&R, S-390 | Orrery model | 8A10.10 | A mechanical model of the inner planets |
| TPT 16(4), 223 | scale model of the Solar System | 8A10.15 | The scale model of the Solar System as a hallway demo. |
| TPT 29(6), 371 | scale model of the Solar System | 8A10.15 | The 1:10 billion Colorado Scale-Model Solar System on the University of Colorado - Boulder campus. |
| TPT 27(1), 38 | scale model of the Solar System | 8A10.15 | Globes and balloons used to model the planets of the Solar System. |
| | Scale of the Solar System - Video | 8A10.15 | |
| | Inflatable Solar System | 8A10.15 | |

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| | Solar System on a String | 8A10.15 | |
| TPT 43(2), 120 | scale of the orbital radii of the planets | 8A10.16 | A hat pin, roll of tape, and some markers used to scale the orbital radii of the planets. |
| AJP 53(6),591 | locating stars | 8A10.20 | A simple analytical method at the descriptive astronomy level for locating stars. |
| TPT 44(3), 168 | locating stars | 8A10.20 | Using the stars of the Big Dipper to teach vectors. |
| AJP, 78 (11), 1128 | tracking stars, Sun, and Moon | 8A10.22 | Construction of an electromechanical device that automatically and continually tracks celestial objects. |
| AJP 43(1),113 | diurnal motion | 8A10.25 | Punch holes in a can bottom in the Big Dipper pattern and place over a point source of light. Rotate the can. |
| Hil, O-5h | planispheric planetarium | 8A10.30 | Description of a homemade planetarium. |
| Hil, O-5g | small planetarium | 8A10.30 | Description of a small homemade planetarium dome. |
| PIRA 500 | day & night | 8A10.33 | |
| PIRA 1000 | local zenith | 8A10.35 | |
| UMN, 8A10.20 | local zenith | 8A10.35 | |
| TPT 29(5), 265 | sidereal time | 8A10.40 | An explanation of how a sidereal day differs from a solar day and how to calculate the difference. |
| TPT 30(9), 558 | sidereal day | 8A10.42 | A simple method to measure the length of the sidereal day. |
| TPT 34(2), 94 | sidereal day | 8A10.42 | Use simple equipment to measure the sidereal day. |
| TPT 32(2), 111 | sidereal year | 8A10.44 | Use orbital mechanics and centripital force to calculate the sidereal year. |
| AJP 55(9),848 | precession of the equinox graph | 8A10.50 | A graph that shows the precession of the equinox from 1890 to 2000 and a discussion of its pedagogical value. |
| TPT 35(3), 167 | apparent motion of the Sun | 8A10.60 | The autumn and spring equinoxes do not have equal length days and nights. Index of refraction through the atmosphere makes the day about 9 minutes longer than the night. |
| TPT 29(9), 566 | distortion due to refraction by Earth atmosphere | 8A10.70 | A demonstration using sugar water to show why the Sun appears elliptical instead of round when viewed through the atmosphere. |
| TPT 35(9), 553 | distortion due to refraction by Earth atmosphere | 8A10.70 | The appearance of the flattening of the solar disk and the appearance of the "anti-Sun" captured on film. |
| TPT 20(6), 404 | distortion due to refraction by Earth atmosphere | 8A10.70 | The apparent ellipticity of the setting Sun. |
| AJP 71(4), 379 | distortion due to refraction by Earth atmosphere | 8A10.70 | On the flatness of the setting Sun. |
| TPT 39(2), 92 | distortion due to refraction by Earth atmosphere | 8A10.75 | A complete explanation of distortions produced by the atmosphere. |
| TPT 34(6), 355 | Analemma | 8A10.80 | A good explanation of how the analemma couples the seasonal declination changes of the Sun with the "Equation of Time". |
| TPT 38(9), 570 | Analemma | 8A10.80 | How to plot and demonstrate the noncircularity of the Earth's orbit around the Sun. |
| TPT 34(1), 58 | Analemma | 8A10.80 | Analemma used to show why sunrise can be at the same time for several weeks while the length of the day increases. |
| TPT 43(5), 260 | Analemma | 8A10.80 | Additional comments on TPT 34(1), 58 |
| ref. 1A10.41 | Geochron | 8A10.80 | The standard Geochron is used to show analemma, the part of the Earth lit by the Sun at any given time, etc. |
| TPT 29(5), 318 | subsolar point | 8A10.80 | An experiment plotting the subsolar point ( the place on Earth where the Sun is directly overhead at solar noon). |
| TPT 23(2), 85 | Analemma, clocks, apparent motion of the Sun | 8A10.80 | Explains why the length of the morning and afternoon do not increase in the same proportion as the length of the day gets longer. |
| TPT 31(8), 508 | apparent motion of the Sun | 8A10.90 | |
| TPT 31(9), 536 | apparent motion of the Sun | 8A10.90 | |
| TPT 34(6), 351 | apparent motion of the Sun | 8A10.90 | Using simple equipment to measure the length of the solar day. |
| TPT 35(5), 310 | apparent motion of the Sun | 8A10.90 | Using the apparent motion of the Sun to teach vectors and scalar products. |
| AJP, 71(12), 1242 | apparent motion of the Sun | 8A10.90 | A formula for the number of days between the winter solstice and the latest sunrise. |
| | **EARTH - MOON MECHANICS** | **8A20.00** | |
| TPT 31(7), 419 | Earth's Seasons | 8A20.05 | Showing the Earth's seasons with a 3-D model. |
| | Seasonal Tilt | 8A20.07 | |
| | Tilt of the Earth - Video | 8A20.08 | |
| PIRA 200 | phases of the Moon - terminator line demo | 8A20.15 | View a ball illuminated by a distant light with a TV camera as the angle between the ball and light varies. |
| UMN, 8A10.25 | phases of the Moon | 8A20.15 | |
| TPT 38(6), 371 | phases of the Moon | 8A20.15 | How the view of the crescent moon changes from the northern to southern hemisphere. |

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| TPT 34(6), 360 | phases of the Moon | 8A20.15 | Phases of the moon shown with a styrofoam ball, light source, and a CCD camera. |
| TPT 31(3), 178 | phases of the Moon | 8A20.15 | A handy way to teach "Moon Phases". |
| TPT 32(2), 126 | phases of the Moon | 8A20.15 | An exercise in Moon watching and observation of phases of the Moon. |
| TPT 3(6),263 | phases models | 8A20.17 | Illuminated models for showing the phases of Venus and the Moon. |
| TPT 37(9), 528 | phases of the planets | 8A20.19 | Calculating the phases of the outer planets. |
| | albedo | 8A20.20 | |
| TPT 23(5), 293 | brightness of the Moon | 8A20.20 | Two methods to determine the brightness of the Moon. |
| AJP, 78 (8), 834 | eccentricity of the Moon's orbit | 8A20.22 | A piece of cardboard with a hole slid up and down a yardstick is used to determine the eccentricity of the Moon's orbit. |
| PIRA 500 | eclipse models | 8A20.25 | |
| TPT 34(6), 376 | eclipse model | 8A20.25 | An eclipse model built from Hoola Hoops to show the eclipse seasons. |
| | solar eclipse | 8A20.30 | |
| TPT 17(7), 443 | solar eclipse | 8A20.30 | On the observation of the 1979 solar eclipse. |
| TPT 9(5), 276 | solar eclipse | 8A20.30 | Preparations and observation of the March 7, 1970 eclipse. |
| TPT 35(9), 515 | solar eclipse | 8A20.30 | The path of the February 26, 1998 solar eclipse. |
| TPT 34(4), 232 | solar eclipse | 8A20.31 | Using a solar eclipse to estimate the Earth-Moon distance. |
| TPT 32(6), 347 | solar eclipse, pinhole images | 8A20.32 | Using pinholes and natural phenomenon to view a solar eclipse. |
| | lunar eclipse | 8A20.35 | |
| TPT 44(3), 181 | lunar eclipse | 8A20.35 | Why the Moon appears red during a lunar eclipse |
| | umbra, penumbra | 8A20.37 | |
| PIRA LOCAL | umbra, penumbra | 8A20.37 | Why there are crisp, dark or fuzzy shadows during eclipses. |
| | Transit - Mercury & Venus | 8A20.40 | |
| TPT 21(4), 218 | occultations | 8A20.45 | Lunar geography shown determined by grazing occultation. |
| TPT 30(5), 290 | occultations | 8A20.45 | Occultation used to determine the diameter of the Moon. |
| AJP 45(10), 914 | occultations | 8A20.45 | Occultation used to determine the diameter of a planet. |
| PIRA LOCAL | Earth/Moon system | 8A20.50 | Add abstract in Handbook.FM |
| TPT 44(1), 48 | Earth/Moon system | 8A20.50 | The Earth-Moon system orbits the Sun at its center of mass or barycenter. |
| | Center of Mass - Earth/Moon | 8A20.50 | |
| TPT, 44(7), 414 | Earth/Moon system | 8A20.55 | Using Earth-Moon communication to calculate the speed of light. |
| TPT 33(2), 90 | Earth/Moon distance | 8A20.60 | Retroreflector arrays and laser pulses to measure the Earth/Moon distance. |
| TPT 10(1), 40 | Earth/Moon distance | 8A20.60 | How to determine the distance to the Moon. |
| PIRA 1000 | pinhead Earth | 8A20.70 | |
| UMN, 8A10.40 | pinhead Earth | 8A20.70 | |
| TPT 38(2), 115 | scale model of the Earth/Moon/Sun system | 8A20.70 | Using a basketball and a push pin to model the Sun-Earth system. |
| TPT 11(8), 489 | scale model of the Earth/Moon/Sun system | 8A20.70 | Pinholes used to enhance a 1:2 billion scale model of the Earth/Moon/Sun system. |
| | Moon & Tides | 8A20.80 | |
| | **VIEWS FROM EARTH** | **8A30.00** | |
| PIRA 1000 | horizon astronomy model | 8A30.10 | |
| UMN, 8A10.50 | horizon astronomy model | 8A30.10 | |
| D&R, S-360 | horizon calculations | 8A30.10 | A method for calculating the distance to the horizon. |
| TPT 38(9), 528 | estimating the distance to the horizon | 8A30.10 | How to accurately estimate the distance to the horizon. |
| AJP, 50 (9), 795 | estimating the distance to the horizon | 8A30.10 | An analysis for calculating the distance to the horizon as a function of the altitude of the observer. Also takes into account the variation of atmospheric refractive index with height. |
| D & R, S-360 | estimating the distance to the horizon | 8A30.13 | How to accurately estimate the distance to the horizon when at sea. |
| PIRA 1000 | Cinhelium | 8A30.20 | |
| UMN, 8A10.51 | Cinhelium | 8A30.20 | |
| PIRA 200 | retrograde motion model | 8A30.30 | Two balls, connected with a rod fixed through one ball and sliding through the other, orbit on a common focus. |
| UMN, 8A10.55 | retrograde motion model | 8A30.30 | |
| AJP 55(5),393 | retrograde motion model letter | 8A30.30 | Pointer to AJP 43,693(1975). |
| AJP 54(11),1021 | retrograde motion model | 8A30.30 | Two balls driven by independent clock motors are connected with a rod fixed through one ball and sliding through the other. |
| TPT 37(6), 342 | retrograde motion of Mars | 8A30.32 | How to plot the retrograde motion of Mars on paper. |
| AJP 43(7), 639 | retrograde motion | 8A30.32 | Three methods to plot retrograde motion, one is simpler than the others. |
| TPT 30(5), 302 | retrograde motion | 8A30.32 | A method of plotting retrograde motion on a large scale to be done outdoors with twine and students. |
| TPT 21(4), 252 | retrograde motion | 8A30.32 | Plotting retrograde motion in a manner that gives a better diagram. |

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| AJP 73(11), 1023 | retrograde motion | 8A30.32 | Using retrograde motion to understand and determine orbital parameters of a planet using only geometry and trigonometry. |
| TPT 35(9), 554 | retrograde motion | 8A30.34 | Retrograde motion and epicycles are shown using polar graph paper and a fender washer. |
| Mei, 8-8.5 | epicycles | 8A30.40 | An Orrery carries a small flashlight on a rod between Earth and Jupiter to project epicycloidal motion. |
| Mei, 8-8.4 | epicycles | 8A30.40 | A elliptical Lucite dish has two arms attached to one foci. Place some ball bearings between the two arms and rotate the rear arm at constant angular velocity. |
| Mei, 8-8.6 | epicycles | 8A30.40 | A diagram of how to make a fairly simple crank device to trace out elliptical through cusped figures with a penlight. |
| TPT 19(2), 116 | synodic period | 8A30.50 | Using calculations to show that the conjuction and opposition of a planet are not "perfect" due to non-circular orbits. |
| TPT 23(3), 154 | synodic period | 8A30.50 | Use relative angular velocity to calculate the synodic period. |
| TPT 35(6), 379 | tidal locking | 8A30.60 | A demonstration on how the Moon and other moons become tidally locked. |
| TPT 41 (6), 363 | tidal locking | 8A30.60 | Why the same side of the Moon always faces the Earth. |
| TPT 35(1), 34 | parallax | 8A30.70 | Measuring the distance to an outer planet by parallax with a camera. |
| AJP 45(5), 490 | parallax | 8A30.70 | Have students measure the distance to objects in the classroom by parallax using a camera to better understand stellar parallax. |
| AJP 45(12), 1221 | parallax | 8A30.70 | Another simple photographic experiment to help students understand parallax. |
| AJP 45(11), 1124 | parallax | 8A30.72 | A laboratory model to calculate stellar distances by parallax and relative magnitude. |
| AJP, 69(10), 1096 | autoresonance | 8A30.80 | 3:2 and 2:1 resonances of the planets and asteroids. |
| TPT, 44(6), 381 | Roche Limit | 8A30.90 | A calculation of the Roche limit of a Jovian planet and a simulated experiment to test the calculation. |
| | **VIEWS FROM EARTH - 2** | **8A35.00** | |
| PIRA 200 | celestial sphere | 8A35.10 | A simple model celestial sphere is made from a round bottom flask. Pictures. |
| UMN, 8A10.80 | celestial sphere | 8A35.10 | |
| Mei, 8-8.8 | celestial sphere | 8A35.10 | A simple model celestial sphere is made from a round bottom flask. Pictures. |
| TPT 18(6), 465 | celestial sphere | 8A35.15 | Modifying the Replogle Model 15620 celestial sphere. |
| TPT 25(7), 438 | celestial sphere | 8A35.16 | Making your own celestial sphere by locating stars. |
| TPT 10(2), 96 | celestial sphere | 8A35.18 | Difficulties teaching concepts with a celestial sphere may be simplified by construction of a mechanical Armillary. |
| AJP 73(11), 1030 | celestial sphere | 8A35.18 | Introducing students to the celestial sphere should always be done with a companion Earth-Sun model. |
| TPT, 45(6), 369 | satellite orbits | 8A35.30 | Plotting the orbits of the planets from existing data and charts. |
| TPT 31(2), 122 | satellite orbits | 8A35.30 | Orbital periods of Mercury, Venus, and the Earth simulated using a whirligig setup. |
| TPT 36(2), 122 | satellite orbits | 8A35.30 | Calculating how long it takes for a planet to fall into the Sun if its orbital motion is arrested and relating that to the orbital period of the planet. |
| TPT 19(3), 181 | satellite orbits | 8A35.32 | The orbital motion of the Moon explained by projectile motion. |
| TPT 23(1), 29 | satellite orbits | 8A35.35 | Calculation showing that an orbiting satellite is in freefall. |
| TPT 46(4), 237 | satellite orbit model | 8A35.35 | Making a satellite/Earth system model from glass tubing, a model rocket, nylon thread, a support stand, wooden sphere, and hooked masses. |
| TPT 43(7), 452 | satellite orbits | 8A35.40 | The effect of atmospheric drag and temperature on satellite orbits. |
| TPT 23(8), 466 | slingshot effect | 8A35.50 | A simple explanation of the "slingshot effect" or "gravity assist". |
| | **PLANETARY PROPERTIES** | **8A40.00** | |
| | **GLOBES, HEMISPHERES, & MAPS** | | |
| PIRA 1000 | globes | 8A40.10 | |
| UMN, 8A20.10 | globes | 8A40.10 | Globes of Earth, the Moon, Mercury, Venus, Mars, etc. |
| TPT 32(8), 506 | globes and hemispheres | 8A40.20 | The angles of any triangle on a sphere or hemisphere always add up to more than 180 degrees. |
| TPT 26(5), 280 | globes and hemispheres | 8A40.20 | The minimum path length joining two points on a sphere's surface is a segment of a "great circle". |
| | **PLANETARY PROPERTIES - 2** | **8A50.00** | |

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| | **THE PLANETS** | | |
| | Mercury | 8A50.10 | |
| TPT 29(6), 346 | Mercury's orbit | 8A50.12 | Plotting Mercury's orbit from data in *The Astronomical Almanac.* |
| AJP 56(12), 1097 | perihelion of Mercury | 8A50.15 | A calculation for the precession of the perihelion of Mercury. |
| AJP 73(8), 730 | perihelion of Mercury | 8A50.15 | The precession of the perihelion of Mercury's orbit calculated using the LaPlace-Runge-Lenz vector. |
| AJP 70(5), 498 | perihelion of Mercury | 8A50.15 | A Lagrangian yielding the same equations of motion that Einstein derived for the precession of the perihelion of Mercury. |
| AJP, 54, 245 | perihelion of Mercury | 8A50.15 | Mercury's precession according to special relativity. |
| | Venus | 8A50.20 | |
| | Earth | 8A50.30 | |
| TPT 25(2), 86 | Earth's rotation | 8A50.30 | Does the Earth rotate. Seven "proofs" for the rotation of the Earth. |
| TPT 25(7), 418 | Earth's rotation | 8A50.30 | Several other experiments carried out that proved the Earth rotates. |
| TPT 30(4), 196 | Earth's rotation | 8A50.30 | One more "proof" the Earth rotates. |
| TPT 30(2), 111 | Earth's rotation | 8A50.30 | Additional experiments on how we sense the Earth rotates. |
| TPT 33(3), 144 | Earth's rotation | 8A50.30 | Leeuwenhoek's "Proof" of the Earth's rotation. |
| TPT 33(2), 116 | Earth's rotation | 8A50.30 | Emperical evidence the Earth rotates by marking the length of a shadow of a rod in two minute intervals starting 20 minutes before midday and ending 20 minutes after midday. |
| | Geological Timeline - Earth | 8A50.34 | |
| | The Moon | 8A50.35 | |
| TPT 38(3), 179 | The Moon | 8A50.35 | What information it takes to calculate the size of the Moon. |
| TPT 11(1), 43 | The Moon | 8A50.35 | A calculation of how high you can jump on the Moon. |
| TPT 29(3), 160 | The Moon's orbit | 8A50.36 | How to observe the Moon's path with a cross-staff and plot its path. |
| TPT 18(7), 504 | The Moon's orbit | 8A50.36 | Measuring the Moon's orbit |
| TPT 38(9), 522 | moonquakes | 8A50.38 | Detection and analysis of moonquakes by the seismometers left on the Moon by the Apollo astronauts. |
| AJP 46(7),762 | The Moon's offset center-of-mass | 8A50.39 | Comments on the center-of -mass offset of the Moon. |
| | Mars | 8A50.40 | |
| TPT, 43(5), 293 | Mars Missions, Orbital Timing | 8A50.41 | The problems, physics principles, and timing involved in a mission from Earth to Mars. |
| TPT 36(3), 154 | Aerobraking at Mars | 8A50.42 | The physics of aerobraking at Mars. |
| | Mars' moons | 8A50.45 | |
| | Jupiter | 8A50.50 | |
| TPT 35(3), 178 | Jupiter | 8A50.52 | Looking at the Solar System from Jupiter's reference frame. |
| | Jupiter's moons / Galilean Satellites | 8A50.55 | |
| TPT 19(6), 402 | Io | 8A50.55 | The volcanos on Io. |
| TPT 25(8), 508 | Europa's Ocean | 8A50.55 | An exercise exploring the effect of freefall acceleration on buoyancy and waves. |
| TPT 30(2), 103 | Galileo's discovery of Jupiter's moons | 8A50.55 | A look at the challenges Galileo faced during his observation of the Jovian moons. |
| | Saturn | 8A50.60 | |
| | Saturn's moons | 8A50.65 | |
| TPT 26(4), 207 | Mimas | 8A50.65 | Statistics about Mimas and the view of Saturn from Mimas. |
| | Uranus | 8A50.70 | |
| | Uranus' moons | 8A50.75 | |
| | Neptune | 8A50.80 | |
| | Neptune's moons | 8A50.85 | |
| | **PLANETARY PROPERTIES - 3** | **8A60.00** | |
| | **PLANETIODS, MINOR OBJECTS** | | |
| TPT 45(1), 14 | Pluto/Charon | 8A60.10 | The history and process that resulted in Pluto's demotion from a planet to a minor object. |
| TPT 38, 534 | Pluto/Charon | 8A60.10 | How big does an object have to be to be considered a planet. |
| | asteroids | 8A60.20 | |
| TPT 40(8), 487 | asteroids | 8A60.25 | The physics of asteroid/Earth collisions. |
| AJP 74(8), 717 | asteroids | 8A60.25 | Describes the trajectory of an asteroid as it approaches a planet of much greater mass. Values are given for Earth, Mars, Jupiter, and Saturn. |
| AJP 74(9), 789 | asteroids | 8A60.25 | Estimates of catastrophic asteroid and comet impacts on the Earth. |
| AJP 71(7), 687 | asteroids | 8A60.25 | How asteroid or comet impacts is not the cause of and would not significantly change the eccentricity of Earth's orbit. |
| TPT 5(1), 5 | meteorites | 8A60.30 | Mass spectroscopy of meteorites. |
| TPT 37(2), 123 | meteors | 8A60.35 | "Observing" a meteors ionized trail by using radio. |

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| | Outer Solar System Objects | 8A60.40 | |
| | The Kuiper Belt | 8A60.50 | |
| TPT 39(2), 120 | extra - solar planets | 8A60.60 | Teaching about and helping with the search for extra-solar planets. |
| TPT 39(7), 400 | extra - solar planets | 8A60.60 | The precision it takes to detect extra-solar planets. |
| TPT 42(4), 208 | extra - solar planets | 8A60.60 | Teaching about data and detection of extra-solar planets by asking how our solar system would look if viewed by an observer from far away using the same detection methods. |
| TPT 20(4), 222 | matter from outside our solar system | 8A60.70 | Using cosmic rays to study matter in the galaxy outside our solar system. |
| TPT 20(5), 289 | matter from outside our solar system | 8A60.70 | Using cosmic rays to study matter in the galaxy outside our solar system. |
| | **PLANETARY PROPERTIES - 4** | **8A70.00** | |
| | **PLANETARY CHARACTERISTICS** | | |
| | geological samples | 8A70.05 | Assortments of rocks, minerals, or gemstones. |
| | Planetary Magnetism | 8A70.10 | |
| TPT 45(3), 168 | Earth's magnetic field | 8A70.10 | An elementary model of Earth's magnetic field capturing some features of the geodynamo. |
| TPT 26(5), 266 | Earth's atmosphere | 8A70.20 | The interaction of radiation from the Sun and the Earth's atmosphere determines the Earth's climate. |
| ref. 6A40.47 | refraction/twinkling | 8A70.20 | Refer to 6A40.47 to demonstrate how observing planets and stars through the atmosphere makes them appear to twinkle. |
| TPT 35(2), 90 | effective depth of Earth's atmosphere | 8A70.20 | Using "The Old Farmers Almanac" to calculate the effective depth of the atmosphere. |
| AJP 71(10), 979 | thickness of Earth's atmosphere | 8A70.20 | A method of estimating the thickness of the atmosphere by light scattering. |
| TPT 43(9), 578 | sounding balloon experiment | 8A70.22 | Atmospheric measurements using sounding balloons. |
| AJP 74(9), 804 | sprites | 8A70.30 | Exotic lightening that takes place above thunderstorms. |
| ref. 4B50.60 | greenhouse effect | 8A70.40 | See 4B50.60 for demonstrations of the greenhouse effect. |
| ref. 4B70.20 | Cloud Formation | 8A70.45 | See 4B70.20 for cloud in a bottle demonstrations. |
| PIRA LOCAL | IR Telescope Model | 8A70.48 | Construction of a simple IR telescope. |
| | Gaseous Planets | 8A70.50 | |
| TPT 16(7), 490 | gaseous planet atmospheres | 8A70.50 | Float bubbles on layers of Freon, CO2, or other heavy gasses in the bottom of a fish tank. |
| PIRA LOCAL | Rotational Banding | 8A70.55 | Rheoscopic fluid in a round bottom flasked placed on a turntable will show rotational banding when turned for a few seconds. |
| TPT 35(7), 391 | planetary atmospheres | 8A70.55 | A demonstration that can be used to explain rotational banding in planetary atmospheres. |
| TPT 40(4), 239 | planetary atmospheres | 8A70.55 | The composition of the atmospheres of the planets and the moon Titan. How would acoustic waves travel in these atmospheres. |
| TPT 45(8), 502 | precipitation in the Solar System | 8A70.60 | Descriptions of the types of precipitation that fall on the other planets and moons in the Solar System. Some of these can be brought into the classroom. |
| TPT 17(4), 228 | aurora | 8A70.65 | Historical and detailed explanation of Earth's aurora. |
| TPT 43(9), 573 | aurora | 8A70.65 | A brief description of aurora and how to photograph them. |
| TPT 44(2), 68 | aurora | 8A70.65 | Comments and corrections to TPT 43(9), 573. |
| TPT 33(1), 34 | auroral measurements | 8A70.65 | How to obtain and plot auroral data in the classroom. |
| TPT 33(2), 71 | auroral measurements | 8A70.65 | Additions to TPT 33(1), 34. |
| | lightening whistlers | 8A70.70 | Ionospherice whistlers at radio frequencies. |
| ref. 3B25.67 | culvert whistlers | 8A70.70 | See 3B25.67 for acoustical examples, demonstrations, and comparisons to ionospheric whistlers. |
| PIRA LOCAL | planetary density model | 8A70.75 | Add abstract in Handbook.FM |
| PIRA LOCAL | planetary gravities | 8A70.78 | Use pennies and soda cans to show how a can of soda would feel on different planets. Mercury = 38 pennies, Venus = 101, Earth = 1 can of soda or 100 pennies, the Moon = 12, Mars = 38, Jupiter = 293, Saturn = 119, Uranus and Neptune = 133, Pluto = 0. |
| PIRA LOCAL | Red Hot Ball | 8A70.80 | Heat a small metal ball until it glows red hot. Watch it cool with a black and white camera or an IR camera. Observe that it still glows in the camera even though the eye can no longer see it. A match may be lit off the apparently non-glowing ball for effect. |
| TPT 35(4), 230 | Earth's glow | 8A70.80 | The Earth glows from nuclear processes in the interior. |
| TPT 16(7), 479 | earthquakes | 8A70.85 | Student participation in P-wave and S-wave demonstrations. |
| PIRA 500 | cratering | 8A70.90 | |

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| UMN, 8A20.30 | cratering | 8A70.90 | Drop ball bearings into a pan of glass beads or flour. Illuminate with a lamp from the side of the pan to provide contrast. |
| PIRA LOCAL | cratering | 8A70.90 | Add abstract in Handbook.FM |
| AJP 68(8), 771 | cratering | 8A70.90 | Impact cratering studied in the laboratory using a marble for the meteorite, salt for the target, and a video camera to record the impact. Frame by frame analysis. |
| TPT 27(2), 118 | cratering | 8A70.91 | High speed photography and analysis of milk drops falling into coffee that can be applied to cratering. |
| | **PLANETARY PROPERTIES - 5** | **8A80.00** | |
| | **COMETS AND THE SEARCH FOR LIFE** | | |
| PIRA LOCAL | make a comet | 8A80.10 | Add abstract in Handbook.FM |
| PIRA LOCAL | Ed's comet | 8A80.10 | Add abstract in Handbook.FM |
| PIRA 1000 | comet orbit | 8A80.20 | |
| UMN, 8A10.65 | comet orbit | 8A80.20 | |
| TPT 23(1), 6 | comet orbits | 8A80.20 | The erroneous view that in Newton's *Principia* one can find a proof that inverse-square central forces implies a conic-section orbit. |
| TPT 22(8), 488 | Halley's comet | 8A80.30 | About Halley's comet. |
| TPT 15(2), 110 | Halley's comet | 8A80.30 | Preparing to observe Halley's comet in 1986 |
| TPT 15(4), 260 | Halley's comet | 8A80.30 | Getting ready for observation of Halley's comet. |
| TPT 23(4), 225 | Halley's comet | 8A80.30 | More on Halley's comet. |
| TPT 23(8), 490 | Halley's comet | 8A80.30 | Making a Halley's comet orbit model. |
| TPT 23(8), 485 | Halley's comet | 8A80.30 | Making sense of the apparent path of Halley's comet. |
| TPT 34(9), 558 | comet Hale-Bopp | 8A80.40 | A computer preview of comet Hale-Bopp. |
| TPT 35(6), 348 | comet Hale-Bopp | 8A80.40 | Photographs and data review of comet Hale-Bopp. |
| TPT 35(4), 247 | comets emit x-rays | 8A80.80 | Surprise, comets emit x-rays. |
| PIRA LOCAL | creating life in the classroom | 8A80.90 | Spoof the creation of life in the classroom by putting the necessary ingredients in a tank, add UV light and lightening, and voila. |
| TPT 20(2), 90 | life on other planets | 8A80.95 | Searching for life on other planets. What to look for. |
| | **STELLAR ASTRONOMY** | **8B00.00** | |
| | **THE SUN** | **8B10.00** | |
| PIRA LOCAL | 60 W Sun | 8B10.10 | Add abstract in Handbook.FM |
| TPT, 42(4), 196 | the solar constant | 8B10.20 | Accurate methods to calculate the amount of energy the Earth receives from the Sun. |
| TPT 38(6), 333 | solar constant | 8B10.20 | |
| TPT 42(4), 196 | solar constant | 8B10.20 | |
| TPT 15(3), 172 | solar constant lab | 8B10.20 | Inexpensive equipment used to measure the solar constant. |
| AJP 45(10), 981 | solar energy | 8B10.22 | Measurement of solar energy from the Sun. |
| TPT 29(2), 96 | solar luminosity | 8B10.24 | Use a light bulb of known wattage to calculate the luminosity of the Sun. |
| AJP 74(8), 728 | solar luminosity | 8B10.24 | Experiments measuring the solar constant used to calculate the luminosity of the Sun. |
| AJP 73(5), 457 | solar luminosity | 8B10.24 | Estimating *hc/k* from observations of sunlight. |
| AJP 73(10), 979 | solar luminosity | 8B10.24 | Corrections to AJP 73(5), 457. |
| AJP 71(12), 322 | solar Wien peak | 8B10.25 | A calculation that puts the Sun's Wien peak at 710 nm. |
| AJP 71(3), 216 | solar Wien peak | 8B10.25 | A discussion of why the human eye sees best at the yellow-green wavelengths which is well away from the Wien peak. |
| AJP 71(6), 519 | solar Wien peak | 8B10.25 | Additional comments on AJP 71(3), 216. |
| TPT 17(8), 531 | The Sun's temperature | 8B10.30 | How to calculate the Sun's temperature from known data. |
| TPT 38(5), 272 | The Sun's diameter | 8B10.35 | How to use a pinhole to calculate the diameter of the Sun. |
| TPT 13(7), 417 | The Sun's diameter | 8B10.35 | How to use a pinhole to calculate the diameter of the Sun. |
| TPT 38(2), 115 | The Sun's size | 8B10.35 | Using ratios and models in class to bring the size of the Sun into perspective. |
| TPT 39(4), 249 | The Sun's size | 8B10.35 | How the observed size of the Sun changes from perihelion to aphelion. |
| Bil&Mai, p 3 | The Sun's diameter | 8B10.35 | Use an index card with a small hole and a meter stick to determine the diameter of the Sun. |
| TPT 35(8), 391 | solar convection cells (Rayleigh-Bernard cells) | 8B10.40 | An explanation of the convection cells and how do make a demonstration using a skillet, aluminum powder, and silicon oil. |
| TPT 35(7), Cover shot | solar convection cells | 8B10.40 | The cover of this edition of TPT showing the convection cells made with a skillet, aluminum or brass powder, and silicon oil. |
| TPT 46(4), 219 | lava lamp | 8B10.40 | Making a lava lamp which can be used to show convection cells. |
| | sunspots | 8B10.50 | |

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| PIRA 200 | sunspot on the overhead | 8B10.50 | A light bulb on a variac is turned up to visible glow and placed on an overhead projector that is turned off. When the overhead is turned on, the filament appears as a dark spot. |
| PIRA LOCAL | sunspot on the overhead | 8B10.50 | A light bulb on a variac is turned up to visible glow and placed on an overhead projector that is turned off. When the overhead is turned on, the filament appears as a dark spot. |
| TPT 35(6), 334 | sunspot hallway demo | 8B10.50 | In a brightly lit room open the door to a dimly lit hallway. The hallway appears dark. Gradually dim the room lights and observe how the hallway dramatically lights up. |
| PIRA 200 | random walk - modeling the energy outflow in stars | 8B10.60 | Use a Bumble Ball ( a common toy ) to illustrate the random walk of high energy photons in a star. |
| TPT,37(4), 236 | random walk - modeling the energy outflow in stars | 8B10.60 | Use a Bumble Ball ( a common toy ) to illustrate the random walk of high energy photons in a star. |
| Sprott, 1.21 | random walk | 8B10.60 | Flip coin to model 1-d random walk. Execute a computer program or shake a pan of ping pong balls or tennis balls to model a 2-d random walk. |
| | solar oscillations | 8B10.70 | |
| AJP 62(9), 804 | stellar/nuclear fusion | 8B10.80 | A model built from magnets to demonstrate the forces in nuclear fusion. |
| TPT 43(5), 303 | stellar fusion | 8B10.80 | A look at fission and fusion and a determination as to which processes or nuclei release more energy. |
| TPT 42(2), 119 | Poynting-Robertson Effect | 8B10.90 | How to demo the Poynting-Robertson effect using an air track, air cart, and an air hose blowing air down onto the air track. |
| | **STELLAR SPECTRA** | **8B20.00** | |
| TPT 38(1), 35 | stellar spectra | 8B20.10 | Using stellar spectra to classify stars according to temperature. |
| TPT 21(9), 616 | Doppler effect & stellar spectra | 8B20.20 | How the energy of a photon is directly proportional to frequency and how this is not a violation of energy conservation when applied to the observed Doppler effect. |
| TPT 22(6), 350 | Doppler effect & stellar spectra | 8B20.20 | A further discussion on energy conservation and the Doppler effect. |
| TPT 26(2), 102 | Doppler effect & stellar spectra | 8B20.20 | A flaw in the argument of observed red shifts as proof of an expanding universe. |
| TPT 35(3), 160 | Doppler effect & stellar spectra | 8B20.20 | The effect of the Doppler shift on the spectrum of stars as observed by space travelers. |
| TPT 19(8), 527 | gamma ray line astronomy | 8B20.40 | Gamma ray line astronomy (GRLA) used to detect spectral features from stars. |
| | **STELLAR EVOLUTION** | **8B30.00** | |
| TPT 29(5), 273 | stellar magnitude | 8B30.10 | An explanation of stellar magnitude and how it is used. |
| PIRA 1000 | stellar magnitude simulator | 8B30.10 | |
| AJP 46(8),813 | stellar magnitude simulator | 8B30.10 | Six LEDs are adjusted so they appear to form a linear progression from dim to bright. The actual brightness is then measured. |
| TPT 17(7), 460 | HR diagram | 8B30.20 | Using part of the PSSC text to teach about the HR diagram. |
| TPT 25(7), 420 | HR diagram | 8B30.20 | The use of variable stars as a means to observe aging of stars. |
| TPT 27(4), 231 | HR diagram | 8B30.20 | Corrections to TPT, 25(7), 420. |
| TPT 34(6), 327 | HR diagram | 8B30.20 | A discussion of a simple but often missed important implication of the Main Sequence. |
| TPT 42(6), 347 | HR diagram | 8B30.20 | A student-centered, learning-cycle approach to teaching star life cycles. |
| AJP 74(1), 10 | HR diagram | 8B30.20 | Why is the Sun so large. Deriving a lower limit on the radius and mass of a hydrogen-burning star. Why 90 percent of stars lie in the "main sequence". |
| AJP 74(10), 938 | HR diagram | 8B30.20 | Additional comments on AJP 74(1), 10. |
| AJP 68(5), 421 | HR diagram | 8B30.20 | Transformation of a main sequence star to a red giant is discussed. |
| TPT 42(6), 347 | stellar lifecycle | 8B30.30 | Inquiry based Stellar lifecycle exercise. |
| TPT 17(4), 278 | stellar lifecycle | 8B30.30 | How the force of gravity can be responsible for the birth and death of stars. |
| TPT 10(4), 182 | stellar lifecycle | 8B30.30 | A look at how a star is born and the processes that determine it's lifecycle. |
| TPT 10(5), 250 | stellar lifecycle | 8B30.30 | Part 2 of a look at how a star is born and the processes that determine it's lifecycle. |
| TPT 10(6), 299 | stellar lifecycle | 8B30.30 | Corrections to TPT 10(5), 250. |
| TPT 28(6), 425 | binary star system | 8B30.35 | Two different size balls on a rod can be used to model a binary star system. |
| TPT 17(7), 456 | binary star system | 8B30.35 | A model eclipsing binary star system using light bulbs. |
| AJP 35(9), 817 | binary star system | 8B30.35 | A discussion of the aberration of light from a binary star system. |
| TPT 7(8), 453 | binary star system | 8B30.35 | How to observe eclipsing binary stars and make a model from an "N" gauge railroad set and light bulbs. |
| PIRA 1000 | variable star simulation | 8B30.40 | |

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| AJP 51(7),668 | variable star simulation | 8B30.40 | A ball eclipses a lamp. The output from a phototransistor is conditioned by a ADC/microcomputer/DAC on the way to an oscilloscope display. |
| TPT 31(9), 541 | variable stars | 8B30.40 | Variable stars are used to provide information about properties, processes, and evolution of stars. |
| AJP 46(11),1197 | synthesized variable star | 8B30.42 | Use a PROM to store the curves for variable stars. No microprocessor, the curve is generated with a simple hardware circuit. |
| AJP 44(12),1227 | variable star simulation | 8B30.42 | A dimmer control is varied by a cam on a motor drive. |
| AJP 54(11),976 | digital variable star | 8B30.42 | A simple circuit drives a lamp with data stored in EPROM to generate real light curves from various types of variable stars. Also includes discussion of a classroom photometer. |
| PIRA LOCAL | variable star simulation | 8B30.42 | Add abstract in Handbook.FM |
| AJP 71(1), 11 | supernova | 8B30.42 | Resource Letter: OTS-1: Obervations and theory of supernovae. Also, many books and review articles. |
| TPT 9(6), 326 | supernova | 8B30.45 | What happens and what results from the death of a star. |
| TPT 7(1), 24 | supernova | 8B30.45 | The Crab Nebula and some results from the death of a star. |
| PIRA 500 | supernova core bounce | 8B30.50 | |
| TPT 28(8),558 | supernova core bounce | 8B30.50 | Use the double ball bounce to illustrate supernova core bounce. |
| TPT 33(6), 358 | supernova core bounce | 8B30.50 | Use the "Astro-Blaster" toy to demonstrate the supernova core bounce. |
| TPT 33(9), 548 | supernova core bounce | 8B30.50 | Other combinations of ball that can be used to demonstrate a supernova core bounce. |
| TPT 33(1), 56 | supernova core bounce | 8B30.50 | How to make an aligner for elastic collision of multiple dropped balls. |
| AJP 39(6), 656 | supernova core bounce | 8B30.50 | Velocity amplification in collision experiments involving Superballs. Analysis and how to make the demonstration. |
| TPT 30(1), 46 | supernova core bounce | 8B30.50 | Analysis of multiple ball collisions and suggestions for safer multiple ball collision demonstrations. |
| TPT 30(4), 197 | supernova core bounce | 8B30.50 | Comments on nonideal multiball collisions. |
| PIRA LOCAL | flashbulb supernova | 8B30.55 | Add abstract in Handbook.FM |
| AJP 72(7), 892 | neutron stars | 8B30.60 | Neutron star projects for undergraduates. |
| PIRA 1000 | pulsar model | 8B30.65 | |
| PIRA 1000 | pulsar recording | 8B30.70 | |
| TPT 9(5), 232 | pulsars | 8B30.70 | Observations and speculation of 4 pulsars. |
| AJP 46(5), 530 | pulsars | 8B30.70 | Observations of pulsars used in the lab or the classroom. |
| AJP 68(8), 775 | x-ray pulsar | 8B30.72 | Calculation of the "spindown" rate of the x-ray pulsar SGR 1806-20. |
| | white dwarfs | 8B30.75 | |
| | nebula | 8B30.90 | |
| PIRA 1000 | forward and backward scattering | 8B30.95 | |
| UMN, 8B10.40 | forward and backward scattering | 8B30.95 | Clap erasers in front of and behind a clear 60 W lamp. |
| PIRA LOCAL | forward and backward scattering | 8B30.95 | Aim a laser or laser pointer through a fish tank filled with water that has a small amount of Pine-Sol added to it. Forward, side, and back scattering can be observed. |
| | **BLACK HOLES** | **8B40.00** | |
| TPT 41(5), 299 | black holes | 8B40.10 | Some simple black hole thermodynamics. |
| TPT 41(6), | black holes | 8B40.10 | Corrections to TPT 41(5), 299. |
| AJP 73(12), 1148 | black holes | 8B40.10 | Two analytical models of gravitational collapse. |
| AJP 45(5), 423 | black holes | 8B40.10 | A look inside a black hole. |
| AJP 46(6),678 | black holes | 8B40.10 | A simple model for the emission of particles by black holes. |
| TPT 23(9), 540 | black holes | 8B40.10 | Part 1. To convey the properties of black hole to students it is useful to put them human terms, such as "The hazards of encountering a black hole". |
| TPT 24(1), 29 | black holes | 8B40.10 | Part 2. To convey the properties of black hole to students it is useful to put them human terms, such as "The hazards of encountering a black hole". |
| AJP 56(1), 27 | black holes | 8B40.10 | How long can an observer wait before rescuing an object falling into a black hole. |
| TPT 39(2), 84 | black holes | 8B40.10 | How dense is a black hole?? |
| AJP 42(11), 1039 | black holes | 8B40.10 | On the radius of black holes. |
| TPT 46(1), 10 | black holes | 8B40.10 | A black hole in our galactic center. |
| PIRA 1000 | black hole surface | 8B40.20 | |
| UMN, 8C20.10 | black hole surface | 8B40.20 | A large fiberglass black hole potential surface from some museum in Philly. |
| PIRA 200 | membrane table | 8B40.30 | |
| PIRA 500 - Old | membrane table | 8B40.30 | |
| UMN, 8C20.20 | membrane table | 8B40.30 | Swimsuit fabric stretched over a wood frame is deformed with a weight and balls are rolled around. |

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| TPT 16(7), 504 | potential well/hill | 8B40.35 | How to make a potential well or hill from a Pexiglas sheet on a frame. |
| ref. 1L20.10 | gravity well | 8B40.40 | Use this demonstration when discussing black holes and gravity wells. |
| | magnetic field coupling | 8B40.50 | |
| | **STELLAR MISCELLANEOUS** | **8B50.00** | |
| TPT 39(3), 187 | distance to stars | 8B50.10 | How to construct an "Astronomy Angulator" to calculate small angles to assist in naked-eye observations. |
| Mei, 35-2.13 | stellar diameter measurement | 8B50.20 | The angular separation of two artificial stars is measured by the Michelson method of measuring stellar diameters. Diagrams, Reference: AJP 27(2),101. |
| TPT 39(7), 428 | interferometry | 8B50.30 | Stellar interferometers used to measure the angular diameters of stars. |
| TPT 28(8), 526 | stellar energy radiation | 8B50.40 | A look at the processes that determine the energy radiated by a star. |
| AJP 46(1), 23 | stellar radiation | 8B50.50 | What does it take to make a sun shine. |
| TPT 31(7), 422 | lookback time | 8B50.60 | Note historic events going on when light from specific distant stars started its journey to Earth. |
| TPT 27(7), 518 | lookback time | 8B50.60 | Lookback times and how to calculate them. |
| TPT 38(2), 122 | Olbers' paradox | 8B50.70 | Why is the sky dark at night when there are so many stars. |
| AJP 45(2), 119 | Olbers' paradox | 8B50.70 | Why is the sky dark at night when there are so many stars. |
| AJP 46(9), 923 | Olbers' paradox | 8B50.70 | The expansion of the universe may also be used to explain Olbers' paradox. |
| TPT 36(3), 176 | gamma ray bursts | 8B50.80 | Gamma Ray Bursts (GRB's) and the effects of time dialation and time contraction. |
| | **COSMOLOGY** | **8C00.00** | |
| | **MODELS OF THE UNIVERSE** | **8C10.00** | |
| TPT 18(9), 639 | cosmological models | 8C10.05 | A discussion of Red Shift, unbound universe, and other factors, and how they are applied to comological models. |
| TPT 38(9), 564 | The Big Bang | 8C10.10 | The Big Bang and chirality of the universe. |
| TPT 36(9), 529 | cosmic microwave background | 8C10.20 | The study of anisotropies in the CMB. |
| AJP 70(2), 106 | cosmic microwave background | 8C10.20 | The study of anisotropies in the CMB. |
| TPT 16(3), 137 | steady state, expanding, or contracting universe | 8C10.25 | A look at the question " Is the universe open or closed"? |
| AJP 45(7), 642 | steady state, expanding, or contracting universe | 8C10.25 | The general Doppler formula in a nonstatic universe is derived. |
| PIRA 200 | expanding universe | 8C10.30 | Pull a rubber hose threaded through five large styrofoam balls. |
| UMN, 8C10.10 | expanding universe | 8C10.30 | Pull a rubber hose threaded through five large styrofoam balls. |
| AJP 50(6),571 | expanding universe | 8C10.30 | Pull on a rubber rope with "galaxies" attached. |
| TPT 29(2), 103 | expanding universe | 8C10.30 | Use transparencies of a sample universe on the overhead to show center of expansion in an expanding universe. |
| AJP 69(2), 125 | expanding universe | 8C10.30 | Using a strip of latex to model how long a light pulse would take to travel from one galaxy to another in an expanding universe. |
| PIRA 1000 | inflating balloon | 8C10.35 | |
| UMN, 8C10.15 | inflating balloon | 8C10.35 | A balloon with galaxies drawn on is blown up with compressed air. |
| PIRA 1000 | expanding universe on a white board | 8C10.37 | |
| TPT 20(9), 617 | expanding universe | 8C10.39 | Are we able to use experimantal evidence to calculate the total vector momentum of our expanding universe. Is it zero? |
| PIRA 1000 | bubble universe | 8C10.40 | |
| UMN, 8C10.20 | bubble universe | 8C10.40 | Use a straw to blow bubbles in liquid soap. |
| PIRA 1000 | galaxy model | 8C10.50 | |
| UMN, 8C10.30 | galaxy model | 8C10.50 | Show a 16" diameter galaxy model. |
| | View of Galactic Center | 8C10.55 | |
| | Spiral Galaxies | 8C10.60 | |
| | Radio Galaxies | 8C10.70 | |
| | One Million Galaxies | 8C10.80 | A poster showing 1 million galaxies taken at radio wavelengths. |
| | **GRAVITATIONAL EFFECTS** | **8C20.00** | |
| PIRA 1000 | Klein bottle | 8C20.10 | |
| UMN, 8C10.40 | Klein bottle | 8C20.10 | A Klein bottle has been made from a 20 L flask. |
| PIRA 1000 | Moebius strip | 8C20.20 | |
| UMN, 8C10.45 | Moebius strip | 8C20.20 | A strip of aluminum about six inches wide and six feet long is made into a Moebius strip. |
| PIRA 1000 | saddle shape | 8C20.30 | |
| UMN, 8C10.50 | saddle shape | 8C20.30 | |

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| TPT 33(5), 286 | saddle shape | 8C20.30 | Two models of a negatively curved two-dimensional space. One of fiberglass, and one made with strings. |
| TPT 15(5), 298 | saddle shape | 8C20.30 | A butternut squash provides a negative space over small distances. At large distances the space becomes positive. A hubbard squash has a positive space. |
| TPT 16(1), 8 | saddle shape | 8C20.30 | Two more examples. A hollowed out grapefruit is a positive space. Pringles potato chips are examples of negative space. |
| AJP 63(2), 186 | saddle shape | 8C20.30 | A ball is not stable when placed on a saddle shape, but surprisingly does become stable if the saddle shape is rotated. |
| TPT 30(2), 92 | non-Euclidean geometry | 8C20.35 | Counting distant radio sources to determine if the overall curvature of space is positively curved, flat, or negatively curved. |
| TPT 22(9), 557 | non-Euclidean geometry | 8C20.35 | A discussion of gravity touching on non-Euclidean geometry and the geometry of three dimensional space. |
| TPT 29(3), 147 | non-Euclidean geometry | 8C20.35 | A helpful discussion about space curvature and how to visualize it. |
| PIRA 500 | gravitational lens | 8C20.40 | |
| UMN, 8C20.40 | gravitational lens | 8C20.40 | A machined Plexiglas lens bends light like a black hole. |
| TPT 25(7), 440 | gravitational lens | 8C20.40 | Viewing a fish in a fish tank. Refraction of light as the optical counterpart of a gravitational lens. |
| TPT 34(9), 555 | gravitational lens | 8C20.40 | Constructions of a simple gravitational lens demonstration. |
| AJP 48(10),883 | gravitational lens | 8C20.40 | An equation is developed for constructing a Plexiglas lens. |
| AJP 37(1),103 | gravitational lens | 8C20.40 | Directions for constructing a gravitational lens simulator from Plexiglas. Ref: Phys.Rev. 133, B835 (1964). |
| AJP 49(7),652 | gravitational lens | 8C20.40 | A plastic lens that bends light the same way a black hole does. Theory and directions for construction of a lens. |
| AJP 69(2), 218 | gravitational lenses | 8C20.40 | A computer program to visualize gravitational lenses. |
| AJP 56(5), 413 | gravitational lens | 8C20.42 | Henry Cavendish and Johann von Soldner calculated that light would be deflected by gravitational bodies long before Einstein. |
| AJP 55(4), 336 | gravitational lens | 8C20.42 | How would the outer world look from an observer located in a gravitational lens. |
| AJP 46(8), 801 | gravitational lens | 8C20.42 | The principle of equivalence and the deflection of light by the Sun. |
| TPT 38(9), 524 | gravitational lens | 8C20.42 | The prediction and test of Einstein's 1916 prediction. |
| TPT 39(4), 198 | gravitational lens | 8C20.42 | Additional comments on TPT 38(9), 524. |
| AJP 55(5), 428 | gravitational lens | 8C20.43 | The black hole as a gravitational lens. |
| PIRA 500 | galactic lens | 8C20.45 | |
| UMN, 8C20.45 | galactic lens | 8C20.45 | Same as AJP 51(9),860. |
| AJP 51(9),860 | galactic lens | 8C20.45 | A machined Plexiglas lens bends light like an extended mass distribution. |
| TPT 44(7), 416 | gravitational waves | 8C20.50 | Icebreaker activities to use when introducing the subject of gravitational waves. |
| TPT 44(7), 420 | gravitational waves | 8C20.50 | About the new generation of gravitational wave detectors. |
| TPT 22(5), 282 | gravitational waves | 8C20.50 | On the detection of gravitational waves. |
| TPT 34(8), 496 | quasars | 8C20.60 | Quasars and superluminal velocities in astronomy. |
| TPT 35(1), 5 | quasars | 8C20.60 | More on TPT 34(8), 496. |
| AJP 55(3), 214 | quasars | 8C20.60 | The use of quasars in teaching introductory special relativity. |
| | Cosmic Strings | 8C20.70 | |
| | Dark Matter | 8C20.80 | |

## MISCELLANEOUS 8D00.00

### MISCELLANEOUS ASTRONOMY 8D10.00

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| TPT 21(4), 250 | astrophotography | 8D10.10 | Problems with the photography of stars and galaxies. |
| TPT 35(3), 186 | astrophotography | 8D10.10 | A homemade mount for guided astrophotos. |
| TPT 29(7), 459 | daytime observations | 8D10.20 | Compare the size of the Sun and the Moon using welder's filters for daytime observation. |
| TPT 29(8), 500 | daytime observations | 8D10.20 | Calculating Sun-Earth and Earth-Moon distances using trigonometry and foam plastic balls. |
| TPT 30(2), 70 | daytime observations | 8D10.20 | Make observations to determine if the Moon revolves around the Earth in the same direction as the Earth itself rotates or in the opposite direction. |
| TPT 42(7), 423 | tossing on a rotating space station | 8D10.30 | Amusement park rides are used to answer the question "Where does a tossed ball go?" on a rotating space station. |
| TPT 43(1), 4 | tossing on a rotating space station | 8D10.30 | A graphical approach to the tossed ball on a rotating space station problem. |
| | soda can gravity demo | 8D10.40 | |
| PIRA LOCAL | space debris | 8D10.80 | |

### TELESCOPES 8D20.00

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| TPT 48(4), 251 | radio telescopes | 8D20.10 | Introducing radio astronomy as a classroom stimulus. |
| TPT 49(9), 546 | very small radio telescope | 8D20.10 | Using the very small radio telescope (VSRT) to teach high school physics. |
| TPT 18(7), 548 | radio telescopes | 8D20.10 | Six articles by Prof. George Swenson and how to instructions for building a portable radio interferometer. |
| TPT 14(8), 479 | radio telescopes | 8D20.10 | Observing "cosmic synchrotrons" with a radio telescope. |
| TPT 4(3), 99 | radio telescopes | 8D20.10 | About the 210 foot diameter radio telescope at Parkes, New South Wales. |
| TPT 2(2), 72 | radio telescopes | 8D20.10 | About the radio telescope at Mullard Observatory, Cambridge, England. |
| PIRA LOCAL | microwave telescopes | 8D20.20 | Show the old microwave telescope. |
| TPT 17(2), 132 | infrared telescopes | 8D20.30 | Build an infrared telescope using the 1P-25 image conversion tube. |
| TPT 18(1), 64 | infrared telescopes | 8D20.30 | How to build an improved handheld infrared telescope. |
| TPT 22(4), 248 | infrared telescopes | 8D20.30 | A simple infrared telescope made with kitchen materials. |
| | optical telescopes | 8D20.40 | See 6A70.20. |
| PIRA LOCAL | UV telescopes | 8D20.50 | A look at the Polar and Dynamic Explorer satellites. |
| TPT 36(7), 403 | X-ray telescopes | 8D20.60 | Views of our Sun at the soft X-ray wavelengths. |
| TPT 24(1), 21 | gamma ray telescopes | 8D20.70 | An explanation of gamma ray astronomy and the instruments used to observe very high energy gamma ray sources. |
| TPT 19(8), 527 | gamma ray telescopes | 8D20.70 | Gamma ray line astronomy and the instruments used for observation. |
| | **ASTRONOMICAL INSTRUMENTS** | **8D30.00** | |
| TPT 46(4), 237 | satellite models | 8D30.10 | Building a satellite model to demonstrate centripital force and satellite motion. |
| PIRA LOCAL | spacecraft models | 8D30.20 | Spacecraft models of Pioneer, Voyager, Cassini, PDP, Hawkeye, Juno, and the Radiation Belt Storm Probes, etc. |
| TPT 43(7), 454 | satellites | 8D30.50 | How to simulate realistic satellite orbits and the effect that atmospheric drag has on them. |
| TPT 44(7), 424 | GPS satellites | 8D30.50 | Relativistic effects on clocks aboard GPS satellites. |
| TPT 2(2), 70 | satellites | 8D30.50 | Determination of a satellite orbit using the doppler effect. |
| TPT 23(1), 29 | satellites | 8D30.50 | Calculating the velocity of orbiting satellites. |
| TPT 37(4), 196 | spacecraft | 8D30.60 | A demonstration to show why the Voyager 2 spacecraft had an unwanted wobble when a tape recorder on the spacecraft was turned on. |
| TPT 39(8), 476 | spacecraft artifacts | 8D30.60 | A classroom exercize deciphering the information contained on the plaque that accompanied the Pioneer 10 and Pioneer 11 spacecraft. |
| TPT 13(4), 232 | spacecraft orbits | 8D30.60 | A classroom experiment where students are given a comet or spacecraft's initial velocity and distance from the Sun. They use Newton's laws and a process of iteration to approximate its orbit. |
| | **ASTRONOMY TEACHING TECHNIQUES** | **8E00.00** | |
| | **TECHNIQUES AND PROJECTS** | **8E30.00** | |
| TPT 44(9), 607 | teaching astronomy with games | 8E30.10 | Using a game based on "Who wants to be a Millionaire" to teach astronomy. |
| TPT 38(9), 544 | building an observational astronomy program | 8E30.20 | Tips on how to build an observational astronomy program to expand your physics department. |
| TPT 44(3), 153 | teaching with astronomical catalogues | 8E30.30 | Using online astronomical catalogues to expand your experimental astronomy possibilites. |
| TPT 37(2), 102 | using space to teach physics | 8E30.40 | Student projects using up to date world wide web book sized sites and spaceflight as the means to ask questions. |

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| | **Support Systems** | **9A00.00** | |
| | **Blackboard Tools** | **9A10.00** | |
| PIRA 1000 | compass | 9A10.10 | |
| Mei, 6-1.4 | compass | 9A10.11 | Modifying a steel tape measure to make a blackboard compass. Diagram. |
| PIRA 1000 | protractor | 9A10.12 | |
| Mei, 6-1.3 | protractor | 9A10.12 | A blackboard straight edge with a permanently mounted angle indicator. Diagram. |
| TPT 4(1),19 | drawing conic sections | 9A10.14 | Simple blackboard tools for drawing the ellipse, parabola, and hyperbola. |
| Hil, M-10b | drawing vectors | 9A10.15 | A drafting machine mounted on the blackboard helps in drawing vectors. |
| Mei, 6-1 | blackboard graphs | 9A10.21 | Sources of help for making large blackboard graphs. |
| Mei, 6-1.6 | blackboard graphs | 9A10.21 | Slides of coordinate systems can be projected on the blackboard with an overhead projector. |
| PIRA 1000 | angle templates | 9A10.31 | |
| UMN, 9A10.31 | angle templates | 9A10.31 | Large triangles are used on the chalkboard. |
| PIRA 1000 | sine wave templates | 9A10.35 | |
| Mei, 6-1.5 | templates for drawing waves | 9A10.35 | Cardboard templates for various sine waves. |
| AJP 43(10),927 | templates for sine curves | 9A10.35 | Make a Masonite half period template with a scale at 10 degree intervals. |
| AJP 55(3),219 | moveable blackboards | 9A10.40 | A long article on movable blackboards. |
| | **Audio** | **9A20.00** | |
| PIRA 1000 | wireless microphone | 9A20.10 | |
| UMN, 9A20.10 | wireless microphone | 9A20.10 | |
| PIRA 1000 | multiple wireless microphones | 9A20.11 | |
| UMN, 9A20.11 | multiple wireless microphones | 9A20.11 | |
| PIRA 1000 | cord microphone | 9A20.15 | |
| UMN, 9A20.15 | cord microphone | 9A20.15 | |
| PIRA 1000 | multiple cord microphones | 9A20.16 | |
| UMN, 9A20.16 | multiple cord microphones | 9A20.16 | |
| PIRA 1000 | CD player | 9A20.20 | |
| UMN, 9A20.20 | CD player | 9A20.20 | |
| PIRA 1000 | audio cassette | 9A20.30 | |
| UMN, 9A20.30 | audio cassette | 9A20.30 | |
| PIRA 1000 | phonograph | 9A20.40 | |
| UMN, 9A20.40 | phonograph | 9A20.40 | |
| PIRA 1000 | reel to reel | 9A20.50 | |
| UMN, 9A20.50 | reel to reel | 9A20.50 | |
| | **Slide Projectors** | **9A30.00** | |
| PIRA 1000 | mobile screen | 9A30.05 | |
| UMN, 9A30.05 | mobile screen | 9A30.05 | |
| Mei, 34-2.4 | projection screen | 9A30.06 | Drafting linen makes a good projection screen. |
| PIRA 1000 | 35 mm projector | 9A30.10 | |
| UMN, 9A30.10 | 35 mm projector | 9A30.10 | |
| PIRA 1000 | two 35 mm projectors | 9A30.11 | |
| UMN, 9A30.11 | two 35 mm projectors | 9A30.11 | |
| PIRA 1000 | 35 mm to go | 9A30.15 | |
| UMN, 9A30.15 | 35 mm to go | 9A30.15 | |
| PIRA 1000 | lantern projector | 9A30.20 | |
| UMN, 9A30.20 | 3 1/4 x 4 projector | 9A30.20 | |
| Sut, L-1 | projection lanterns | 9A30.21 | On using projection lanterns to magnify demonstrations. Diagram. |
| PIRA LOCAL | light pointer | 9A30.30 | Add abstract in Handbook.FM |
| | **Film Projectors** | **9A34.00** | |
| PIRA 1000 | 16 mm projector | 9A34.10 | |
| UMN, 9A34.10 | 16 mm projector | 9A34.10 | |
| PIRA 1000 | film loop projector | 9A34.20 | |
| UMN, 9A34.20 | film loop projector | 9A34.20 | |
| PIRA 1000 | super 8 mm projector | 9A34.30 | |
| UMN, 9A34.30 | super 8 mm projector | 9A34.30 | |
| PIRA 1000 | 8 mm projector | 9A34.35 | |
| UMN, 9A34.35 | 8 mm projector | 9A34.35 | |
| PIRA 1000 | film strip projector | 9A34.40 | |
| UMN, 9A34.40 | film strip projector | 9A34.40 | |
| AJP 34(8),706 | anechoic chamber | 9A34.51 | Eliminate the sound of the projector with a portable anechoic chamber. |
| | **Overhead Projectors** | **9A36.00** | |
| TPT 2(2),77 | overhead projection techniques | 9A36.05 | On the advantages of using the overhead projector. Many examples. |
| Mei, 34-2.3 | overhead projector construction | 9A36.06 | Make your own overhead projector. Diagram. |

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| PIRA 1000 | overhead projector | 9A36.10 | |
| UMN, 9A36.10 | overhead projector | 9A36.10 | |
| AJP 55(1),89 | longer focal length | 9A36.11 | Adding an auxiliary lens to increase the focal length of an overhead projector. |
| AJP 51(2),183 | projecting vertical objects with the overhead | 9A36.12 | Lay the projector on its back and tape a shaving mirror to the lens box. |
| AJP 37(1),108 | "vertical" overhead projectors | 9A36.12 | Add an additional mirror to a projector on its back to invert the image left to right. |
| PIRA 1000 | two overhead projectors | 9A36.15 | |
| UMN, 9A36.15 | two overhead projectors | 9A36.15 | |
| AJP 52(4),379 | LCD on the overhead | 9A36.20 | Take the back off the LCD. |
| AJP 54(3),282 | digital multimeter on the overhead | 9A36.20 | Remove the reflecting foil from the back of the LCD display. |
| AJP 29(6),374 | projection meter | 9A36.20 | Review of a commercial projection meter (HV meter - Williamson Development Company) |
| AJP 52(5),467 | LCD devices on the overhead | 9A36.20 | Take the backing off LCD devices and use them in the transmission mode on the overhead projector. |
| AJP 41(9),1116 | projection galvanometer | 9A36.20 | Use a laser with a d'Arsonval galvanometer. |
| Mei, 30-1.8 | projection meter | 9A36.20 | Use the Cenco projection meter in a lantern projector. |
| Mei, 30-1.9 | projection meter | 9A36.20 | A projection meter mount for a slide projector. |
| Mei, 30-1.7 | projection meter | 9A36.20 | Project a standard meter on a screen. |
| Hil, E-2a | projection meters | 9A36.20 | Two projection meters for the overhead with assorted accessories. |
| PIRA 1000 | write on film rolls | 9A36.30 | |
| UMN, 9A36.30 | write on film | 9A36.30 | |
| AJP 32(10),xiv | projecting thermometers | 9A36.40 | Alcohol thermometers are easily projected on the overhead projector. Add a scale on the side. |
| AJP 32(9),xiii | multiexposure transparencies | 9A36.50 | Use Polaroid 146-L film to make instant transparencies. |
| AJP 47(3),291 | action effects on the overhead | 9A36.60 | A review of special commercially available polarizing materials that allow simulation of various motions on the overhead projector. |
| | **Video and Computer Projection** | **9A38.00** | |
| PIRA 1000 | TV table (color) | 9A38.10 | |
| UMN, 9A38.10 | TV table (color) | 9A38.10 | |
| PIRA 1000 | TV table (B&W) | 9A38.11 | |
| UMN, 9A38.11 | TV table (B&W) | 9A38.11 | |
| PIRA 1000 | tripod TV (color) | 9A38.15 | |
| UMN, 9A38.15 | tripod TV (color) | 9A38.15 | |
| PIRA 1000 | tripod TV (B&W) | 9A38.16 | |
| UMN, 9A38.16 | tripod TV (B&W) | 9A38.16 | |
| PIRA 1000 | tripod TV (IR) | 9A38.17 | |
| UMN, 9A38.17 | tripod TV (IR) | 9A38.17 | |
| AJP 33(1),xxvi | projecting oscilloscopes on TV | 9A38.18 | Use a TV cameras and classroom monitors to enlarge an oscilloscope screen. |
| PIRA 1000 | video projector | 9A38.20 | |
| UMN, 9A38.20 | video projector | 9A38.20 | |
| PIRA 1000 | LCD panel | 9A38.21 | |
| UMN, 9A38.21 | LCD panel | 9A38.21 | |
| PIRA 1000 | color LCD panel | 9A38.22 | |
| UMN, 9A38.22 | color LCD panel | 9A38.22 | |
| PIRA 1000 | classroom monitors | 9A38.25 | |
| UMN, 9A38.25 | classroom monitors | 9A38.25 | |
| PIRA 1000 | monitor on cart | 9A38.26 | |
| UMN, 9A38.26 | monitor on cart | 9A38.26 | |
| PIRA 1000 | video disc | 9A38.30 | |
| UMN, 9A38.30 | video disc player - level I | 9A38.30 | |
| UMN, 9A38.31 | video disc with computer | 9A38.31 | |
| PIRA 1000 | VHS tape deck | 9A38.40 | |
| UMN, 9A38.40 | VHS tape deck | 9A38.40 | |
| PIRA 1000 | 3/4" tape deck | 9A38.45 | |
| UMN, 9A38.45 | 3/4" tape deck | 9A38.45 | |
| PIRA 1000 | IBM clone | 9A38.50 | |
| UMN, 9A38.50 | IBM clone | 9A38.50 | |
| PIRA 1000 | Mac | 9A38.60 | |
| UMN, 9A38.60 | Mac | 9A38.60 | |
| | **Photography** | **9A40.00** | |
| AJP 30(12),921 | strobe photography | 9A40.10 | A strobe photography primer. |
| AJP 37(2),227 | strobe photography | 9A40.11 | On using the Polaroid "Big Swinger" camera with a rotating disk strobe. |

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| AJP 42(5),387 | light flasher for lab | 9A40.12 | Design of a small battery powered light flasher with "grain of wheat" lamps. |
| AJP 39(3),343 | miniflashers for "strobe" photos | 9A40.12 | Circuit design for a small battery powered neon flasher. |
| TPT 28(1),12 | high-speed flash photography | 9A40.15 | A long article on high speed flash photography with sound triggering. |
| AJP 58(4),397 | video peak store | 9A40.18 | A video technology that combines several images into a single frame resembling strobe photography. |
| AJP 38(8),1044 | scope camera | 9A40.20 | A scope camera made from a 2 lb coffee can and a Polaroid camera. |
| AJP 37(2),226 | scope camera | 9A40.20 | A hood design for using the Polaroid CU5 camera with Tektronix oscilloscopes. |
| AJP 36(11),1022 | polaroid positive and negative | 9A40.30 | Treat the negatives with an 18% solution of sodium sulfite. |
| AJP 38(3),385 | Schlieren photography | 9A40.40 | Diagram of an optical system for Schlieren photography, suggestions of interesting Schlieren effects. |
| AJP 44(3),308 | Polaroid ED-10 attachment | 9A40.50 | An attachment for mounting the Polaroid ED-10 camera on divided circle spectrometers. |
| AJP 44(3),309 | Polaroid ground glass back | 9A40.50 | On making a ground glass back for Polaroid cameras. |
| | **X-Y, Chart Recorders** | **9A50.00** | |
| AJP 38(8),1046 | chart recorder pen | 9A50.01 | Use a Leroy reservoir pen on a Leeds and Northrup or Brown chart recorder. |
| AJP 46(10),1082 | projection plotter | 9A50.10 | Replace the X-Y recorder plate with a Fresnel mirror and use as the stage on an overhead projector. |
| AJP 30(6),439 | X-Y projection plotter | 9A50.10 | Apparatus Drawings Project No 28: Mechanical and electrical construction plans for a plotter designed to fit the 10x10 stage of an overhead projector. |
| AJP 34(4),361 | projection X-Y plotter | 9A50.10 | A long extension arm translates the motion from an X-Y plotter to an adjacent overhead projector. |
| Mei, 7-1.9 | X-Y projection plotter | 9A50.10 | An X-Y projection plotter, Pictures, Diagram, Construction details in appendix, p.537. |
| Mei, 7-1.11 | X-Y projector plotter | 9A50.10 | The Huston X-Y recorder is adapted for the overhead projector. Pictures. |
| AJP 33(11),xvii | X-Y recorder | 9A50.11 | Two Heath Servo Recorders are used (non-destructively) to make an X-Y recorder that is suitable for overhead projection. |
| Mei, 7-1.10 | X-Y projection plotter | 9A50.11 | An X-Y recorder is constructed from two Heath Servo Recorders without disabling either unit. Diagram. |
| AJP 37(9),861 | spot follower attachment | 9A50.14 | Two photocells in a bridge arrangement to attach to a chart recorder. Made for the Cavendish experiment. |
| AJP 53(8),792 | cheap optical scanner | 9A50.15 | Mount a photocell at the pen location of a computer controlled X-Y plotter. |
| | **Buildings** | **9A60.00** | |
| AJP 38(11),1366 | "The Design of Physics Buildings" | 9A60.10 | Book review: "The Design of Physics Buildings", from England. Also mentions "Modern Physics Buildings" |
| AJP 33(12),1050 | science lecture hall - Berkley | 9A60.10 | A 550 seat hall with triangular rotating stage and CCTV facilities. |
| AJP 36(10),964 | lecture auditoria design | 9A60.10 | Design of a 380 seat auditorium. |
| AJP 41(11),1233 | Frank C. Waltz Lecture Halls | 9A60.10 | Post use review of new lecture halls with rotating stage. |
| AJP 29(1),50 | physics building classroom addition | 9A60.10 | Discussion of a building project. |
| AJP 30(11),841 | about lecture tables | 9A60.20 | Cover your black table tops with matte white. |
| AJP 33(1),45 | Kansas State building | 9A60.40 | Floor plans, construction details, and special features of a new physics-math building at Kansas State University. |
| AJP 31(6),417 | physics building at UC - Riverside | 9A60.40 | Planning and plans for a building for a twenty staff, ninety grad students and a 300 seat lecture hall with rotating front. |
| AJP 29(11),753 | Pierre S. du Pont Science Building | 9A60.40 | Article on building design with particular attention on procedure in planning. |
| | **Museums** | **9A65.00** | |
| AJP 43(12),1049 | physics learning center | 9A65.01 | Description of the physics learning center at UC Santa Barbara. |
| AJP 40(7),978 | The Exploratorium | 9A65.01 | Description of the Exploratorium. |
| AJP 39(3),243 | European scientific museums | 9A65.01 | A survey of west European scientific museums. |
| AJP 40(3),433 | modern physics in European museums | 9A65.01 | Four museums display some discovery apparatus in modern physics. |
| | **Resource Books** | **9A70.00** | |
| AJP 47(10),835 | resource letter PhD-1 | 9A70.10 | A listing of many sources of information on lecture demonstrations. |
| AJP 32(1),56 | Soviet lecture demonstrations | 9A70.20 | A translation project on a series of eight volumes on lecture demonstrations is available in microfilm. |
| | **Unclassified Demonstrations** | **9A73.00** | |
| AJP 40(1),183 | rope sliding off table | 9A73.01 | Analysis of the rope sliding off the table for beginning students. |
| AJP 42(12),1123 | surface plasmons on gold | 9A73.01 | A demonstration of the surface plasmons at the gold-air interface. |
| AJP 35(6),482 | apparatus competition awards | 9A73.10 | List of awards for the 1967 apparatus competition awards - three lecture demonstration, three undergraduate laboratory. |

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| TPT 28(7),495 | Ballistic Pendulum demonstrations | 9A73.11 | Five additional demonstrations using the Ballistic pendulum. |
| TPT 28(7),492 | demo collection | 9A73.12 | Ten demonstrations from "Turning the World Inside Out". This book should be entered into the bibliography at some point. |
| TPT 28(5),312 | meter stick mechanics | 9A73.13 | Five standard demonstrations performed with meter sticks: reaction time, finding the center of mass, cantilevered stack, greater than "g", pendulum vibrations. |
| AJP 44(6),602 | corridor displays | 9A73.20 | A list of twenty interactive displays in corridor glass cabinets. |
| AJP 34(8),660 | quantitative corridor exhibits | 9A73.20 | These corridor type exhibits are actually used as low cost laboratories. Not much description of individual displays. |
| AJP 53(7),690 | second order phase transition model | 9A73.30 | A mechanical model exhibits spontaneous symmetry breaking similar to that in a ferroelectric material. |
| AJP 53(12),1172 | bird-in-shell toy | 9A73.31 | A discussion of the bird-in-shell toy exhibiting a catastrophe similar to first-order phase transition. |
| AJP 47(6),539 | air table interstitial atoms | 9A73.32 | Magnetic cylinders on an overhead projector air table demonstrate all the features of dumbbell shaped interstitial atoms. |
| Sprott, 6.13 | fractals | 9A73.40 | Transparencies or computer images containing fractals are projected on the wall or screen. |
| TPT 46(8), 473 | Diet Coke and Mentos | 9A73.50 | An open ended experiment that explores the variables of the Diet Coke and Mentos reaction. |
| AJP 76(6), 551 | Diet Coke and Mentos | 9A73.50 | Experiments that identify the surface roughness for bubble growth sites and the chemical reaction of potassium benzoate and aspartame as the two main reasons for the explosive reaction. |
| AJP 77(8), 677 | Diet Coke and liquid nitrogen | 9A73.50 | Direct immersion of an open bottle of Diet Coke into liquid nitrogen can also cause rapid nucleation and a violent reaction. |
| AJP 77(4), 293 | Diet Coke and iron filings | 9A73.50 | Iron filings are a substitute for Mentos in the popular reaction. |
| | **Philosophy** | **9A75.00** | |
| AJP 30(8),594 | films vs. demonstrations | 9A75.10 | A study finding the use of films in place of demonstrations is an effective instructional tool. |
| AJP 39(4),454 | cost of labs and lecture | 9A75.10 | Cost per student contact hour for labs and lecture is compared. |
| AJP 51(4),305 | conceptual physics lecture | 9A75.11 | Paul G. Hewitt's Millikan lecture 1982 on conceptual physics. |
| AJP 28(4),306 | rationale of lecture demonstrations | 9A75.11 | Four unique contributions lecture demonstrations make to physics teaching. |
| AJP 51(4),297 | philosophy of lecture demonstrations | 9A75.11 | The activity of "demonstrating" is actually one of the many ways of doing physics, and more straight talk from Harald C. Jensen. |
| AJP 28(6),539 | Wesleyan conference summary | 9A75.12 | Summary of the conference on lecture demonstrations listing eight points and ten recommendations. |
| AJP 35(5),440 | labs as lecture demonstrations | 9A75.20 | Set up labs as lecture demonstrations in such a way that allows all the students to take data directly in their lecture seats. Example of a glider on an inclined air track. |
| AJP 45(5),433 | demonstration homework problems | 9A75.23 | Demonstration problems as homework performed at the Physics Learning Center. |
| AJP 28(3),263 | "Continental Classroom" reviews | 9A75.50 | Three appraisals of the "Continential Classroom" television program featuring Harvey White. |
| AJP 28(4),368 | physics on TV | 9A75.50 | Harvey E. White discusses the turntable lecture room front and teaching from a studio. |
| M-002 (D&R) | buttons & signs | 9A75.60 | Make bumper stickers or buttons with puns and slogans. Several are shown. |
| D&R, M-002 | buttons and signs | 9A75.60 | Buttons and signs with puns and logos. |
| D&R, O-045 | buttons and signs | 9A75.60 | Sign of Maxwell's Equations. |
| D&R, M-006 | buttons and signs | 9A75.60 | Buttons and signs with puns and logos. |
| | **Films** | **9A80.00** | |
| AJP 41(4),604 | Kodansha color slide set | 9A80.05 | Review of the Kodansha set of 360 color slides. |
| AJP 45(4),384 | quantum computer generated images | 9A80.05 | Description of a set of computer generated slides. |
| AJP 41(6),848 | physics transparencies | 9A80.06 | Review of a collection of 82 color transparencies with 159 overlays. |
| AJP 44(12),1236 | films released | 9A80.10 | A list of 17 films released. |
| AJP 44(11),1146 | films released | 9A80.10 | List of 25 films released, some film loops. |
| AJP 44(8),811 | films released | 9A80.10 | A list of 19 films released. |
| AJP 44(10),1022 | films released | 9A80.10 | A list of 18 films released, includes some film loops. |
| AJP 36(4),302 | films - 16 mm (1020) | 9A80.10 | A list of 1020 films by field, with addresses of distributors. (1968). |
| AJP 44(4),407 | films released | 9A80.10 | A list of 23 films released. |
| AJP 44(2),197 | films released | 9A80.10 | A list of eighteen films released. |
| AJP 36(6),475 | resource letter - films | 9A80.10 | A resource letter on physics films. 149 films were selected with brief annotation. |
| AJP 30(5),321 | film listing - 220 films | 9A80.10 | 220 more films are added to the 1960 list. |

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| AJP 29(4),222 | films for physics - 1960 | 9A80.10 | 450 films listed by field with distributors. |
| AJP 44(6),621 | films released | 9A80.10 | A list of 28 films released. |
| AJP 33(10),806 | single concept films | 9A80.11 | Franklin Miller introduces the concept of single concept films. |
| AJP 35(3),177 | making quantum computer movies | 9A80.20 | The details of generating computer movies in quantum mechanics. |
| AJP 39(1),4 | short films | 9A80.20 | The Millikan lecture (1970) by Franklin Miller, Jr. on making short physics films. |
| AJP 30(7),517 | making physics films | 9A80.20 | Twenty single concept films were produced. Film production from a physicist's perspective. |
| AJP 39(5),588 | film competition | 9A80.21 | Announcement of the third film competition (1972). |
| AJP 35(2),166 | films released | 9A80.21 | List of fifteen films released for commercial distribution by Education Services Inc. |
| AJP 44(1),116 | film loop review | 9A80.23 | "Electrostatic Series" 19 film loops; Baez, Powell, and Bosserman; Encyclopedia Britannica Education Corp.; color. |
| AJP 44(4),406 | film review | 9A80.25 | "The Plutonium Connection" and "A Small Case of Blackmail" 60 min. and 27 min. (1976?). |
| AJP 32(1),62 | film/film loops: Ripple Tank | 9A80.25 | Film Review: "Ripple Tank Wave Phenomena" (Series of three): B&W, 25 min, 19 min, 23 min, (1963?) ALSO: Nine film loops of the same. |
| AJP 41(8),1034 | film loop review | 9A80.25 | Review of the fifteen loops in the "Standing Waves Series" Produced by Encyclopedia Britannica Education Corp. |
| AJP 44(6),619 | film loop review | 9A80.25 | "Relativity, A series of Computer Animated Films", set of eight, Houghton Mifflin. |
| D&R, S-030 | film loop - Relativistic Ride | 9A80.25 | Computer animated visual effects of the finite velocity of light. Also, includes the effects of time dialation and the Penrose-Terrell rotation. |
| AJP 44(10),1021 | film loop review | 9A80.25 | "Skylab Film Series" , set of 12. |
| AJP 43(3),290 | Skylab film loops | 9A80.26 | The AAPT purchased two miles of unedited film from the skylab missions. The thirteen edited loops are announced here. |
| AJP 44(11),1144 | film loop review | 9A80.30 | "Lissajous Figures and Phase Measurements" and "Lissajous Figures and Frequency Measurements" |
| AJP 40(10),1502 | computer film notes | 9A80.30 | Notes on generating the computer film loop "Eigenvalues in Quantum Mechanics" |
| AJP 40(1),46 | dynamic electric field pictures | 9A80.30 | The equations for generating pictures of the electric fields of various moving charges. |
| AJP 40(2),343 | film loop review | 9A80.30 | The physical significance of the bumps occurring in the momentum-space representation is elucidated. |
| AJP 37(5),514 | computer film notes | 9A80.30 | Complete background for the film loop "Expanding Wavefronts in Special Relativity" |
| AJP 38(8),984 | hydrogen wave functions - computer | 9A80.30 | Description of the mathematics of the film loop "Quantum-Mechanical Wave Functions of the Hydrogen Atom" |
| AJP 40(11),1657 | computer film notes | 9A80.30 | Notes on a series of computer generated films for solid state physics - "Wave Packets in Periodic Potentials" |
| AJP 34(6),470 | quantum-mechanical harmonic oscillator | 9A80.30 | A description of the "Quantum Mechanical Harmonic Oscillator" film loop and the possibility of other films. |
| AJP 39(8),952 | computer film notes | 9A80.30 | Background for the film loop "Tunneling Between Two Square Wells". |
| AJP 41(6),836 | computer film loop notes | 9A80.30 | Notes on "Synchrotron Radiation", a fifth film in the series Electric Fields of Moving Charges. |
| AJP 39(12),1540 | film loop notes | 9A80.30 | Notes on making the computer generated series of four film loops on electric fields of moving charges. |
| AJP 36(5),412 | film notes | 9A80.30 | Film notes on "Image Methods in Electrostatics" computer animated film loop. |
| AJP 44(8),810 | film loop review | 9A80.30 | "Kinetic Theory by Computer Animation", 11 films, Fitch, Kinsley, and Martin. |
| AJP 31(5),400 | film review: Forces (PSSC) | 9A80.40 | Film Review: "Forces" (PSSC), B&W, 23 min, (1963?) -- Excerpt 7 1/2 min. |
| AJP 44(4),405 | film review | 9A80.40 | "Wave-Particle Duality" color, 2min., British Films, Ltd. (1976?). |
| AJP 31(7),552 | film review | 9A80.40 | Film Review: "Time and Clocks" (PSSC), B&W, 27 min. (1963?) |
| AJP 42(11),1047 | film review | 9A80.40 | "Refraction, Dispersion and Resonance" color, sound, 35 min., (1973). |
| AJP 44(5),499 | film review | 9A80.40 | "Galileo: The Challenge of Reason" color, 26 min. Learning Corp of America (1970). |
| AJP 31(5),390 | film announcement | 9A80.40 | Announcement of "the Ultimate Speed" and "Time Dilation" |
| AJP 39(7),849 | film review | 9A80.40 | Film Review: "The World of Enrico Fermi" 16mm, B&W, 47 min, (1970), Harvard Project Physics. |
| AJP 44(12),1234 | film review | 9A80.40 | "P-N Junction" and "The Crystal Diode" 14 and 18 min. |
| AJP 44(11),1145 | film review | 9A80.40 | "Fusion: The Ultimate Fire" color, 15 min., (1976?). |
| AJP 44(5),498 | film review | 9A80.40 | "Technology: Catastrophe or Commitment?" color, 24 min., Hobel-Leiterman Productions, (1976?). |
| AJP 31(9),735 | film review | 9A80.40 | Film Review: "Measuring Large Distances" (PSSC), B&W, 29 min., (1963?) |

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| AJP 44(4),405 | film review | 9A80.40 | "Life and the Structure of Hemoglobin" color, 30 min, KCET (1976?). |
| AJP 31(6),463 | film review: Inertial Mass (PSSC) | 9A80.40 | Film Review: "Inertial Mass", B&W, 19 1/2 min., (1963?) |
| AJP 44(12),1236 | film review | 9A80.40 | "Schlieren" 18 min. |
| AJP 44(5),499 | film review | 9A80.40 | "Ee Yi Ee Yi Oh" color, 10 min. Perennial Education Inc. (1976?). |
| AJP 43(7),659 | film review | 9A80.40 | "Volta and Electricity", color, sound, 33 min., Samuel Devons |
| AJP 30(11),844 | film review: An Experiment in Physics | 9A80.40 | Film review of "An Experiment in Physics", B&W, 23 min, (1962?). |
| AJP 31(9),735 | film review | 9A80.40 | Film Review: "Coulomb's Law", "Coulomb's Force Constant", B&W, 30 min. each, (1963?) |
| AJP 44(8),810 | film review | 9A80.40 | "The Fossil Affair", color, 24 min., (1976?). |
| AJP 43(5),473 | film review | 9A80.40 | "Albert Einstein: The Education of a Genius" color, sound, 44 min., Films for Humanities. (1975?) |
| AJP 44(12),1235 | film review | 9A80.40 | "The Energy Crunch" - three films series. 40, 34, 38 min. |
| AJP 44(10),1021 | film review | 9A80.40 | "The Kinematics of Vectors" color, 30 min. |
| AJP 44(5),498 | film review | 9A80.40 | "Day of the Dark Sun" color, 17 min. Iowa State, (1976?). |
| AJP 43(12),1120 | film review | 9A80.40 | "Explorations in Space and Time" Series of eight, color, sound, 7-10 min each, Houghton Mifflin. (1973). |
| AJP 44(7),718 | film review | 9A80.40 | "Space: Life Out There", color, 24 min., (1976?). |
| AJP 44(11),1146 | film review | 9A80.40 | "Birth and Death of a Star" color, 30 min. |
| AJP 42(6),525 | film review | 9A80.40 | "Introduction to Lasers" color, 17 min. Encyclopedia Britannica Corp. (1974?) |
| AJP 31(5),342 | film background -"Rel.Time Dilation" | 9A80.40 | A long background article on the experiment that was the basis of the film "Time Dilation - An Experiment With mu-Mesons" |
| AJP 44(9),901 | film review | 9A80.40 | "Railroad to the Stars", "Solar Eclipse", "A Stranger Near the Sun", NSF, color, sound, 5 min each. |
| AJP 39(9),1102 | film review | 9A80.40 | "Laser Light" 37 1/2 min., Color, (1971? |
| AJP 30(12),932 | film review | 9A80.40 | Film Review: Archimedes' Principle, B&W, 6 min, (1953). |
| AJP 31(11),889 | film review | 9A80.40 | Film Review: "Time Dilation", B&W, 37 min, (1963?) |
| AJP 31(7),552 | film reviews | 9A80.40 | Film Review: "Long Time Intervals" (PSSC), B&W, 24 min. (1963?) |
| AJP 44(11),1144 | film review | 9A80.40 | "Museum of the Solar System", color, 23 min., (1976?). |
| AJP 32(7),571 | film review | 9A80.40 | Film Review: "Similarities in Wave Behavior", B&W, 27 1/2 min, (1964?) Bell Laboratories, John Shive |
| AJP 31(7),552 | film reviews | 9A80.40 | Film Review: "Short Time Intervals" (PSSC), B&W, 22 min. (1963?) |
| AJP 44(12),1234 | film review | 9A80.40 | "The Ultimate Energy" 28 min. |
| AJP 42(9),804 | film review | 9A80.40 | You Can't Go Back" color, sound, 6 min., Elementary Penguin Productions. |
| AJP 42(9),803 | film review | 9A80.40 | "Anti-Matter" color, animated, sound, 12 min., UCLA Animation Workshop. (1973). |
| AJP 43(2),203 | film review | 9A80.40 | "Introduction to Holography" color, sound, 17 min., Encyclopedia Britannica Corp. (1975). |
| AJP 43(8),752 | film review | 9A80.40 | "The Physicists: Playing Dice with the Universe", color, sound, Document Associates, (1975?). |
| AJP 31(4),307 | film: Mechanical and Thermal Energy | 9A80.40 | Film Review: Mechanical and Thermal Energy, B&W, 22 min, (1963?). |
| AJP 32(7),571 | film review | 9A80.40 | Film Review: "Simple Waves", B&W, 27 min, (1964?) Bell Laboratories, John Shive |
| AJP 44(2),197 | film review | 9A80.40 | "The Ultimate Machine" color, 30 min., Time-Life (1971). |
| AJP 33(5),414 | film review: | 9A80.40 | Film review: "Liquid Helium II: The Superfluid" 16min., B&W (1965?) |
| AJP, 50 (3), 202 | superfluid helium | 9A80.40 | Resource letter SH-1: superfluid helium. |
| AJP 33(10),859 | film review | 9A80.40 | Film Review: "Lasers. Coherent Light Sources for Science and Industry: the Princeton Report" Color, 30 min. |
| AJP 31(6),463 | film review: Inertia (PSSC) | 9A80.40 | Film Review: "Inertia", B&W, 27 min., (1963?) |
| AJP 32(3),234 | film Review: The Ultimate Speed | 9A80.40 | Film Review: "The Ultimate Speed", B&W, 38 min, (1963?) |
| AJP 44(6),617 | film review | 9A80.40 | "Wondering About Things", color, 22 min. |
| AJP 33(1),63 | film review: Matter Waves | 9A80.40 | Film review: "Matter Waves", Bell Laboratories, B&W, 28 min. |
| AJP 44(9),902 | film review | 9A80.40 | "Power from the Earth", "Putting the Sun to Work", NSF, color, 12 min, 4 min. |
| AJP 31(9),735 | film review | 9A80.40 | Film Review: "Speed of Light" (PSSC), B&W, 21 min., (1963?) |
| AJP 30(10),772 | film review: Photons | 9A80.40 | Film review of "Photons", B&W, 19 min, 1962? |
| AJP 31(5),400 | film review: Frames of Reference (PSSC) | 9A80.40 | Film Review: "Frames of Reference" (PSSC), B&W, 28 min, (1963?) -- Excerpt I - 7 min., Excerpt II - 5 1/2 min. |
| AJP 43(12),1121 | film review | 9A80.40 | "Shadows of Bliss" color, sound, (1972). |
| AJP 44(6),618 | film review | 9A80.40 | "Keyhole to Eternity", color, 27 min., (1976?). |
| AJP 44(7),718 | film review | 9A80.40 | "Science New Frontiers Series - No Easy Answers" color, 14 min., (1976?). |
| AJP 31(9),735 | film review | 9A80.40 | Film Review: "Change of Scale" (PSSC), B&W, 23 min., (1963?) |
| AJP 31(6),462 | film announcement | 9A80.40 | "Liquid Helium II, The Superfluid", B&W, 40 min., (1963?) |

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| AJP 44(1),116 | film review | 9A80.40 | Joseph Fraunhoffer: Dispersion" and "Joseph Fraunhoffer: Diffraction" color, sound, 16, 14 min. (1975). |
| AJP 30(10),772 | film: Interference of Photons | 9A80.40 | Film review of "Interference of Photons", B&W, 14 min., PSSC, (1962?) |
| AJP 44(9),902 | film review | 9A80.40 | "Action and Reaction" color, sound, 15 min., (1967). |
| AJP 44(9),900 | film review | 9A80.45 | "Take the World from Another Point of View" 3/4" video, 60 min. |
| | **Computer Programs** | **9A85.00** | |
| AJP 44(8),792 | analog computer uses | 9A85.05 | Additional uses of the analog computer as a teaching aid. |
| AJP 42(1),75 | analog computer module | 9A85.05 | The Analog Devices 433 multifunction module simplifies analog computer simulations. |
| AJP 44(11),1139 | Heath analog computer modification | 9A85.05 | An op amp module replaces the vacuum tube op amps in the Heath ES-201 computer. |
| AJP 42(7),591 | Fourier transform with analog computer | 9A85.05 | Use the EIA TR-20 instructional analog computer to find the Fourier transform of some real, even functions. |
| AJP 41(5),622 | analog computer applications | 9A85.05 | Description of the analog computer with applications in harmonic motion, quantum mechanics, and radioactive decay. |
| AJP 36(12),1088 | quantum mechanical ripple tank | 9A85.10 | Graphical presentations of the probability density of a scattering problem. |
| AJP 53(7),694 | alternate velocity conception | 9A85.20 | A program identifies students who use position criterion for judging when two objects are moving with the same velocity and includes a remedial program. |
| AJP 39(5),539 | waves in media: BASIC program | 9A85.30 | A program showing waves in a dispersive media with a listing in BASIC. |
| AJP 36(9),907 | FORTRAN mechanics programs | 9A85.30 | Brief descriptions of 11 dynamics programs for tutorial use. |
| AJP 35(5),434 | "Photographic" objects - relativity | 9A85.30 | A tutorial fortran program in special relativity to investigate the "photographic" appearance of objects moving past the camera at relativistic speeds. |
| AJP 35(3),275 | the square well | 9A85.30 | A sequence of five programs (printout of one, student handouts shown) allowing the student to explore several features of the square well. |
| AJP 36(3),273 | simple pendulum experiment | 9A85.30 | Description of a tutorial program in FORTRAN. |
| AJP 37(4),386 | Hamilton's principle of least action | 9A85.30 | A PDP-1 based tutorial program. |
| AJP 39(4),442 | optics programs - BASIC | 9A85.30 | Three simple optics programs in BASIC. Listings. |
| | **ELECTRONIC** | **9B00.00** | |
| | **Timers** | **9B10.00** | |
| AJP 37(5),563 | spark timer | 9B10.10 | A transistorized spark timer. |
| AJP 36(1),60 | transistorized spark timer | 9B10.10 | Circuit diagram for a transistorized spark timer. |
| AJP 48(4),321 | spark timer circuit | 9B10.10 | A complete spark timer circuit. |
| AJP 40(3),487 | solid state spark timer | 9B10.10 | Another circuit. |
| AJP 37(3),326 | spark timer | 9B10.10 | A solid state spark timer with five frequencies between 5 and 60 Hz. |
| AJP 36(7),642 | spark timer | 9B10.10 | Circuit diagram for a simple low cost solid state synchronous spark timer. |
| AJP 41(5),743 | wide range spark timer | 9B10.10 | Six ranges from 5 to 120 Hz. |
| AJP 36(8),761 | double sparker for air track | 9B10.10 | Replace the jumper wire on each cart with a parallel RC combination. |
| AJP 40(10),1549 | spark timer for air track | 9B10.10 | A spark timer for the Eduquip air track. |
| AJP 48(11),989 | spark timer modification | 9B10.11 | Cenco spark timer modification. |
| AJP 29(6),367 | spark timer | 9B10.12 | Circuit for a tube based AC spark generator. |
| AJP 34(6),536 | electronic spark timer | 9B10.12 | A tube based variable frequency spark timer. |
| AJP 35(6),ix | spark timer | 9B10.13 | A DC relay combined with a RC circuit to form a relaxation oscillator. |
| AJP 40(12),1864 | double spark timer - air track | 9B10.14 | Plans for a double spark timer for the air track. |
| AJP 39(5),566 | coincident spark timer | 9B10.14 | A coincident spark timer starts sparking at the manual release of the glider. Improves the first mark timing for impulse experiments. |
| AJP 37(10),1065 | double sparker for air track | 9B10.14 | Another double sparker method. |
| AJP 37(4),455 | double sparker note | 9B10.14 | Re: AJP 36,761 (1968), recommends a different capacitor. |
| AJP 36(4),ix | two-glider spark records | 9B10.14 | Leave the air track floating and attach the spark timer across the two wires. |
| AJP 41(6),831 | continuous spark timer record | 9B10.15 | The spark timer paper strip is replaced by a rotating cylinder. |
| AJP 29(8),498 | electric stop clock control | 9B10.20 | Apparatus Drawings Project No. 20: A system for controlling a timer with photoconductive cells and/or electric contacts. |
| AJP 43(12),1076 | electric timer control | 9B10.20 | A circuit for cycle counting and clock control. |
| AJP 51(2),183 | versatile digital timer | 9B10.21 | An inexpensive hardwired timer based on the 7217A timer chip. |
| AJP 46(8),864 | sequential timer | 9B10.22 | A timer to sequentially switch many channels into a single channel strip chart recorder. |
| AJP 28(5),507 | household clock conversion | 9B10.23 | Add a rectifier in parallel with the switch to stop the residual motion of the clock motor. |
| AJP 31(2),132 | time switch for corridor display | 9B10.24 | Circuit for a switch with a reset timer that will open after times from a few seconds to ten minutes. |
| AJP 43(11),1017 | lecture room counter | 9B10.28 | Complete plans and circuit boards for a high speed counter with 22 cm high display. |
| AJP 34(8),iv | scaler as timer | 9B10.30 | Gate a 100 KHz oscillator to a scaler. |

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| AJP 33(2),xiii | scaler becomes photocell timer | 9B10.30 | Circuit diagram for interfacing scalers to photocell timers. |
| AJP 28(9),817 | free fall timer | 9B10.30 | Gate a multivibrator to a scaler. |
| AJP 33(6),v | interval timing with a scaler | 9B10.30 | Gate a tuning fork oscillator to a scaler. |
| AJP 40(8),1168 | photodiode gate | 9B10.31 | A photodiode gate for the Beckman-Berkeley electronic timer. |
| AJP 44(8),803 | light operated millisecond timer | 9B10.32 | Light activated gating of a 555 timer running at 100 kHz. |
| AJP 49(7),701 | big X4 timer | 9B10.40 | Abstract from the 1981 apparatus competition of a 1 ms timer with 2.8 in high digits. |
| AJP 45(9),881 | phototransistor adaptor | 9B10.45 | A photo transistor adaptor to control stopclocks, digital stopwatches, and digital timers. |
| AJP 43(3),280 | pendulum counter/timer | 9B10.50 | Circuit for a timer using a photocell that keeps track of the total time and the number of cycles. |
| AJP 45(11),1126 | pulse counter | 9B10.60 | Modify a four function pocket calculator to function as a pulse counter. |
| | **Position and Velocity Detectors** | **9B15.00** | |
| Mei, 7-1.8 | kinematics instrumentation | 9B15.10 | Motors, plotters, electronics, etc. to show simultaneous correlation between actual displacement, velocity, and acceleration. Diagrams and pictures. |
| AJP 42(5),409 | ladder of light | 9B15.11 | Reflect a beam across an air track many times and record the output of a audioamp. |
| AJP 40(1),202 | air track velocity meter | 9B15.12 | A capacitor is charged while a light beam is blocked. |
| AJP 56(10),950 | air track timing circuit | 9B15.13 | A circuit that interfaces five digital stop watches to five gates on the air track. |
| AJP 48(8),685 | mechanical start-stop gates | 9B15.14 | Mechanical gates instead of photogates control relays which in turn can control something else. |
| AJP 52(3),281 | model race track kinematics | 9B15.15 | Twenty optical sensors with an Apple computer interface are attached to a model race track to give successive time intervals. |
| AJP 56(8),739 | distributed infrared detector | 9B15.15 | Forty-six permanently mounted emitter-detector pairs are interfaced to a computer. |
| AJP 48(1),85 | multitimer air track system | 9B15.16 | Photoelectric sensors combined with solid state memories store a sequence of time intervals which are then transferred to a digital display. |
| AJP 55(11),1050 | multiphotogate timer system | 9B15.16 | A multiprocessor based multiphotogate array system that allows the time interval between any set of gates to be displayed by selecting from a keyboard. |
| AJP 50(4),381 | air track multitimer | 9B15.16 | As the air cart passes along a tape with holes, a light beam is transmitted to a photodetector. A circuit is given to store and read out the timing information. |
| AJP 54(10),894 | ultrasonic ranging module interface | 9B15.20 | Interface the TI sonar ranging module to an Apple II through the game port. |
| AJP 55(7),658 | two glider ultrasonic ranging | 9B15.21 | Modification of the Western and Crummett system (AJP 54,894) to accommodate two gliders. |
| TPT 28(6)423 | corner reflectors with sonic detect. | 9B15.22 | Simple corner reflectors eliminate alignment problems with reflectors. |
| AJP 45(8),711 | air track Doppler radar | 9B15.28 | A homodyne Doppler velocimeter with two parallel explanations. |
| AJP 35(2),159 | air track Doppler radar | 9B15.28 | Use X-band radar for air track velocity measurements. |
| AJP 44(9),879 | air track ultrasonic Doppler | 9B15.29 | Ultrasonic Doppler shift measurement of the velocity of an air track glider. |
| AJP 53(1),86 | air track glider position | 9B15.30 | Ferrite magnets on the air track glider pass by a wire bent into a square wave and the induced pulses are shaped and then recorded by a microcomputer. |
| AJP 50(1),84 | induction transducer position sensor | 9B15.31 | A triangular shaped coil is used in an induction system. |
| AJP 41(3),419 | air track induction speedometer | 9B15.32 | Magnets mounted on the air cart pass on both sides of a long squarewave shaped copper wire that goes to an amplifier and oscilloscope. |
| AJP 43(4),375 | air track inductive recorder | 9B15.35 | A container of fine iron particles in suspension on the cart moves past microphones attached to a tape recorder. |
| AJP 37(3),327 | air track timer | 9B15.40 | Circuit for a timer that reads out a voltage proportional to the speed of an object. |
| AJP 36(1),61 | y-t air track recorder | 9B15.50 | A roll of spark paper is used to obtain y-t records of an air track. |
| | **Sources of Sound** | **9B17.00** | |
| Sut, S-67 | point source of sound | 9B17.10 | A mechanical apparatus coupled to a resonator to produce a point source of sound. |
| Mei, 19-4.16 | noise generators | 9B17.20 | Sources of noise and their use in some demonstrations. |
| AJP 50(7),669 | photoacoustic generator | 9B17.30 | Chop an intense light beam illuminating a sealed blackened funnel. |
| Hil, O-7k | acoustical radiator | 9B17.30 | Four speakers at one end of a glass lined box make a 5-10 KHz acoustical radiator. Reference: AJP 17(12),581. |
| AJP 42(9).780 | edge tone generator | 9B17.40 | Produce tones by blowing air by a wedge. |

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| Sut, S-58 | high pitched whistle | 9B17.90 | Directions for making a high pitched whistle. Diagram. |
| Sut, S-60 | directional sound source | 9B17.91 | Directions for constructing a directional sound source using a high pitched whistle. Diagram. |
| | **Sound Detectors** | **9B18.00** | |
| Sut, S-75 | microphones | 9B18.10 | Connecting a carbon-granule microphone to a tube amplifier. |
| Sut, S-76 | manometric flames | 9B18.20 | A rubber diaphragm in a device (diagram) controls flame height which is viewed in a rotating mirror. |
| Hil, S-3e | manometric capsule | 9B18.20 | A sensitive flame is viewed with a rotating mirror. |
| Mei, 17-7.4 | sensitive flame | 9B18.30 | Noise changes a high-calm flame to the turbulent state. Leybold No. 41197. |
| Sut, S-71 | sensitive flames | 9B18.30 | Hold copper gauze above a jet and light. |
| Sut, S-70 | sensitive flames | 9B18.30 | A hood for a ordinary Bunsen burner (Diagram) that will produce a flame sensitive to sound. |
| Sut, S-69 | sensitive flame | 9B18.30 | A flame lit at the end of a glass tube drawn into a fine tip can be tuned to be very sensitive to sound. |
| Sut, S-72 | sensitive flames | 9B18.30 | A Bunsen burner with air holes covered and gas pressure reduced becomes sensitive to sound. |
| Sut, S-73 | Sensitive liquid jet | 9B18.35 | Make a sensitive jet in an aquarium to show conclusively that the jet and not the flame is sensitive. |
| Mei, 19-9.1 | sound amplification with water | 9B18.36 | A tuning fork coupled to a steady water stream breaks it up and the drops fall on a drum head. |
| Sut, S-74 | sensitive liquid jet | 9B18.36 | Place a tuning fork against a nozzle and let the drops hit a drumhead. Couple the drumhead to the nozzle with a rod for self sustaining oscillations. |
| Sut, S-78 | phonodeik | 9B18.40 | Diagrams of four phonodeiks and one phonelescope. All the devices are acoustic oscillographs using a diaphragm to move a small mirror. |
| Sut, S-77 | phonodeik | 9B18.40 | Cement a small mirror on a rubber diaphragm on one end of a tube. Reflect light off a rotating mirror to the small mirror onto a screen. |
| | **Circuits/Components/Inst.** | **9B20.00** | |
| AJP 56(7),665 | displacement transducer | 9B20.10 | An optical wedge made with a strip of 35 mm slide film. |
| AJP 32(11),xxiv | seismometer | 9B20.11 | A ceramic phonograph pick-up modified to be a seismometer, drives a oscilloscope directly. |
| AJP 35(3),xxii | electrometer display | 9B20.13 | Use the recorder output of an electrometer to drive a projection meter or lecture table meter. |
| AJP 34(3),xxix | inexpensive electrometer amplifier | 9B20.13 | Circuit for an inexpensive transistor electrometer amplifier. |
| AJP 40(4),623 | electrometer circuit | 9B20.13 | A solid state electrometer circuit. |
| AJP 36(10),969 | vacuum tube electrometer | 9B20.13 | Circuit for an inexpensive vacuum tube electrometer. |
| AJP 28(7),xiii | electrometer circuit | 9B20.13 | A three tube circuit to extend the range of a RCA Ultra-Sensitive DC Microammeter (Model WV-84A). |
| AJP 44(10),1016 | picoammeter | 9B20.14 | Circuit for a simple picoammeter with adjustable input potential. |
| AJP 34(7),vii | versatile test instrument | 9B20.20 | A circuit for a mercury pulser, sliding pulsar, and stable potentiometer. |
| TPT 3(5),226 | calibrating meters | 9B20.20 | Improves on TPT 3(2),78 (1965). Ammeter range switch and ohmmeter zero adjustment. |
| TPT 3(2),77 | meter tester | 9B20.20 | A tester to determine full scale current and internal resistance. |
| AJP 33(8),603 | inexpensive student potentiometer | 9B20.21 | A 0.1% student potentiometer and calibration source made from off the shelf parts. |
| AJP 35(10),xi | null indicator circuit | 9B20.21 | Add a battery and current limiting resistor to a bridge / microammeter null indicator. |
| AJP 35(7),iii | meter guard | 9B20.21 | Protect your meter movements. |
| AJP 42(2),108 | strain gauge | 9B20.23 | Apparatus competition merit award looks like the precursor of the PASCO product. |
| AJP 52(1),86 | precision voltage reference | 9B20.25 | Use a precision voltage reference built with an LM399 for use as a Wheatstone bridge reference. |
| AJP 34(12),xvi | use mototcycle batteries | 9B20.28 | Motorcycle batteries are a convenient size. |
| AJP 30(6),vi | infrared detector | 9B20.30 | Data for the Block Associates KH-51 indium antimonide photoconductive infrared detector. |
| AJP 44(2),188 | LED photometer | 9B20.30 | A circuit for using an LED as a light detector. |
| AJP 46(10),1079 | photodiode photometer | 9B20.30 | A photodiode photometer based on the PIN-125 photodiode and 741 op-amp. |
| AJP 42(1),77 | fringe intensity photometer | 9B20.30 | Mount a photocell on a traveling microscope stage. |
| AJP 28(6),563 | optical tachometer | 9B20.30 | Simple photodiode circuit detects black and white sides of a spinning top. |
| AJP 41(7),931 | photointerrupt module | 9B20.30 | On using the GE A13A1 photointerrupt module. |
| AJP 42(4),342 | solid state photometer | 9B20.30 | A high sensitivity solid state photometer based on the MRD 14B photo Darlington and ULN 2157 op amp. |
| AJP 57(10),840 | Pasco photogate evaluation | 9B20.30 | Thorough evaluation of the Pasco photogate. |

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| AJP 52(6),550 | selective surface solar radiometer | 9B20.30 | Black and white painted surfaces give directly an absolute determination of the solar irradiance. |
| AJP 35(12),ix | photometer | 9B20.30 | Make a photometer out of a meter and photosensitive resistance cell. |
| AJP 35(4),359 | inexpensive photodensitometer | 9B20.30 | Use a photodiode in conjunction with a X-Y recorder to make a direct reading photodensitometer. |
| AJP 44(4),399 | holography light meter | 9B20.30 | A selenium photocell hooked to a microammeter will give the reference to object beam ratio. |
| AJP 38(8),987 | small area photometer | 9B20.30 | Simple photometer for measuring small light intensities over small areas. Suitable for single and multiple slit experiments. |
| AJP 53(11),1108 | optical radiation power meter | 9B20.30 | A new accurate power meter based on new 100% efficient silicon photodiodes |
| AJP 34(3),240 | counting photons | 9B20.30 | Counting photons, here for the optical barrier penetration experiment, with a liquid N2 cooled photomultiplier (1P21). |
| AJP 55(12),1147 | inexpensive photometer | 9B20.30 | A photoresistor with a LED that lights when a preset level is exceeded. Use neutral density filters to vary range. |
| AJP 29(8),iv | light actuated PNPN switch | 9B20.30 | "Photran" light switch from Solid State Products. (1961) |
| Sut, A-101 | photomultiplier tube | 9B20.30 | Using the recently developed electron multiplier photocell. Picture. |
| AJP 34(10),xv | variable frequency switch | 9B20.35 | A transistor switch in series with a DC supply is used as a audio amplifier where waveform requirements are not stringent. |
| AJP 44(12),1228 | V to F | 9B20.35 | Simple three transistor V to F converter. |
| AJP 37(5),566 | transistor based opamp | 9B20.35 | Make a low noise, high input impedance opamp with transistors. Circuit given. |
| Sut, A-86 | mechanical model of a amplifier | 9B20.35 | A mouse trap triggering a rat trap is a mechanical model of a two stage amplifier. |
| Sut, A-85 | multistage tube amplifier | 9B20.35 | Circuit diagram for a multistage tube amplifier. |
| AJP 31(2),xi | temperature controller | 9B20.40 | Control the temperature of small systems to 0.2 C using a photoresistor in the light beam of a galvanometer. |
| AJP 47(1),120 | glass resistance thermometer | 9B20.40 | Use ordinary glass instead of a carbon glass thermistor to construct a inexpensive resistance thermometer. |
| AJP 58(12),1210 | temperature controller | 9B20.40 | A circuit for a wide range temperature controller for solid samples. |
| AJP 45(3),311 | millidegree temperature thermostat | 9B20.40 | Millidegree temperature control in a double oven chamber. |
| AJP 29(6),v | low temp thermistors | 9B20.40 | Announcement of a bead type "Veco" thermistor good down to liquid nitrogen temperatures. |
| AJP 57(11),1049 | LM 34/35 temperature sensor | 9B20.40 | National Semiconductor LM34/35 temperature sensors have 10 mV/deg outputs. |
| AJP 49(6),599 | inexpensive digital thermometer | 9B20.40 | A digital thermometer based on the AD590 and A/D converter with 6 digit LED driver. |
| AJP 45(3),312 | proportional temperature control | 9B20.40 | Millidegree temperature controller. |
| AJP 46(8),863 | differential thermostat | 9B20.40 | A low cost differential thermostat developed for use in solar energy control. |
| AJP 41(3),443 | simple diode radiometer | 9B20.40 | Circuit for a simple diode (1N 5179) radiometer. |
| AJP 33(5),xvii | strain gauge bridge | 9B20.45 | Circuit for a strain gauge bridge, used here to measure the deformation of a brass ring. |
| AJP 43(2),155 | phono cartridge as transducer | 9B20.45 | On the utility of inexpensive piezoelectric type phono cartridges as displacement transducers. |
| AJP 53(11),1108 | Motorola pressure transducer | 9B20.50 | A short note on the Motorola MPX100 pressure transducer. |
| AJP 39(3),348 | simple pressure transducer | 9B20.51 | The thickness of an optically dense dye between two anvils is measured electroptically. |
| AJP 30(4),xiv | electrohumidity transducer | 9B20.55 | A humidity sensor that changes resistance with humidity. |
| AJP 53(10),1011 | silica gel humidity sensor | 9B20.55 | The change of conductivity of silica gel is used to measure humidity. |
| AJP 46(2),192 | LN2 level probe | 9B20.65 | The simplest probe is to blow on a meter stick which frosts up to the level of the LN2. Also, a thermocouple on a rod connected to a microammeter or millivoltmeter is inserted until the meter deflects. |
| AJP 57(10),954 | low cost LN2 monitor | 9B20.65 | A circuit monitors LN2 levels in a dewar. |
| AJP 57(12),1153 | flow detector | 9B20.66 | An optoswitch detects the ball in an inline ball flow indicator. |
| AJP 36(7),641 | making solenoids | 9B20.70 | Make a coil of 3500 turns of No. 16 wire. Data. |
| AJP 34(5),x | high Q inductors | 9B20.70 | High Q inductors from United Transformer Corp. are useful in demonstrating resonance at power line frequencies. |
| AJP 32(10),xvi | inexpensive coils | 9B20.70 | Focus coils from old TV sets or field coils from old speakers are convenient due to large opening and can usually be connected directly to 120 V AC. |
| AJP 40(7),1040 | making coils | 9B20.70 | Directions for winding coils for use with 10 V DC. |
| AJP 35(8),vi | winding transformers | 9B20.70 | Use Scotch tape between layers if you are trying to wind a transformer without a winder. |
| AJP 57(2),184 | field stabilized electromagnet | 9B20.71 | Transformer windings are used for the core of an electromagnet. |

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| AJP 28(7),xiv | mercury-wetted contact relays | 9B20.75 | A catalog describing design features and operating characteristics. |
| Sut, A-97 | photoelectric relays | 9B20.75 | On using photocells to turn things on. Diagram. |
| Sut, A-98 | photocell-thyratron relay | 9B20.75 | On using photocells for sensitive control. Diagram. |
| AJP 35(11),1047 | electric and magnetic field probes | 9B20.80 | Electric and magnetic field probes where the strengths are presented audibly. Circuit diagrams. |
| AJP 56(7),622 | Hall effect transducer | 9B20.80 | Using integrated circuit Hall effect transducers. |
| AJP 54(1),89 | Hall effect sensor | 9B20.80 | Using the Microswitch 91SS12-2 Hall effect sensor. |
| AJP 54(1),88 | digital integrator | 9B20.90 | A circuit starts with a VFC, ends with a counter. |
| AJP 49(4),374 | negative feedback demonstration | 9B20.90 | A very simple lamp, photocell, opamp circuit to demonstrate negative feedback. |
| AJP 49(11),1035 | Josephson junction analog | 9B20.90 | An electronic analog of a resistively shunted Josephson junction. |
| AJP 47(5),471 | two component exponential decay circuit | 9B20.90 | A circuit provides a output composed of both fast (20 sec) and slow (100 sec) time constants. |
| Mei, 30-2.8 | integrator and differentiator | 9B20.90 | A circuit provides both RC integrating and differentiating circuits with 1 KHz square wave input. |
| AJP 46(8),866 | digital logic monitor | 9B20.92 | An LED on each pin shows the logic state of integrated circuits. |
| AJP 50(3),283 | simple universal logic state checker | 9B20.92 | A circuit for a simple universal logic state checker. |
| AJP 41(9),1117 | reverse sudden death lead | 9B20.95 | Make a breakout box with a standard duplex receptacle to banana plugs. |
| AJP 46(9),952 | digital lecture hall display | 9B20.99 | A circuit for a four digit LED display with 24 LEDs in each digit. |
| | **Function Generators** | **9B30.00** | |
| Sut, A-27 | audio frequency oscillator | 9B30.10 | A tube with a resonant RLC circuit oscillating in the audio range. A bank of capacitors with separate keys makes an organ. Diagram. |
| Sut, S-68 | audio oscillator | 9B30.10 | A tube era audio oscillator. Circuit. |
| AJP 32(7),v | noise generators | 9B30.11 | Schematic for a thyatron noise source. Listen and show white noise on a scope, insert a tunable adjustable width resonant circuit and show sinusoid as Q increases, some interference demonstrations. |
| AJP 44(1),110 | square wave generator | 9B30.12 | A five component TTL square wave generator with a range of 0.1 to 50 kHz. |
| AJP 44(7),710 | digital waveform synthesizer | 9B30.13 | A simple ten step waveform digitizer made from three chips. |
| Sut, A-28 | plucked string oscillator | 9B30.14 | Modify the audio oscillator in A27 to be a damped oscillator that sounds like a plucked string. |
| AJP 49(3),275 | gating amplifier for tone bursts | 9B30.15 | This circuit gates bursts of periodic signals to simulate Fourier analysis of a single pulse on a wave analyzer. |
| AJP 46(10),1080 | harmonic oscillator circuit | 9B30.16 | An op-amp based harmonic oscillator capable of demonstrating the interaction between the initial transient and steady-state motion. |
| AJP 35(8),v | frequency scanning for wave analyzer | 9B30.17 | A frequency scanning device and output coupler for use with the HP 300A wave analyzer. Circuits given. |
| AJP 33(11),965 | low frequency current source | 9B30.20 | A mirror on a pendulum directs light onto a photovoltaic cell giving a oscillating output. |
| AJP 45(12),1234 | very low frequency oscillator | 9B30.20 | Circuit for a .25 to 2.5 Hz oscillator based on the Intersil 8038 IC. |
| AJP 43(1),113 | ultra low frequency oscillator | 9B30.20 | Mechanically rotate a Polaroid between a light source and photodetector pickup covered with another Polaroid |
| Sut, A-24 | very low frequency oscillator | 9B30.20 | A tube circuit for generating very low frequency sine waves for AC circuit demos. Diagram. |
| Sut, A-23 | very low frequency alternator | 9B30.20 | Plates connected to a 12 V battery rotating in a salt water bath give AC at the frequency of rotation for use with slow circuits. Diagram. |
| Hil, S-1f | Welch turntable oscillator | 9B30.20 | A slow oscillator made from two turntables. |
| Mei, 33-2.7 | RC phase shift oscillator | 9B30.30 | A single tube RC phase shift oscillator. Diagram. |
| Sut, A-30 | spark discharge oscillator - parallel resistance | 9B30.40 | A circuit for generating high frequency damped oscillations by spark discharge with parallel resistance. |
| Sut, A-32 | 10 MHz oscillator | 9B30.40 | Directions for making a 10 MHz oscillator. |
| Sut, A-36 | UHF oscillator | 9B30.40 | Using "modern" tubes to generate UHF oscillations. |
| Sut, A-40 | modulation of HF | 9B30.40 | The plate of the oscillator in A-36 is modulated at an audio frequency. Diagram. |
| Sut, A-29 | spark discharge oscillator - series | 9B30.40 | A circuit for generating high frequency damped oscillations by spark discharge and a series resonant circuit. |
| | **Oscilloscopes** | **9B37.00** | |
| AJP 43(2),182 | TV as oscilloscope | 9B37.10 | A simple circuit to convert a black and white TV set into a multiple trace oscilloscope. |
| AJP 29(5),xii | large oscilloscopes | 9B37.10 | Large oscilloscopes on the market in 1960 and reference to plans for constructing one by Harold Jensen. |
| AJP 35(9),ix | demonstration oscilloscope | 9B37.10 | Use the Welch demonstration oscilloscope as a slave to a high quality oscilloscope with vertical and horizontal outputs. |
| Mei, 33-2.10 | large oscilloscope | 9B37.10 | A 12" oscilloscope. Picture, Details in appendix, p.1337. |

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| AJP 32(4),xvi | project oscilloscope traces | 9B37.15 | A ten inch focal length lens projects a high intensity oscilloscope pattern with magnifications up to twenty. |
| AJP 48(4),318 | oscilloscope trigger | 9B37.20 | Simple circuit provides a calibrated sweep for cheap oscilloscopes. |
| AJP 51(3),283 | tektronix 503 power transformer repair | 9B37.30 | Install a separate transformer if the CRT filament windings are the problem. |
| | **Advanced Instruments** | **9B40.00** | |
| AJP 29(7),iii | GM scaler | 9B40.14 | Review of Radiation Equipment and Accessories Corp model E-115 GM scaler and accessories. (1961) |
| AJP 53(8),793 | single-channel pulse height analyzer | 9B40.14 | A six IC single-channel pulse height analyzer. |
| AJP 52(10),890 | time to amplitude converter | 9B40.14 | A time-to amplitude circuit suitable for multichannel analyzer input. |
| AJP 29(9),xvii | mercury-relay pulse generator | 9B40.15 | Pulse generator at 60 Hz with variable decay time. |
| AJP 28(6),559 | rate meter circuit | 9B40.15 | A four tube ratemeter circuit for standard GM negative pulses. |
| AJP 36(9),920 | scintillation preamp and power supply | 9B40.15 | Use an RCA CA 3001 IC as a pulse preamp. |
| AJP 43(11),1017 | multichannel analyzers in the lab | 9B40.16 | On the use of multichannel analyzers in the intro labs. |
| AJP 55(12),1150 | RF null detector | 9B40.20 | Three methods of connecting microammeters to radios as null detectors. |
| Sut, A-34 | radios | 9B40.20 | A crude radio is made by coupling an antenna to the oscillator in A-32. |
| Sut, A-33 | wavemeter | 9B40.20 | A simple RLC wavemeter with a flashlight lamp for use with high frequencies. |
| AJP 29(7),451 | NMR apparatus | 9B40.30 | Apparatus Drawings Project No. 18: NMR apparatus. |
| AJP 29(8),492 | electron paramagnetic resonance | 9B40.31 | Apparatus Drawings Project No. 19: Simple lab apparatus for investigating EPR. |
| AJP 43(5),465 | ballistic galvanometer | 9B40.35 | Plans for a simple ballistic magnetometer. |
| AJP 29(7),445 | small X-ray tube | 9B40.40 | Apparatus Drawings Project No. 17: Small X-ray tube 28 kv. |
| AJP 43(2),194 | make an X-ray tube | 9B40.40 | Convert a Liebig distillation condenser into an X-ray tube. |
| AJP 45(1),104 | light bulb X-ray tube | 9B40.40 | Convert an ordinary showcase light bulb into an X-ray tube. |
| Sut, A-102 | X-ray tubes and equipment | 9B40.40 | A discussion of X-ray tubes. |
| AJP 42(2),169 | plasma device | 9B40.45 | A device to produce a large, quiet, uniform plasma for senior laboratory. |
| AJP 43(3),280 | double plasma machine | 9B40.45 | A double plasma machine constructed from "throw-away" items. |
| AJP 37(9),859 | droplet suspension | 9B40.50 | A small chamber where a nonuniform AC field provides three dimensional containment. |
| AJP 59(9),807 | "Paul" trap - macroscopic | 9B40.50 | A simplified "Paul" trap to demonstrate trapping of dust particles in a AC electric quadrupole field. |
| AJP 37(10),1013 | droplet suspension | 9B40.50 | Same as AJP 37(9),859: A small chamber where a nonuniform AC field provides containment. Circuits and drawings. |
| AJP 41(3),442 | frequency spectrum analyzer | 9B40.60 | Two four quadrant multiplier integrated circuits (MG 1594L) are the basis of a frequency spectrum analyzer. |
| | **Power Supplies** | **9B50.00** | |
| AJP 30(10),738 | direct coupled amp and power supply | 9B50.01 | Apparatus Drawings Project No. 30A: Power supply with built in direct coupled amplifier (tube based). |
| AJP 53(11),1116 | lab power supply | 9B50.10 | A circuit for a low cost 0 to 28 V, 0.5 A power supply. |
| AJP 42(2),158 | four output power supply | 9B50.11 | Schematic for a four output, single transformer, DC power supply using IC regulators. |
| AJP 44(3),301 | high current supply | 9B50.12 | Circuit for a 28 V DC 20 Amp power supply. |
| AJP 43(4),376 | inverter | 9B50.15 | Schematic for a 12 V DC to 115 V AC converter. |
| AJP 34(10),xvi | precision adjustable DC standard | 9B50.20 | Team a Kelvin-Varley voltage divider with a constant voltage supply to obtain a precision adjustable DC voltage standard. |
| AJP 38(6),769 | precision voltage divider | 9B50.25 | An inexpensive variation of the Kelvin-Varley divider has constant input impedance for all values of the voltage ratio. |
| TPT 3(7),321 | surplus power supplies | 9B50.30 | Replace selenium rectifiers, use 400 cycle inverters with the 400 cycle aircraft equipment. |
| AJP 35(10),xi | keeping storage cells charged | 9B50.35 | Plug all storage cells into a charger on a timer that comes on for two hours every night at midnight. |
| AJP 28(9),815 | e/m power supply | 9B50.40 | Power supply circuit for coils, tube. |
| AJP 45(5),495 | e/m power supply | 9B50.40 | Independently regulated heater, focus, and plate supplies. |
| AJP 35(10),972 | capacitor discharge switch | 9B50.99 | Operate a gas pulse switch "backwards". |
| | **Light Sources** | **9B60.00** | |
| PIRA 1000 | eosin mister | 9B60.10 | |
| Mei, 34-2.6 | large arc lamp | 9B60.10 | Use a movie theater arc lamp. |
| AJP 33(9),xii | cool-beam projection system | 9B60.20 | The GE PAR 56/2NSP cool beam lamp has a dichroic reflector and 6 1/2" diameter. |
| Mei, 34-2.7 | projection system | 9B60.20 | Add for the 300W GE PAR 56/2NSP narrow spot cool beam Lamp. Picture. |
| AJP 29(7),iii | pinlite | 9B60.22 | 1/64" dia x 1/16" incandescent lamp from Kay Electric Company. |
| Mei, 34-2.2 | point source of light | 9B60.22 | Add for the Osram HBO-109 high pressure mercury vapor lamp. |

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| AJP 48(5),418 | LED point source | 9B60.23 | Cut the lens off an LED and use as a point source for generating a columinated light beam. |
| AJP 45(1),106 | LED point source | 9B60.23 | Use an LED in inverse square law experiments. |
| AJP 54(10),952 | crossed gratings diverging beams | 9B60.25 | Use a laser and crossed gratings to generate a pattern of diverging beams, collimated if needed, for optics demonstrations in a smoke box. |
| AJP 49(1),91 | single grating - parallel beams | 9B60.26 | Pass a laser beam through a grating, then collimate the diverging beams with a lens to obtain parallel beams for optics demonstrations. |
| AJP 33(6),v | strobe for hall displays | 9B60.30 | A circuit to vary the rate of a neon strobe. |
| Mei, 7-2.5 | motion study stroboscope | 9B60.30 | Fan blades chop a beam from a masked lamp. Diagram. |
| Sut, L-2 | incandesent lamps | 9B60.50 | Line filaments, point sources, photofloods, 7/16" brass tube lamp holder. |
| AJP 29(3),xxvi | straight line filament lamps | 9B60.55 | Chicago Miniature Lamp Works makes three way spring suspension lamps that retain straight axial filament position. |
| Mei, 34-2.5 | straight line filament | 9B60.55 | A standard showcase lamp is a good line source. |
| AJP 39(4),454 | ripple free sources | 9B60.59 | After starting, switch spectral sources to DC from batteries. |
| Sut, L-4 | sodium and mercury vapor lamps | 9B60.60 | Sodium vapor lamp was new in the thirties, Mercury has UV, reference for constructing other glass lamps: Rev.Sci.Inst.,3,7,1932. |
| AJP 52(8),762 | sodium lamps | 9B60.61 | The Norelco SOX-35 and SOX-18 low pressure sodium lamps. |
| AJP 44(12),1227 | sodium street lamps | 9B60.62 | The GE Lucalux LU250/BD lamp. |
| AJP 47(2),197 | sodium source | 9B60.62 | Low pressure sodium street lamps are discussed. Neon carrier, increased brightness, broader lines. |
| AJP 28(9),ix | cesium vapor lamp | 9B60.63 | The Westinghouse CL-2 lamp has two strong lines at 8521 and 8944 A. Can be modulated at 10 KHz. |
| AJP 29(6),371 | mercury source | 9B60.65 | Use a small germicidal ozone lamp in series with a ballast. |
| AJP 43(10),927 | monochromatic mercury source | 9B60.65 | Use a medium pressure Hg arc (GE H-100-A4/t3) lamp and an interference filter. |
| AJP 29(12),856 | hydrogen lamp | 9B60.65 | Review of the Hassler hydrogen lamp. |
| AJP 28(6),xi | atomic hydrogen lamp | 9B60.65 | Announcement of the Hassler 75 W 500 hr. Balmer series lamp. |
| AJP 28(6),xi | Hg point source | 9B60.65 | Announcement of the Osram HBO-109 high pressure mercury arc lamp. |
| TPT 2(6),281 | mercury arc | 9B60.65 | Directions for making a mercury arc that runs off 110 V DC. |
| AJP 35(11),ix | electrodeless discharge tubes | 9B60.66 | Excite electrodeless discharge tubes with a microwave generator. |
| AJP 36(2),x | improves gas discharge tube | 9B60.67 | A procedure for making fluorescent screens for discharge tubes. |
| AJP 43(12),1111 | Fe-Ne source | 9B60.68 | The Westinghouse WL-22810A Fe-Ne lamp is a good standard wavelength source for spectroscopy. |
| AJP 30(2),127 | blackbody source | 9B60.69 | Apparatus Drawings Project No. 24: A platinum wedge that can be used a blackbody or non-blackbody source. Temperatures to 1500 K. |
| Sut, L-3 | glow lamps | 9B60.70 | Glow lamps with standard medium base are used as polarity indicators on direct current, dim strobe flashers at twice AC frequency. Argon lamp has some UV. |
| AJP 28(6),xii | strobe flashtube | 9B60.80 | Inexpensive GE FT-30 flashtube is suitable for stroboscopic operation. |
| AJP 43(8),747 | blinky calibration | 9B60.80 | Calibrate a blinky with a photocell to scaler. |
| AJP 29(11),787 | optical bench source | 9B60.90 | A Nite Lite makes an inexpensive extended optical bench source. |
| AJP 38(1),43 | resource letter of radiometry | 9B60.99 | A resource letter reprinted from "Journal of the Optical Society of America" lists general references. |
| | **Light Paths Made Visible** | **9B61.00** | |
| F&A, Ob-8 | optical disc | 9B61.20 | A ground glass disc makes rays of light more visible and has provision to mount various optical elements. |
| Sut, L-6 | optical disc | 9B61.20 | A description of the optical disc. |
| Hil, O-4b | optical disc | 9B61.20 | Many optical demonstrations can be shown with the optical disc. |
| AJP 36(12),1170 | blackboard optics | 9B61.25 | Several suggestions to improve the Klinger blackboard optics system. |
| D&R, O-007 | blackboard optics | 9B61.25 | The Klinger blackboard optics system |
| Sut, L-9 | smoke box | 9B61.30 | A large glass fronted black box filled with smoke or ammonium chloride (A-5) fumes. |
| D&R, O-035 | smoke box | 9B61.30 | A box with acrylic or glass front is filled with smoke. |
| TPT 28(6),420 | bee smoker | 9B61.31 | Bee smokers produce a large amount of smoke from one wadded paper towel. 1-800-Beeswax. |
| AJP 48(4),320 | beam splitting device | 9B61.32 | Use a stack of microscope slides to obtain parallel, convergent, and divergent sets of beams. |
| AJP 49(12),1185 | conical beam in smoke box | 9B61.33 | A mirror set at a small angle on the end of a rotating shaft is used to produce a reflected conical beam. |
| Sut, L-10 | chalk dust | 9B61.35 | Clap dusty chalkboard erasers together. |
| D&R, O-035 | chalk dust | 9B61.35 | Laser beam made visible with chalk dust. |
| Sprott, 6.2 | chalk dust | 9B61.35 | Chalk dust or a smoke generator is used to make a laser beam visible. |
| AJP 43(1),92 | laser mount for optics | 9B61.36 | A mount for a laser permits either transverse or rotational movement of the beam. |
| AJP 41(4),549 | Gaussian beam | 9B61.38 | A rotating device with two offset lenses generates a ray envelope from a laser beam that simulates a Gaussian beam. |

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| Sut, L-8 | gauze screen | 9B61.40 | White threads are stretched 2-3 mm apart on a 2x4' frame. |
| AJP 30(12),929 | tracing paper screen | 9B61.41 | Use tracing paper on embroidery frames. |
| AJP 33(11),970 | optical tank | 9B61.50 | Fluorescein in an aquarium, aerosol generator. |
| Sut, L-7 | optical tank | 9B61.50 | A 3x3x36" water tank with some fluorescein added. Many demos mentioned. |
| TPT 2(6),278 | ink paths on the overhead | 9B61.61 | Ink dipped balls are rolled down chutes at various barriers shaped like optical elements. The incident and reflected paths are traced out. |
| TPT 2(2),87 | elastic string ray model | 9B61.66 | Elastic strings don't sag like regular string when used in three dimensional ray models. |
| Sut, L-5 | invisibility of light | 9B61.71 | Light passing through a glass fronted black box is not visible until a white card is placed inside. |
| | **Lasers** | **9B62.00** | |
| Mei, 36-1-3 | laser theory | 9B62.10 | Introduction to lasers. |
| AJP 43(12),1057 | laser modes display | 9B62.11 | Use a Fabry-Perot etalon to display both longitudinal and transverse modes. |
| AJP 50(1),90 | laser transverse modes | 9B62.11 | Observe the transverse modes of a laser by shining a beam through a defunct laser tube to a screen a meter away. |
| AJP, 50 (1), 90 | laser transverse modes | 9B62.11 | Observe the transverse modes of a laser by shining a beam through a defunct laser tube to a screen a meter away. |
| AJP, 50 (10), 936 | laser modes display | 9B62.11 | An experiment where switching between axial modes during laser start up is used in the correlation of changes in the tube temperature, cavity length, and output polarization. |
| AJP 49(9),891 | polarization and intensity fluctuations | 9B62.12 | Lasers show large intensity fluctuations when externally polarized and so do some internally polarized lasers. |
| AJP 59(8),757 | laser polarization simplified | 9B62.13 | Find the angle to set the polarizer that gives constant intensity. Directions. |
| AJP 49(10),915 | laser resource letter | 9B62.15 | Here's the source of all laser information pre 1980. |
| AJP 49(9),915 | laser resource letter | 9B62.15 | Here's where to go for laser information. |
| AJP 42(11),1006 | laser safety | 9B62.20 | An article on laser safety and the status of federal regulations (1974). |
| Mei, 36-8 | laser safety | 9B62.20 | Don't look into a laser. |
| AJP 34(10),989 | inexpensive CO2 gas laser | 9B62.30 | Plans for an inexpensive CO2 gas laser. |
| AJP 35(8),776 | CO2 laser power increase | 9B62.30 | Power is increased by lengthening the tube and introducing a cooling system. |
| AJP 38(6),777 | chemical detector for CO2 laser | 9B62.30 | A filter paper soaked in a cobalt chloride and ammonium chloride solution turns blue where the beam strikes. |
| AJP 38(5),655 | inexpensive nitrogen laser | 9B62.33 | Directions for constructing a small pulsed ultraviolet nitrogen laser. |
| Sprott, 6.2 | wavelengths of a HeNe laser | 9B62.34 | The light from a HeNe laser tube is observed through a diffraction grating. Many colors are observed. |
| AJP 33(3),225 | HeNe laser construction | 9B62.35 | Design of a 60 cm confocal resonator laser. |
| AJP 37(3),276 | construction of HeNe lasers | 9B62.35 | The general procedures for designing a HeNe laser. |
| AJP 38(10),1250 | inexpensive RF HeNe laser | 9B62.35 | Directions for making an inexpensive 3.39 micron RF excited HeNe laser. |
| AJP 44(12),1172 | N2 laser | 9B62.36 | Design and construction of a low cost N2 pulsed laser. |
| AJP 35(6),ix | uranium hydrite getter | 9B62.38 | A method for preparing uranium hydrite inside a noble gas laser. |
| AJP 35(8),v | correction - uranium hydride getter | 9B62.38 | There are several errors in the description of the preparation of a getter from metallic uranium. |
| AJP 45(11),1118 | laser alignment | 9B62.40 | Use a square aperture to align two beams with no rotation. |
| AJP 32(5),355 | optics of the laser beam | 9B62.40 | Some optics. |
| AJP 35(5),x | plasma tube mirror alignment | 9B62.40 | A method for aligning mirrors on plasma tubes with respect to the tube, not each other. |
| AJP 45(1),107 | HeNe laser rejunevation | 9B62.50 | A HeNe laser was operated in a helium environment for a day and began to lase again. |
| AJP 45(8),778 | reconditioning HeNe tubes | 9B62.50 | Reactivate the getter. |
| AJP 45(11),1127 | laser communication | 9B62.60 | Bounce a laser beam off a earphone driven mirror. |
| AJP 47(3),282 | laser communication system | 9B62.60 | Shine a laser through an ultrasonic light modulator. |
| AJP 38(7),926 | transmitting sound with laser | 9B62.60 | Use an audio transformer in series with the cathode side of the laser power supply. |
| AJP 44(1),111 | laser communication apparatus | 9B62.60 | Modulate a laser beam by passing it through a small plastic strip attached to an earphone. |
| TPT 28(8),560 | laser eavesdropping | 9B62.60 | Development of a crude laser eavesdropping system during a student project. |
| Sut, A-99 | transmission of sound by light | 9B62.60 | Sound-light demonstrations with a commercial photocell. |
| | **Microwave Apparatus** | **9B65.00** | |
| AJP 35(8),761 | microwave system | 9B65.10 | Description of a low cost x band system for research and demonstration. |
| D&R, O-030 | microwave system | 9B65.10 | The Welch 3 cm system. |
| AJP 32(4),xv | microwave absorber | 9B65.13 | A bag of charcoal absorbs microwaves. |
| AJP 39(1),120 | supports for microwave studies | 9B65.20 | Styrofoam sheets with the edges outside the beam introduce no perturbations to the beam. |

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| AJP 39(1),121 | microwave probe antennas | 9B65.25 | Design of microwave probe antennas for both electric and magnetic waves. |
| AJP 41(10),1198 | microwave coherer | 9B65.40 | A coherer in series with a battery and galvanometer is much more sensitive than a spark gap or neon glow lamp. |
| Mei, 33-7.5 | introduction to microwave optics | 9B65.90 | General comments about use of microwaves in optics. |
| AJP 44(7),628 | microwave optics with 1 cm waves | 9B65.91 | The advantages of using 1 cm wavelengths in physical optics including overhead projection techniques. |
| AJP 49(12),1149 | microwave optics | 9B65.91 | A 9 GHz system used in microwave versions of the Michelson interferometer, Bragg reflection, Brewster's law, and total internal reflection, Young's interference. |
| Hil, O-7j | microwave demonstrations | 9B65.91 | Microwave demonstrations using 420 MHz. Reference: AJP 20(5),307-8. |
| Hil, O-7g | microwave optics | 9B65.91 | A complete set of 12 cm microwave optics. |
| Hil, O-7h | microwave optics | 9B65.91 | A complete set of 3cm microwave optics. |
| | **Computer Interface** | **9B90.00** | |
| AJP 57(6),561 | IBM parallel printer port interface | 9B90.20 | Very good discussion on using the parallel printer port. |
| AJP 59(11),998 | ultrasonic ranging module | 9B90.20 | Interfacing the TI module to a PC. |
| AJP 59(2),187 | A to D on the IBM | 9B90.20 | Hook up an ADC0804 to the parallel port. |
| AJP 48(4),317 | computer - AV interface | 9B90.30 | Pick up the pulses that drive a computer's speaker and decode them for use in operating projectors, cameras, etc. Circuit given. |
| AJP 56(10),953 | Apple II paddle port ADC | 9B90.40 | A simple single chip ADC interface to the paddle port with a little program to write the data. |
| AJP 51(11),1048 | specialized interface | 9B90.40 | Interface for the Nuclear Data 2200 or 555 multichannel analyzer to Apple II. |
| TPT 28(5),332 | ADC for the Apple II | 9B90.40 | Construct a high quality ADC that plugs into an expansion slot. |
| AJP 43(9),839 | PDP-8 signal averager | 9B90.50 | A signal averager for the PDP-8. |
| AJP 50(2),187 | multichannel analyzer -TRS-80 interface | 9B90.50 | Interface the LeCroy 3001 multichannel analyzer to a TRS-80. |
| AJP 52(6),566 | TRS-80 data logger | 9B90.50 | Use the joystick inputs of the TRS-80 in a simple scheme for a four channel data logger. |
| | **MECHANICAL** | **9C00.00** | |
| | **Motors** | **9C10.00** | |
| | **Pumps** | **9C20.00** | |
| | **Vacuum** | **9C25.00** | |
| AJP 36(3),234 | high vacuum system | 9C25.10 | Design of a high vacuum system suitable for lecture demonstration. |
| Mei, 16-6.1 | movable vacuum system | 9C25.10 | Pictures of a movable vacuum system good to high vacuum. Construction Details in the Appendix, p 610. |
| Sut, A-57 | vacuum system | 9C25.10 | Construction of a portable high vacuum system. |
| AJP 32(7),vi | vacuum lore | 9C25.15 | Let in only dry gas or heat traps to 100 C to reduce water contamination. |
| AJP 37(1),109 | liquid nitrogen cold trap | 9C25.15 | Mount a styrofoam bucket on top of a minimum sized reentrant can-type trap. |
| AJP 30(8),v | Bayard-Alpert type ionization gauge | 9C25.20 | A single device contains a titanium vapor pump that consists of a titanium filament depositing a film on the wall to act as a getter, and a Bayard-Alpert type ionization gauge. |
| AJP 32(6),504 | power supply for Penning vacuum gage | 9C25.20 | Schematic diagram for a Penning vacuum gauge power supply. |
| AJP 32(6),483 | homemade high vacuum techniques | 9C25.20 | Make experimental vacuum tubes with solder glass, mass produced headers, and multiple gettering. |
| AJP 28(7),654 | thin films of dielectrics and metals | 9C25.25 | Directions for making a transparent aluminum oxide film on a front surface mirror. The interference colors of the mirror and glass sides are complementary. A parallelogram frame permits demonstrating the change of color with angle of incidence. More. |
| Hil, M-21b | vacuum deposition system | 9C25.26 | A picture of a vacuum deposition system. |
| AJP 28(6),xii | vacuum tube construction kit | 9C25.30 | The Physikit 100A from Harries Microphysics contains parts to make several tubes. |
| AJP 29(10),xiii | high vacuum epoxy joints | 9C25.40 | From J. Sci. Instr. 37,203 (1960): Techniques for making successful high vacuum joints with epoxy resin. |
| AJP 36(5),viii | vacuum lines and connections | 9C25.40 | Use thermoplastic polyethylene tubing and connectors with vacuum grease. |
| AJP 32(4),xv | cheap vacuum fittings | 9C25.40 | Standard plumbing "Flex Fittings" from Imperial-Eastman work very well as vacuum connectors. |
| AJP 31(4),xiii | vacuum apparatus | 9C25.40 | Use Pyrex brand pipe and fittings for student high vacuum experiments. |
| AJP 35(11),ix | vacuum feed through | 9C25.41 | Just use a spark plug. |
| AJP 33(4),xxvi | vacuum electrical feed-throughs | 9C25.41 | High vacuum electrical lead-throughs good to 6000 V and up to 5/16 in diameter conductor. |

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| AJP 40(10),1550 | vacuum electrical feed through | 9C25.41 | Use an automobile spark plug. |
| AJP 35(7),iv | vacuum seal | 9C25.45 | Use teflon tape. |
| | **Air Support** | **9C30.00** | |
| AJP 43(9),840 | air track flatness | 9C30.20 | A device for checking air track flatness. |
| AJP 35(3),281 | cooling air for the air track | 9C30.25 | Add a heat exchanger to cool the hot air from a vacuum cleaner source. |
| AJP 36(1),59 | photograph the air track | 9C30.26 | Use a stroboscopic shutter on a Polaroid camera instead of "black box" timers for air track demonstrations. |
| AJP 47(9),825 | flat air track | 9C30.30 | An air track made from 1 X 3 extruded aluminum tubing with discussion of gliders, etc. |
| AJP 44(5),493 | central blower and timer | 9C30.30 | Centralized blowers and spark timers. |
| AJP 39(3),340 | improving the air track and table | 9C30.30 | Enlarge the holes with a No. 57 drill. |
| AJP 36(3),x | mobile air track | 9C30.30 | A picture of an air track mounted on a mobile cart containing all the accessories. |
| AJP 30(11),839 | making air tracks | 9C30.30 | Make air tracks out of standard 2" square extruded aluminum tubing. |
| TPT 28(9),618 | long air track | 9C30.30 | Three air tracks are carefully combined into one 8.3 m track for a hall display. |
| Hil, M-15g | moving air tracks | 9C30.30 | Mount the air track on a table with castors. See AJP 36(3),x. |
| AJP 31(4),255 | linear air trough | 9C30.31 | Long article on a linear air trough. |
| AJP 35(10),xi | crush proof springs for gliders | 9C30.35 | Back the spring with a post so it doesn't go beyond the elastic limit. |
| AJP 42(5),414 | magnetic coupling at a distance | 9C30.37 | Magnet configurations used to couple air carts at a distance. |
| AJP 29(10),xiv | modify Apparatus Drawings Project No. 10 | 9C30.40 | Two minor modifications to the air suspended pucks of Apparatus Drawings Project No. 10. |
| AJP 33(2),168 | gas supported puck theory | 9C30.40 | In contrast to AJP 32,306,(1964), experimental gas layer thickness is within 3% of theory. |
| AJP 32(4),306 | air supported puck theory | 9C30.40 | An approximate solution of the Navier-Stokes equation for flow from the center of the puck. |
| AJP 36(11),1022 | double floating puck | 9C30.40 | Drill 1/4" holes in the bottom puck and a second will float on top. |
| AJP 32(9),xiv | another dry ice puck design | 9C30.40 | A cylindrical puck with internal dry ice compartment. |
| AJP 28(7),670 | air supported pucks | 9C30.40 | Apparatus Drawings Project No. 10: Designs for air suspended pucks, both external and internal supplies. |
| AJP 32(5),xiii | dry ice puck base | 9C30.40 | Make a nonwarping plastic base for dry ice pucks. |
| AJP 41(3),355 | gas supported pucks | 9C30.40 | A criterion for a stable design of CO2 supported pucks is developed. |
| AJP 32(9),xiv | an "airless" air puck | 9C30.40 | A plastic puck with a convex surface floated 60 ft. and stops when the speed drops below a critical value. |
| Mei, 10-2 | air supported pucks | 9C30.40 | How to make several different types of air supported pucks. |
| AJP 32(5),xiv | reproducible puck launching | 9C30.41 | A bifilar pendulum hits the puck. |
| AJP 36(5),vii | air table modifications | 9C30.45 | Several modifications to the AJP 35 (1967) 2'x2' air table. |
| AJP 36(11),1020 | air table center bearing | 9C30.45 | A center bearing which allows the cord to pass through the center of the table. |
| AJP 35(4),xv | air table | 9C30.45 | An inexpensive air table made of a Masonite matboard lamination. |
| AJP 36(11),1021 | air table grid | 9C30.45 | Photographing a grid pattern before or after the experiment. |
| AJP 31(11),867 | air table | 9C30.45 | Describing construction of the first air table, 18"x35". |
| AJP 37(9),857 | transparent air table | 9C30.46 | A launcher and transparent air table for the overhead projector. |
| AJP 35(12),ix | transparent air table | 9C30.46 | Directions for making an air table for the overhead projector. |
| AJP 35(10),xii | seat for air gyro | 9C30.50 | Mold technique for making air gyro seats. |
| AJP 31(9),xii | air bearing | 9C30.50 | Announcement of the Ealing air bearing pulley. |
| | **Ripple Tank** | **9C35.00** | |
| AJP 54(11),1002 | ripple tank - water depth | 9C35.01 | A study of the profiles of waves for different water depths. |
| F&A, Sm-1 | ripple tank - general | 9C35.01 | The ripple tank. |
| Mei, 18-6.1 | ripple tank - construction | 9C35.10 | Hints on building ripple tanks. Diagrams and pictures. Construction details in appendix, p. 626. |
| Mei, 18-6.5 | ripple tank - construction | 9C35.10 | Ripple tank construction hints. Picture. |
| Mei, 18-6.2 | ripple tank - construction | 9C35.10 | A mobile ripple tank illuminated by a strobe with air powered wave makers. Picture. Construction details in appendix, p. 631. |
| Sut, S-49 | ripple tanks - general discussion | 9C35.10 | A long discussion on ripple tanks. |
| TPT 2(2),81 | ripple tank - overhead projector | 9C35.11 | Design of a ripple tank for use on the overhead projector. |
| AJP 49(11),1079 | ripple tank - driver | 9C35.20 | A ripple tank driver is make from a loudspeaker. |
| AJP 43(2),195 | electric scissors generator | 9C35.20 | Convert a household electric scissors into a variable speed oscillator. |
| AJP 30(2),133 | electric production of ripples | 9C35.20 | Water climbs a highly charged wire (5000-10,000 V AC) touching the surface. |
| AJP 45(1),105 | ripple tank waves | 9C35.20 | Mount a two tooth comb in an electric toothbrush. |
| F&A, Sm-3 | ripple tank - plane waves | 9C35.20 | Simple plane waves of different frequencies on the ripple tank. |
| F&A, Sd-2 | vibrating reed frequency meter | 9C35.21 | A 60 Hz reed frequency meter is observed with a strobe to show phase differences. |
| AJP 45(7),683 | ripple tank wave generator | 9C35.22 | Use a loudspeaker to drive the ripple tank dippers. |

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| AJP 29(4),xiv | slow ripple tank waves | 9C35.23 | A layer of aniline under an equal layer of water gives waves that travel at 5 cm/sec. Discusses a few of the problems associated with aniline. |
| AJP 30(7),v | ripple tank strobe | 9C35.30 | Advice on adding a sectored disk strobe to your ripple tank. |
| | **Other** | **9C40.00** | |
| Sut, S-9 | mechanical vibrator | 9C40.05 | A SHM driver can be made from a old truck flywheel on bearings attached to a crank. |
| Sut, S-10 | mechanical vibrator | 9C40.05 | Commercial motor driven mechanical vibrators are available. |
| Sut, S-11 | mechanical vibrator | 9C40.05 | A heavy pendulum on a knife edge can be used to generate horizontal motion of periods from 1 to 10 seconds. |
| Sut, S-12 | mechanical vibrator | 9C40.05 | A vibrator of fixed period is made from a clock motor. |
| Hil, S-4e | Macalaster-PSSC oscillator | 9C40.05 | An apparatus for many demonstrations in mechanical resonance. |
| AJP 42(10),914 | cheese dish demonstration collection | 9C40.10 | Eighteen demonstrations of the "string and sticky tape" style that use a cheese dish. |
| AJP 34(12),xvi | microspheres | 9C40.15 | Small hollow glass bubbles ranging from 10 to 270 microns. |
| AJP 31(12),xiv | steam trap spheres | 9C40.15 | Use floats for steam traps in electrostatics demos. Available from 1 1/2" to 6" diameter. |
| AJP 29(8),iv | plastic balls, hemispheres,etc | 9C40.15 | Sources for plastic balls, hemispheres, and styrofoam balls (1961). |
| AJP 31(9),xi | hollow stainless balls | 9C40.15 | A source of hollow stainless balls from 5/8" to 10" diameter. |
| AJP 34(8),iii | labeling cables | 9C40.17 | Use ordinary white paper and heat shrink tubing. |
| AJP 29(11),xiv | stranded tungsten wire | 9C40.17 | Stranded tungsten wire from GE for use in vacuum metalizing. |
| AJP 34(5),ix | spinning thin metal | 9C40.19 | Use a teflon plug at the end of a spinning tool. |
| AJP 34(5),x | bluing steel by heat treatment | 9C40.19 | Form a good corrosion resistant surface by heating to 299 C and quenching in mineral oil. |
| AJP 30(11),xvi | constant torque devices | 9C40.20 | Constant torque devices for providing constant tension to strings and cords in recording instruments. |
| AJP 31(11),xv | springs for harmonic motion | 9C40.20 | Wind springs from #22 piano wire 1 cm diameter, 5-6 cm long for spring constants about 100,000 dyn/cm. Source: Hunter Springs, also make constant force springs. |
| AJP 40(12),1876 | modified mass hanger | 9C40.20 | The masses don't fall off this mass hanger. |
| AJP 30(4),310 | hooked weights | 9C40.20 | How to make small hooked weights out of lead. |
| TPT 3(7),320 | storing Slinky | 9C40.21 | Store a Slinky around a #6 dry cell. |
| AJP 29(12),xvi | graphite-woven furnace fabric | 9C40.22 | Graphite cloth heating elements can release 1 Kw / sq in. Sources for the cloth and furnaces. |
| AJP 29(11),xiii | cercor ceramic structure | 9C40.23 | A thin walled cellular ceramic from Corning Glass that withstands 1000 C and great thermal shock. |
| AJP 30(10),xv | braided glass sleeving | 9C40.23 | This sleeving is suitable for insulating wires in high vacuum systems. |
| AJP 34(10),xvi | soft solder to tungsten wire | 9C40.24 | To soft solder a tungsten wire, first properly tin it. |
| AJP 38(6),776 | soldering refractory metals | 9C40.24 | A method for coating tungsten, molybdenum, and tantalum with brazing metal before soldering with rosin core solder. |
| AJP 34(12),xv | plastic drive belts | 9C40.25 | A method for joining the ends of vinyl or Tygon tubing to make endless belts. |
| AJP 36(3),x | modification of a Tesla leak tester | 9C40.25 | Add a pushbutton switch on the side of the probe. |
| AJP 34(5),ix | polyester film belts | 9C40.25 | Make an endless belt of mylar by stretching a cut circle. Also, splicing various polymers. |
| AJP 29(9),xviii | heat shrink tubing | 9C40.26 | Insulating tubing that shrinks on heating. |
| AJP 30(7),vi | teflon spagetti tubing | 9C40.26 | Describes thinwall teflon tubing. |
| AJP 30(5),x | nylon fasteners | 9C40.28 | Source of fasteners made from nylon 6, a special cold flow plastic. |
| AJP 30(1),xvii | flexible rubber magnet | 9C40.30 | Quarter inch flexible magnet supports 40 g/inch. |
| AJP 29(8),iii | ceramic ring magnets | 9C40.30 | Source of ceramic ring magnets (1961). |
| AJP 28(8),x | gallium-indium eutectic | 9C40.33 | 75% gallium - 25% indium (by weight) freezes at 15.5 C and wets many semiconductor surfaces making low-resistance ohmic contact. |
| AJP 34(7),viii | electroplating tape | 9C40.35 | Scotch brand pressure sensitive tape for electroplating works well for masking surfaces to be etched. |
| AJP 30(8),vi | liquid insulating tape | 9C40.35 | Paint this stuff on instead of using tape. |
| AJP 35(2),xix | vinyl foam tape | 9C40.35 | Foam tape with adhesive on both sides is more compliant than double sided tape. |
| AJP 35(7),iv | epoxy to steel balls | 9C40.36 | Clean steel ball bearings before using epoxy to fasten on a hook. |
| AJP 30(5),x | conducting epoxy | 9C40.36 | Electrically conducting epoxy announcement. |
| AJP 31(2),xi | modified epoxy resins | 9C40.36 | Recipes for sand loaded epoxy, Cab-O-Sil loaded with note about stirring to destroy thixotropic property. |
| AJP 30(7),vi | silicone rubber adhesives | 9C40.36 | Some data on RTV. |
| AJP 31(1),xiv | Plexiglas adhesives | 9C40.36 | A three component Plexiglas cement, or moisten with chloroform and clamp. |
| AJP 31(4),xiv | more glues | 9C40.36 | Rez-n-glue for styrofoam. 3M EC-1368 thermosetting adhesive. 3M AF-42 can be cut to shape, clamped, and cured. |
| AJP 29(9),xviii | conducting epoxy cement | 9C40.36 | Silver filled epoxy cements, source and data. |

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| AJP 29(12),xv | epoxy seals in Geiger-Muller tube construction | 9C40.36 | Anyone can make Geiger-Muller tubes with this simple method. |
| AJP 34(12),xvi | epoxy dispenser | 9C40.36 | Mix epoxy and catalyst in a disposable syringe and then dispense. |
| AJP 30(8),vi | white lubricating compound | 9C40.37 | A compound that lubricates to 1100 C and is a grease from -40 to 140 C. |
| AJP 30(1),xviii | high temperature paint | 9C40.38 | An aluminum pigment paint for use between 500 and 1000 F. |
| AJP 30(1),xviii | pressure sensitive paint | 9C40.38 | Pressure sensitive electrically conductive paint can be used between conducting surfaces to make pressure transducers. |
| AJP 30(4),xiii | spandle for glassblowing | 9C40.40 | A tool designed to simplify straight butt, T and V joint seals, and joining capillaries. |
| AJP 35(7),iv | nonwetting glass surface | 9C40.40 | L-45, a silicone fluid from Union Carbide, makes glass nonwetting to aqueous solutions. |
| AJP 29(12),xvi | polish for acrylic and aluminum | 9C40.40 | X-109 polish (Chem-X Inc.) works well on plastics. |
| AJP 28(8),x | low radioactivity glass | 9C40.40 | Corning Glass has a low radioactivity glass available in early 1961. |
| AJP 30(2),xv | low temperature solder glasses | 9C40.40 | Some data on Schott solder glasses. |
| AJP 30(6),vi | fused quartz products | 9C40.40 | Fused quartz springs, pans, fibers, and other products are available from the Worden Laboratory (1962). |
| AJP 28(7),xiii | IR optical materials report | 9C40.40 | A report listing the optical and physical properties of fifty materials for use in IR optics. |
| Hil, S-3h | large glass tube cutter | 9C40.40 | Loop a wire around a glass tube, heat it red hot electrically, pour on cold water. |
| AJP 32(4),xvi | dry ice chest | 9C40.41 | Line a plywood chest with 4" of styrofoam. |
| AJP 34(12),xv | dry ice from fire extinguisher | 9C40.41 | Discharge a fire extinguisher into a space covered with a towel. |
| AJP 33(12),1090 | foam liquid nitrogen container | 9C40.41 | Use a large foam bowl for a cheap unbreakable container. |
| AJP 34(3),xxx | epoxy resin leak sealant | 9C40.45 | The Varian Associates "Torr-Seal". |
| AJP 28(7),xiv | transparent electroconductive coating | 9C40.45 | Pointer to Rev.Sci.Instr.31,344(1960). Apply a thin oxide film to lead glass with a resistance of 350 ohms/square, light transmittance of 75%. |
| AJP 31(5),362 | radioactive source | 9C40.50 | Irradiate sodium iodate 2hrs to get a radioisotope with a half-life of 25 min. |
| AJP 42(3),254 | determining equivalent focal length | 9C40.60 | A simple string method for determining the equivalent focal length of a lens. |
| AJP 43(12),1111 | making curved slits | 9C40.60 | How to make slits for a double-prism non dispersive premonochromator. |
| AJP 44(3),310 | mobile optical table | 9C40.60 | A 3' x 4' aluminum plate with 2" hole spacing. |
| AJP 29(4),xiv | micropositioners | 9C40.60 | There are micropositioners available for optics. |
| AJP 49(1),88 | making high quality pinholes | 9C40.60 | A short discharge from a pointed to a rounded electrode through a thin metal foil produces some nice pinholes. |
| AJP 35(5),x | making spatial filters | 9C40.60 | A spark from a tesla coil makes a hole in carbon paper or thin metal foil. |
| AJP 40(2),294 | making multilayer dielectric mirrors | 9C40.60 | Techniques for making multilayer mirrors tuned for HeNe laser work. |
| AJP 41(1),138 | eyepiece illuminator | 9C40.60 | Construct an inexpensive Gauss eyepiece illuminator from a neon pilot light in a block of aluminum. |
| TPT 28(9),606 | cheap laser spirograph | 9C40.60 | Small DC motors with front silvered mirrors mounted on the shafts are use to make a cheap spirograph. |
| AJP 33(6),504 | poor man's optical bench | 9C40.61 | Make a cheap optical bench out of round bar stock. |
| AJP 29(2),x | fabricating triangular optical bench | 9C40.61 | A 5/8" hexagonal bar stock mounted on a 1 7/8" hexagonal bar stock gives a bench similar to the Zeiss design. |
| AJP 30(7),vi | electrothermal thermocord | 9C40.64 | A flexible heating cord good to 450 C at 5 W/inch. |
| AJP 32(4),xv | resistor oven | 9C40.65 | Hollow wire wound resistors can be used as small ovens (insert mercury thermocouple for calibration of thermocouple). |
| AJP 36(4),x | simple linear heating rate oven | 9C40.65 | Design of a small oven. |
| AJP 32(9),679 | furnace for growing metal crystals | 9C40.65 | A simple furnace for growing metal crystals has produced a single crystal of aluminum 2" in diameter and 5" high. |
| AJP 32(1),xiii | low cost spot welder | 9C40.66 | Copper tongs, a six volt car battery, and some components are used to make this spot welder. |
| AJP 32(10),xiv | spot welder | 9C40.66 | Schematic for a simple condenser-discharge spot welder. |
| AJP 52(5),468 | interograph for integrals and areas | 9C40.70 | An interograph that produces both definite and indefinite integrals. |
| AJP 28(8),x | gauge blocks | 9C40.70 | Different nonstandard uses of gauge blocks, including feeling the attraction between two. |
| AJP 56(9),857 | profilometer | 9C40.70 | A shop drawing of a profilometer that is inexpensive, accurate, and can be computer interfaced. |
| AJP 40(11),1706 | cheap lab jack | 9C40.80 | Modify a scissors type axle jack by adding metal plates top and bottom. |
| AJP 37(4),456 | adjustable platform | 9C40.80 | A simple adjustable platform that rides on two vertical rods. |
| AJP 36(2),ix | pressure cell - 350 bar | 9C40.81 | Draw up some epoxy into a 0.05 ml Microliter syringe to seal the bottom and lubricate the plunger with light vacuum oil. |

# MECHANICS

## 1A Measurments

**10 Basic Units**
- .10 basic unit set
- .36 1 "nsec"
- .38 body units
- .45 WWV signal
- .50 one liter cube
- .55 mass, volume, and density
- .60 Avogadro's number box
- .65 mole samples
- .70 density samples

**20 Error and Accuracy**
- .10 Gaussian collision board
- .20 coin flip
- .25 dice
- .50 weight judgment
- .60 reaction time

**30 Coordinate Systems**
- .30 polar coordinates
- .41 blackboard hemisphere

**40 Vectors**
- .14 vector components animation
- .20 folding rule
- .25 tinker toys
- .30 magnetic vector addition
- .31 vector addition (parallelogram)
- .33 vector addition (head to tail)
- .35 Vernier Vector Addition II
- .40 resultant of vectors
- .70 vector dot products
- .75 vector cross products

**60 Scaling**
- .20 Scaling model for biological systems
- .30 2:1 scaling
- .40 scaling cube

## 1C MOTION IN ONE DIMENSION

**10 Velocity**
- .27 velocity - air track and glider
- .30 approaching instantaneous velocity
- .60 muzzle velocity
- .65 muzzle velocity - disc

**20 Uniform Acceleration**
- .12 hammer and feather on Moon
- .15 drop lead and cork balls
- .16 drop ball and paper
- .41 blinky track with graphs

**30 Measuring g**
- .15 little big ball dropper
- .20 big big ball dropper
- .40 falling drops
- .55 catch a meter stick

## 1D MOTION IN TWO DIMENSIONS

**10 Displacement in Two Dimensions**
- .10 ball in a tube
- .20 cycloid generator
- .40 mounted wheel
- .50 ball on the edge of a disc

**15 Velocity, Position, and Acceleration**
- .12 Hobbie film loop - AAPT
- .15 kick a moving ball
- .30 catching the train
- .35 passing the train
- .40 Galileo's circle
- .41 sliding weights on triangle
- .50 brachiostochrone
- .55 triple track

**40 Motion of the Center of Mass**
- .15 loaded bolas
- .22 air table center of mass
- .35 earth moon system
- .50 air track pendulum glider
- .55 air track inchworm

**50 Central Forces**
- .15 arrow on a disc
- .20 whirligig
- .26 plane on a string
- .30 carnival ride model
- .45 penny on a coat hanger
- .48 balls on a propeller
- .50 Welch centripetal force
- .60 banked track
- .70 rolling chain

**52 Deformation by Central Forces**
- .20 water parabola
- .21 rotating water troughs
- .30 balls in water centrifuge
- .35 water and mercury centrifuge
- .40 rotating candle
- .50 paper saw
- .61 rotating rubber wheel

**55 Centrifugal Escape**
- .11 the big omega
- .20 grinding wheel
- .23 spinning disc with water
- .30 falling off the merry-go-round

**60 Projectile Motion**
- .05 ball to throw
- .15 howitzer and tunnel on incline
- .16 vertical gun on accelerated car
- .50 parabolic path through rings
- .55 parabolic trajectory on incline
- .60 parabolic trajectory
- .65 water stream trajectory

## 1E RELATIVE MOTION

**20 Rotating Reference Frames**
- .20 Foucault pendulum model
- .30 Foucault pendulum latitude model
- .50 rotating room

**30 Coriolis Effect**
- .10 draw the coriolis curve - vertical
- .11 draw the coriolis curve
- .13 coriolis overhead transparency
- .20 coriolis gun
- .28 coriolis ball on turntable
- .50 rotating TV camera

## 1F NEWTON'S FIRST LAW

**10 Measuring Inertia**
- .10 inertia balance
- .11 inertia balance - leaf spring
- .20 inertia bongs
- .25 foam rocks

**20 Inertia of Rest**
- .11 bowling ball inertia balls
- .15 inertia block
- .20 smash your hand
- .22 hit the nail on the head
- .25 smash block on bed of nails
- .33 inertia cylinder
- .34 coin/card snap
- .36 pin and embroidery hoop
- .40 stick on wine glasses
- .50 shifted air track inertia

**30 Inertia of Motion**
- .21 water hammer
- .30 car on cart on cart
- .40 nail by hand
- .50 pencil and plywood

## 1G NEWTON'S SECOND LAW

**10 Force, Mass, and Acceleration**
- .11 constant mass acceleration system
- .15 roller cart and bungee loop
- .16 strain gage
- .20 accelerated car
- .22 accelerated instructor
- .25 acceleration block
- .30 mass on a scale

**20 Accelerated Reference Frames**
- .10 candle in a bottle
- .20 ball in a thrown tube
- .30 leaky pail drop
- .45 dropped slinky
- .76 suspended ball accelerometers
- .80 cart and elastic band
- .85 acceleration pendulum cart

**30 Complex Systems**
- .20 mass on spring, on balance
- .30 hourglass on a balance

## 1H NEWTON'S THIRD LAW

**10 Action and Reaction**
- .15 reaction air gliders
- .20 Newton's sailboat
- .25 helicopter rotor

**11 Recoil**
- .11 stool on conveyor
- .30 liquid nitrogen cannon

## 1J STATICS OF RIGID BODIES

**10 Finding Center of Gravity**
- .12 irregular object center of mass
- .20 loaded beams - moving scales
- .26 balance beam and bat

**11 Exceeding Center of Gravity**
- .11 topplings cylinders
- .15 tipping block on incline
- .40 male and female center of gravity

**20 Stable, Unstab., and Neut. Equillibrium**
- .12 wood block stability
- .15 block on the cylinder
- .17 block on curved surfaces
- .20 fork, spoon, and match
- .25 nine nails on one
- .32 spoon on nose
- .35 horse and rider
- .46 tightrope walking model
- .51 chair on a pedestal
- .55 broom stand
- .70 double cone

**30 Resolution of Forces**
- .15 normal force
- .26 rope and three weights
- .27 deflect a rope
- .30 break a wire with a hinge
- .40 horizontal boom
- .55 human force table
- .60 sail against the wind
- .70 sand in a tube
- .75 stand on an egg

**40 Static Torque**
- .15 torque wrench
- .16 different length wrenches
- .21 hinge board
- .24 walking the plank
- .25 torque wheel
- .27 torque double wheel
- .30 opening a door
- .32 opening a trap door
- .45 Galileo lever
- .60 suspended ladder
- .65 hanging gate
- .70 crane boom
- .75 arm model

## 1K APPLICATIONS OF NEWTON'S LAW

**10 Dynamic Torque**

.11 tipping blocks
.25 forces on a ladder - full scale
.40 pull the bike pedal
.41 traction force roller
.42 extended traction force
.50 rolling uphill

**20 Friction**
.05 washboard friction model
.42 friction roller
.45 frictional force rotator
.70 falling flask capstan
.90 air track friction

**30 Pressure**
.20 pop the balloons

## 1L GRAVITY

**10 Universal Gravitational Constant**
.20 Cavendish balance model
.50 gravitational field model

**20 Orbits**
.36 film "Motion of Attracting Bodies"
.40 conic sections
.50 ellipse drawer
.71 film "Planetary Motion and Kepler's Laws"

## 1M WORK AND ENERGY

**10 Work**
.10 shelf and block
.15 block on table
.16 carry a block
.25 pile driver with pop cans

**20 Simple Machines**
.01 simple machine collection
.11 pulley advantage
.15 pulley and scales
.25 monkey and bananas
.35 big screw as incline plane
.40 levers
.45 body levers

**30 Non-Conservative Forces**
.10 air track collision/sliding mass

**40 Conservation of Energy**
.23 reverse loop the loop
.25 energy well track
.30 ball in a trough
.33 triple track
.35 roller coaster
.41 Beck ballistic pendulum
.61 1-D trampoline
.63 x-squared spring energy dependence
.64 spring ping pong gun
.65 height of a spring launched ball
.66 mechanical jumping bean
.67 spring jumper
.75 obedient can
.90 rattleback
.91 high bounce paradox

**50 Mechanical Power**
.10 Pony brake

## 1N LINEAR MOMENTUM & COLLISIONS

**10 Impulse and Thrust**
.10 collision time pendula
.35 car crashes
.40 auto collision videodisc
.70 model rocket impulse
.80 fire extinguisher thrust

**20 Conservation of Linear Momentum**
.15 car on a rolling board
.25 elastic band reaction carts

**21 Mass and Momentum Transfer**
.20 catapult from cart to cart
.30 ballistic air glider
.40 drop sandbag on cart
.45 vertical catapult from moving cart

**22 Rockets**
.15 rocket lift-off video
.25 balloon rocket
.30 CO2 cartridge rocket
.33 rocket around the Moon
.40 ball bearing rocket cart

**30 Collisions in One Dimension**
.11 bowling ball collision balls
.20 3:1 collision balls
.30 air track collision gliders
.33 equal and unequal mass air track collisions
.55 elastic and inelastic model
.65 double air glider bounce

**40 Collisions in Two Dimensions**
.10 shooting pool
.21 air table collisions - unequal mass
.22 air table collisions - inelastic

## 1Q ROTATIONAL DYNAMICS

**10 Moment of Inertia**
.20 torsion pendulum inertia
.31 rolling bodies on incline
.55 weary roller
.70 rigid and non-rigid rollers

**20 Rotational Energy**
.15 flywheel and drum with weight
.20 angular acceleration wheel
.25 accelerate light and heavy pulleys
.35 bike wheel on incline
.51 bowling ball faster than "g"
.55 pennies on a meter stick
.60 falling meter sticks - scaling

**30 Transfer on Angular Momentum**
.15 pass bags o' rice
.25 satellite de rotator
.30 catch the bag on the stool

**40 Conservation of Angular Momentum**
.23 centrifugal governor
.25 pulling on the whirligig
.40 train on a circular track
.45 wheel and brake
.50 pocket watch
.60 sewer pipe pull
.70 marbles and funnel
.80 Hero's engine
.82 air rotator with deflectors

**50 Gyros**
.21 bike wheel on gimbals
.23 bike wheel precession
.24 walking the wheel
.30 MITAC gyro
.31 ride a gyro
.35 gyro in gimbals
.40 suitcase gyro
.60 gyrocompass
.70 stable gyros
.72 ship stabilizer

**60 Rotational Stability**
.15 humming top
.37 billiard ball ellipsoid
.40 tossing the book
.45 tossing the hammer
.50 spinning lariat, hoop, and disc
.51 spinning rod and hoop
.80 static/dynamic balance

## 1R PROPERTIES OF MATTER

**10 Hooke's Law**
.20 strain gauge
.25 pull on a horizontal spring
.30 springs in series and parallel

**20 Tensile and Compressive Stress**
.11 elastic limits
.15 Young's modulus
.20 bending beam
.25 sagging board
.40 buckling tubes
.60 Bologna bottles
.70 Prince Rupert's drops

**30 Shear Stress**
.10 shear book
.40 torsion rod

**50 Crystal Structure**
.20 crystal models
.40 crystal fault model
.45 crushing salt

# FLUID MECHANICS

## 2A SURFACE TENSION

**10 Force of Surface Tension**
.15 submerged float
.21 floating metal sheet
.25 leaky boats
.30 surface tension balance
.33 surface tension disc
.35 cohesion plates
.40 drop soap on lycopodium powder
.51 rubber balloons
.80 charge and surface tension

**15 Minimal Surface**
.20 soap film minimal surfaces
.21 catenoid soap film

**20 Capillary Action**
.20 surface tension hyperbola
.35 capillary action

**30 Surface Tension Propulsion**
.10 surface tension boat propulsion
.30 mercury heart

## 2B STATICS OF FLUIDS

**20 Static Pressure**
.15 pressure dependent on depth
.16 pressure vs. depth in water and alcohol
.25 Pascal's paradox
.30 weigh a water column
.32 chicken barometer
.34 hydrostatic paradox - truncated cone
.50 Pascal's fountain
.61 two syringes
.62 hydraulic can crusher
.65 garbage bag blowup
.66 weight on a beach ball
.70 compressibility of water
.71 water/air compression

**30 Atmospheric Pressure**
.05 lead bar
.15 crush the soda can
.25 crush the soda can with vacuum pump
.33 Madgeburg hemisphere swing
.34 Madgeburg tug-of-war
.36 suction cups
.40 soda straw contest
.55 adhesion plates
.70 vacuum bazooka

**35 Measuring Pressure**
.10 mercury barometer
.15 barometer in a tall bell jar
.40 aneroid barometer

**40 Density and Buoyancy**
.14 buoyant force
.15 finger in beaker
.18 board & weights
.25 battleship in a bathtub
.27 ship pictures full & empty
.35 hydrometers

.42 buoyancy balloon
.43 helium balloon in a glass jar
.44 helium balloon in liquid nitrogen
.45 weight of air
.53 water and mercury "U" tube
.54 buoyancy in various liquids
.56 floating square bar
.59 density ball
.60 hydrometer
.61 different density woods

**60 Siphons, Fountains, and Pumps**
.10 Hero's fountain
.20 siphon
.40 Mariotte flask and siphon
.60 hydraulic ram
.75 lift pump

## 2C DYNAMICS OF FLUIDS

**10 Flow Rate**
.26 syringe water velocity

**20 Forces in Moving Fluids**
.25 pitot tube
.36 ball in a stream of water
.44 coin in cup
.50 airplane wing
.70 Bjerknes' tube
.80 Flettner rotator

**30 Viscosity**
.10 viscosity disc
.25 viscosity of oil
.55 ball drop
.65 terminal velocity coffee filters

**40 Turbulent and Streamline Flow**
.10 streamline flow
.25 Poiseuille flow
.50 laminar and turbulent flow

**50 Vorticies**
.15 vortex cannon
.20 liquid vortices
.30 tornado tube
.35 flame tornado

**60 Non Newtonian Fluids**
.20 density balls in beans
.30 cornstarch
.35 slime ball
.40 silly putty
.55 ketchup uzi

# OSCILLATIONS AND WAVES

## 3A OSCILLATIONS

**10 Pendula**
.14 4:1 pendulum
.17 different mass pendula
.40 variable g pendulum

**15 Physical Pendula**
.30 paddle oscillator
.45 oscillating lamina
.57 sweet spot of a meter stick
.70 Kater's pendulum

**20 Springs and Oscillators**
.20 springs in series and parallel
.35 air track gliders between springs
.40 roller cart and springs
.50 oscillating chain

**40 Simple Harmonic Motion**
.25 ball on track vs. pendulum
.30 arrow on the wheel
.35 SHM slide
.41 tuning fork with light
.50 strain gauge SHM
.65 phase shift disc

**50 Damped Oscillators**
.20 damped SHM tracer
.45 oscillating guilotine

**60 Driven Mechanical Resonance**
.31 resonant driven pendula
.35 bowling ball pendula resonance
.40 driven mass on spring
.43 driven spring weight
.44 drunken sailor
.55 driven torsion pendulum
.60 upside-down pendulum (driven)
.70 lamppost resonance

**70 Coupled Oscillations**
.15 swinging mass on a spring
.27 spring coupled physical pendula
.30 string coupled pendula
.40 inverted coupled pendula
.45 coupled masses on springs
.50 oscillating magnets

**75 Normal Modes**
.30 masses on a string
.40 bifilar pendulum modes

**80 Lissajous Figures**
.10 Lissajous sand pendulum
.40 Lissajous figures - laser

**95 Non-Linear Systems**
.10 water relaxation oscillator
.20 wood block relaxation oscillator
.33 pendulum with large amplitude
.38 periodic non-simple harmonic motion
.45 amplitude jumps
.50 chaos systems
.60 parametric resonance
.70 pump a swing
.80 parametric instability

## 3B WAVE MOTION

**10 Transverse Pulses and Waves**
.05 the wave - transverse
.15 tension dependence on wave speed
.16 speed of torsional waves
.17 speed of a slinky pulse
.18 speed of pulses on ropes
.25 standing pulse
.40 Kelvin wave apparatus
.75 pendulum waves

**20 Longitudinal Pulses and Waves**
.05 the wave - longitudinal
.20 longitudinal wave on air track
.30 longitudinal wave model (PASCO)
.35 longitudinal wave machine
.60 speed of particles vs. waves
.70 Crova's disc

**22 Standing Waves**
.15 three tensions standing waves
.40 vertical vibrating bar
.50 slinky standing waves
.60 longitudinal standing waves
.70 soap film oscillations
.90 crank slide

**25 Impedance and Dispersion**
.20 reflection - shive model
.25 spring wave reflection
.26 fixed and free rope reflection
.30 effect of bell
.35 acoustic coupling with speaker
.40 soundboard
.50 dispersion in a plucked wire
.55 space phone (spring horn toy)

**27 Compound Waves**
.10 slinky and soda cans
.15 wave superposition - Shive model
.20 adding waves apparatus
.30 double pendulum beat drawer

**30 Wave Properties of Sound**
.40 speaker and candle
.45 bubbles and bugle
.50 helium talking
.55 sound velocity at different temperatures
.60 speed of sound in rod and air
.65 music box

**33 Phase and Group Velocity**
.20 two combs

**35 Reflection and Refraction (Sound)**
.10 gas lens
.20 refraction prism - CO2
.30 parabolic reflector and sound source
.60 refraction of water waves

**39 Transfer of Energy in Waves**
.10 water wave model
.20 dominoes

**40 Doppler Effect**
.15 Doppler whistle
.25 Doppler reed
.30 Doppler beats

**45 Shock Waves**
.15 shock waves in ripple tank
.20 pop the champagne cork
.30 solition tank
.40 tsunami tank

**50 Interference and Diffraction**
.25 ripple tank - double slit
.50 double slit transparency
.55 interference model

**55 Interference & Diffraction of Sound**
.55 diffraction pattern of a piston
.60 diffraction fence

**60 Beats**
.11 beat bars
.15 beat whistles
.40 ripple tank beats

## 3C ACOUSTICS

**10 The Ear**
.10 model of the ear

**20 Pitch**
.30 siren disc
.40 Savart's wheel

**30 Intensity and Attenuation**
.21 dB meter and horn
.30 loudness (phones and sones)
.35 hearing - 3dB

**50 Wave Analysis and Synthesis**
.15 mechanical square wave generator
.35 resonance tube spectrum
.40 harmonic tones (vibrating string)
.50 noise (pink and white)
.55 distinguishing harmonics with the ear
.70 wave analysis (PASCO filter)
.80 spectrum analyzer

**55 Music Perception and the Voice**
.20 pitch of complex tones
.25 missing fundamental
.30 difference tones
.35 beats vs. difference tones
.40 chords
.45 consonance and dissonance
.55 tuning forks on resonance boxes
.70 tone quality
.74 keyboard and oscilloscope
.80 formants
.85 filtered music and speech

## 3D INSTRUMENTS

**20 Resonance in Strings**
.20 modes of string oscillation on scope
.21 guitar and scope
.50 Aeolian harp

**22 Stringed Instruments**
.10 violin

.20 cigar box cello
**30 Resonance Cavities**
.15 resonance tube with piston
.16 horizontal resonance tube
.40 Hemholtz resonators
.74 variable hoot tubes
**32 Air Column Instruments**
.10 organ pipes
.20 organ pipes with holes
.25 open and closed end pipes
.30 slide whistle
.40 demonstration trumpet
.45 PVC instruments
**40 Resonance in Plates, Bars, Solids**
.10 xylophone
.11 rectangular bar oscillations
.12 high frequency metal bars
.15 musical sticks
.16 musical nails
.33 thick Chladni plate
.35 flaming table
.45 bubble membrane modes
.50 musical goblet
.65 bull roarer
**46 Tuning Forks**
.16 tuning fork
.22 adjustable tuning fork

## 3E SOUND PRODUCTION

**10 Audio Systems**
.10 audio cart - complete audio system
**20 Loudspeakers**
.20 crossover network for speakers
**80 Digital Systems**
.10 CD with holes

# THERMODYNAMICS

## 4A THERMAL PROPERTIES OF MATTER

**10 Thermometry**
.15 mercury thermometer
.20 Galileo's thermometer
.50 cholesteric liquid crystals
**20 Liquid Expansion**
.30 maximum density of water
**30 Solid Expansion**
.11 thermostat model
.15 wire coil thermostat - Zig's model
.40 hopping discs
.50 expansion of quartz and glass
.80 heat rubber bands
**40 Properties of Materials at Low Temperatures**
.20 mercury hammer
.35 cool rubber band
.40 viscous alcohol

## 4B HEAT AND THE FIRST LAW

**10 Heat Capacity and Specific Heat**
.15 water and oil in a hot plate
.30 melting wax
.60 Clement's and Desormes' experiment
.70 elastic properties of gases
**20 Convection**
.20 two chimney convection box
.25 convection chimney with vane
.30 convection chimney with confetti
.40 convection currents projected
.50 Bernard cell
**30 Conduction**
.12 conduction - melting wax
.20 painted rods
.25 four rods - heat conduction
.30 copper and stainless tubes
.35 toilet seats
.50 heat propagation in a copper rod
**40 Radiation**
.30 Leslie's cube
.40 two can radiation
.50 selective absorption and transmission
.60 black and white thermometers
**50 Heat Transfer Application**
.30 Leidenfrost effect
.35 finger in hot oil
.40 reverse Leidenfrost
.60 greenhouse effect
**60 Mechanical Equivalent of Heat**
.11 invert tube of lead
.15 hammer on lead
.20 copper barrel crank
.50 bow and stick
.70 cork popper
**70 Adiabatic Processes**
.25 pop the cork cooling

## 4C CHANGE OF STATE

**20 Phase Changes: Liquid-Solid**
.10 supercooled water
.55 heat of solution
.60 heat of crystallization
**30 Phase Changes: Liquid-Gas**
.15 boiling at reduced pressure
.25 geyser
.30 helium and CO2 balloons in liquid N2
.35 liquid nitrogen in a balloon
**31 Cooling by Evaporation**
.20 freezing by evaporation
**32 Dew Point and Humidity**
.10 sling psychrometer
.40 condensation nuclei
**33 Vapor Pressure**
.10 vapor pressure in barometer
.20 addition of vapor pressures
.30 vapor pressure curve for water
**40 Sublimation**
.15 blow up balloon with CO2
**45 Phase Changes: Solid - Solid**
.10 phase change in iron
.30 polymorphism
**50 Critical Point**
.20 critical opalescence
.40 triple point of water cell

## 4D KINETIC THEORY

**10 Brownian Motion**
.20 Brownian motion simulator
.30 colloidal suspension
.40 Dow spheres suspension
**20 Mean Free Path**
.20 mean free path and pressure
.30 mean free path pin board
**30 Kinetic Motion**
.11 big kinetic motion apparatus
.21 equipartition of energy simulator
.22 pressure vs. column simulator
.23 free expansion simulation
.24 temperature increase simulation
.40 glass beads
.60 flame tube viscosity
**40 Molecular Dimensions**
.10 steric and oleic acid films
**50 Diffusion and Osmosis**
.20 diffusion through porcelain
.45 bromine diffusion
.50 bromine cryophorus
.60 diffusion in liquids - CuSO4
.80 osmosis simulator

## 4E GAS LAW

**10 Constant Pressure**
.11 thermal expansion of air
**20 Constant Temperature**
.15 syringe and pressure gauge
.30 Boyle's law with tap pressure
.40 balloon in a vacuum
**30 Constant Volume**
.20 constant volume thermometer

## 4F ENTROPY AND THE SECOND LAW

**10 Entropy**
.20 balls in a pan
**30 Heat Cycles**
.40 refrigerator
.60 Nitinol engine
.70 rubber band engine

# ELECTRICITY AND MAGNETISM

## 5A ELECTROSTATICS

**10 Producing Static Charge**
.15 triboelectric series
.30 electret
.35 equal and opposite charges
.37 electrostatic rod and cloth
.40 mercury-glass charging wand
.50 cyrogenic pyroelectricity
.55 heating and cooling tourmaline
**20 Coulomb's Law**
.28 beer can pith balls
.30 mylar balloon electroscope
.32 electrostatic spheres on air table
**22 Electrostatic Meters**
.25 soft drink can electrosope
.50 Kelvin electrostatic voltmeter
.70 electrometer
.80 electric field mill
**30 Conductors and Insulators**
.15 acrylic and aluminum bars
**40 Induced Charge**
.15 electroscope charging by induction
.25 paper sticks on board
.60 electrostatic generator principles
**50 Electrostatic Machines**
.15 Toepler-Holtz machine
.31 Van de Graaff principles
.50 Franklin's electrostatic machines

## 5B ELECTRIC FIELDS AND POTENTIAL

**10 Electric Field**
.26 electrified strings
.30 electric chimes
.70 rubber sheet field model
**20 Gauss' Law**
.15 Faraday's ice pail on electroscope
.31 electroscope in a cage/Wimshurst
**30 Electrostatic Potential**
.20 charged ovoid

## 5C CAPACITANCE

**10 Capacitors**
.21 battery and separable capacitor
.30 dependence of capacitance on area
.35 rotary capacitor
**20 Dielectric**
.17 helium dielectric
.20 force on a dielectric
.25 attraction of charged plates
.35 bound charge
.60 displacement current
**30 Energy Stored in a Capacitor**
.10 Leyden jar and Wimshurst
.15 exploding capacitor
.35 lifting weight with a capacitor
.40 series/parallel Leyden jars
.42 series/parallel capacitors
.50 Marx and Cockroft-Walton
.60 residual charge

## 5D RESISTANCE

**10 Resistance Characteristics**
.50 current model with Wimshurst

**20 Resistivity and Temperature**
.15 flame and liquid nitrogen
.50 thermistors
**30 Conduction in Solutions**
.13 salt water string
.20 migration of ions
.30 pickle glow
**40 Conduction in Gases**
.20 conduction of gaseous ions
.30 ionization by radioactivity
.40 conduction from a hot wire
.42 thermionic emisson
.50 neon bulb
.80 x-ray ionization

## 5E ELECTROMOTIVE FORCE & CURRENT

**30 Plating**
.10 copper flashing of iron
.40 silver coulomb meter
**40 Cells and Batteries**
.20 voltaic cell
.75 weak and good battery
**50 Thermoelectricity**
.60 Peltier effect
**60 Piezoelectricity**
.25 piezoelectric gun
.30 stress vs. voltage
.40 piezoelectric speaker

## 5F DC CIRCUITS

**10 Ohm's Law**
.15 water Ohm's law analog
.20 potential drop along a wire
.25 potential drop with Wimshurst
**15 Power and Energy**
.10 electrical equivalent of heat
.30 fuse with 30 V lamp
.40 voltage drops in house wires
.45 IR2 losses
**20 Circuit Analysis**
.20 superposition of current
.25 reciprocity
.30 potentiometer
.40 Wheatstone bridge
.45 light bulb Wheatstone bridge
.51 light bulb board - 12 V
.55 series and parallel resistors
.60 equivalent resistance
**30 RC Circuits**
.15 RC time constant on galvanometer
.50 series and parallel capacitors
.60 neon relaxation oscillator
**40 Instruments**
.10 sensitivity and resistivity of a galvanometer
.20 galvanometer as an ammeter and voltmeter
.21 loading by voltmeter

## 5G MAGNETIC MATERIALS

**10 Magnets**
.15 lodestone
.16 lodestone suspended
.30 Which is a magnet?
.50 lowest energy configuration of magnets
**20 Magnet Domains & Magnetization**
.45 induced magnetic poles
.60 magnetization by current
.61 magnetization by contact
.62 demagnitization by hammering
.71 electromagnet
.72 large electromagnet
.73 magnetically suspended globe
.75 retentivity
**30 Paramagnetism and Diamagnetism**
.15 pull the sample
.20 paramagnetism of liquid oxygen
**40 Hysteresis**
.50 hysteresis waste heat
**45 Magnetostriction and Magnetores**
.10 magnetorestrictive resonance
.30 magnetorestriction of nickel wire
.70 magnetoresistance
**50 Temperature and Magnetism**
.15 Curie nickel
.20 thermomagnetic motor
.25 dysprosium in liquid nitrogen

## 5H MAGNETIC FIELDS AND FORCES

**10 Magnetic Fields**
.50 area of contact
.55 gap and field strength
.60 shunting magnetic flux
.61 magnetic shielding
.65 magnetic screening
**15 Fields and Currents**
.13 right hand rule
.15 Biot-Savart law animation
.20 parallel wires and iron filings
.25 anti-parallel wires and iron filings
**20 Forces on Magnets**
.15 snap the lines of force
.23 centrally levitating magnets
.24 linearly levitating magnets
.30 inverse square law
.35 inverse square law balance
.40 inverse fourth law - dipoles
.50 inverse seventh law - magnet/iron
**25 Magnet/Electromagnet Interaction**
.10 magnet in a coil
.20 jumping magnet
.25 force on a solenoid core
**30 Force on Moving Charges**
.15 bending an electron beam
.25 magnetic mirror
.30 rotating plasma
.50 electromagnetic pump
.55 ion motor
**40 Force on Current in Wires**
.23 filament and magnet with AC/DC
.25 dancing spiral
.35 jumping wire coil
.36 long wire in field
.70 Ampere's motor
**50 Torques on Coils**
.20 force on a current loop
.25 short and long coils in field
.35 dipole loop around long wire
.45 spinning coil over magnet

## 5J INDUCTANCE

**10 Self Inductance**
.30 back EMF - spark

## 5K ELECTROMAGNETIC INDUCTION

**10 Induced Currents and Forces**
.16 tape head model
.21 10/20/40 coils with magnet
.40 induction coils with core
.48 current coupled pendula
.65 jumping rope
.70 What does a voltmeter measure?
**20 Eddy Currents**
.15 Eddy damped pendulum
.20 falling aluminum sheet
.42 Arago's disk
.50 rotating ball
.65 electromagnetic can breaker
**30 Transformers**
.13 salt water string
.30 vertical transformer
.35 light underwater
.40 weld a nail
.60 reaction of a secondary on primary
**40 Motors and Generators**
.10 DC motor
.15 Faraday motor
.45 coupled motor/generator
.83 bicycle generator
.85 generator slowed by load

## 5L AC CIRCUITS

**10 Impedance**
.20 capacitive impedance
.30 capacitive reactance
**20 LCR Circuits - AC**
.18 driven LRC circuit

## 5M SEMICONDUCTORS AND TUBES

**10 Semiconductors**
.50 diode
.71 brillouin/compass array
.90 transistor amplifier
**20 Tubes**
.10 glow discharge
.20 special purpose discharge tubes

## 5N ELECTROMAGNETIC RADIATION

**10 Transmission Lines and Antennas**
.10 model transmission line
.15 HV line model
.20 model transmission line - phases
.55 microwave standing waves
**20 Tesla Coil**
.40 Tesla Coil
**30 Electromagnetic Spectrum**
.50 IR camera and remote control device
.52 IR control devices

# OPTICS

## 6A GEOMETRICAL OPTICS

**01 Speed of Light**
.20 speed of light - two path
.30 speed of light - rotating mirror
**02 Straight Line Propagation**
.10 light in a vacuum
.15 straight line propagation - shadows
.35 chalk dust
**10 Reflection From Flat Surfaces**
.11 optical disk with flat mirror
.18 microwave reflection
.22 aluminum foil reflection
.25 ripple tank reflection
.31 large corner cube
.37 parity reversal in a mirror
.65 half silvered mirror box
**20 Reflection from Curved Surfaces**
.11 optical disc with curved mirrors
.20 spherical abberation in a mirror
.35 optic mirage
.41 projected filament with mirror
.60 energy at a focal point
**40 Refractive Index**
.40 variable index of refraction tank
.45 mirage
.50 oil, water, laser
.60 Schlieren image
.70 short beer
**42 Refraction at Flat Surfaces**
.11 optical disk with glass block
.21 Nakamara refraction tank
.30 refraction model - rolling

.35 ripple tank refraction
.43 light in a tank
.47 acrylic/lead glass refraction
.50 minimum angle of deviation
.51 three prism stack
.55 paraffin prism and microwaves

**44 Total Internal Reflection**
.11 optical disk with prism, semicircle
.25 Snell's wheel
.30 ripple tank total internal reflection
.41 optical path in fibers
.42 steal the signal
.45 water stream light pipe
.55 black ball turns silver

**46 Rainbow**
.20 rainbow model
.30 optical disc with spherical lens

**60 Thin Lens**
.11 optical disk with thin lens
.16 ripple tank concave lens
.31 projected arrow with lens
.35 lens magnification
.45 position of virtual image
.60 paraffin lens and microwaves

**61 Pinhole**
.10 pinhole projection

**65 Thick Lens**
.15 optical disc - circular glass plate
.31 off axis distortion
.35 astigmatism and distortion
.52 fillable air lens
.70 Frensel lens

**70 Optical Instruments**
.35 projector model

## 6B PHOTOMETRY

**10 Luminosity**
.20 inverse square law with photometer
.35 grease spot photometer
.40 Rumford shadow photometer
.50 frosted globe - surface brightness
.55 frosted globes

**30 Radiation Pressure**
.10 radiometer - quartz fiber

**40 Blackbodies**
.25 carbon block
.26 carbon rod
.40 X-Y spectrum recorder
.41 IR spectrum on galvanometer
.45 IR camera and projected spectrum
.50 IR camera and soldering iron
.55 project spectrum and change temperature

## 6C DIFFRACTION

**10 Diffraction Through One Slit**
.12 Cornell plate - single slit
.20 two finger slit
.30 slit on photodiode array
.50 microwave diffraction

**20 Diffraction Around Objects**
.22 shadow of a needle
.40 zone plate lens

## 6D INTERFERENCE

**10 Interference From Two Sources**
.05 interference model
.11 Cornell plate - two slit
.15 double slit on X-Y recorder
.17 double slit on photo diode array
.20 microwave two slit interference
.25 microwave two source interference
.35 ripple tank incoherence

**20 Gratings**
.56 regular and irregular patterns
.59 random multiple gratings

**30 Thin Films**
.60 interference filters

**40 Interferometers**
.15 interference fringes with audio

## 6F COLOR

**10 Synthesis and Analysis of Color**
.25 spinning color disc
.30 recombining the spectrum
.33 purity of the spectrum
.45 complementary shadow
.75 colors in spectral light

**30 Dispersion**
.10 dispersion curve of a prism

**40 Scattering**
.20 optical ceramics scattering
.50 microwave scattering

## 6H POLARIZATION

**10 Dichroic Polarization**
.40 polaroids cut at 45 degrees

**20 Polarization by Reflection**
.15 microwave Brewster's angle
.30 Brewster's cone

**30 Circular Polarization**
.70 microwave optical rotation
.80 Faraday rotation

**35 Birefringence**
.15 calcite and Polaroid on overhead
.17 plexiglass birefringence
.45 half wave plate
.53 butterfly, etc
.65 LCD element between polaroids

**50 Polarization by Scattering**
.30 depolarization by diffuse reflection
.90 Haidinger's brush

## 6J THE EYE

**10 The Eye**
.30 blind spot
.40 inversion of image of retina
.80 resolving power of the eye
.81 resolving power with TV

**11 Physiology**
.10 retinal fatigue - color disc
.20 visual fatigue
.30 persistence of vision
.50 impossible triangles
.70 color blindness

## 6Q MODERN OPTICS

**10 Holography**
.20 in class holograms

**20 Physical Optics**
.10 Abbe demonstrations

# MODERN PHYSICS

## 7A QUANTUM EFFECTS

**10 Photoelectrics Effects**
.12 photoelectric charging
.15 discovery of the photoelectric effect
.35 photoelectric threshold
.40 solar cells
.50 photo conduction vs. thermopile
.60 carrier recombination and lifetime

**15 Millikan Oil Drop**
.10 Millikan oil drop
.20 Millikan oil drop model

**50 Wave Mechanics**
.30 vibrating soap film
.50 complementary rule
.90 Mermin's Bell theorem boxes

**55 Particle/Wave Duality**
.10 wave/particle sound analogy
.15 wave/particle model with dice
.20 single photon interference

**60 X-ray and Electron Diffraction**
.20 diffraction model
.30 electron "Poisson spot"
.40 field emission electron microscope
.60 ripple tank Bragg diffraction
.90 x-ray diffraction
.95 sample x-ray tube

**70 Condensed Matter**
.10 Josephson junction analog
.20 Josephson effect simple demo
.30 F-center diffusion

## 7B ATOMIC PHYSICS

**10 Spectra**
.11 flame salts
.15 line spectra with large grating
.20 project spectral lines

**11 Absorption**
.25 flame absorption projected
.30 mercury vapor shadow
.40 filtered spectrum
.60 band absorption spectra

**13 Resonsance Radiation**
.05 triboluminescence
.20 sodium vapor beam
.40 UV spectrum by fluorescence
.55 luminescence

**20 Fine splitting**
.15 Zeeman - sodium flame in magnet
.25 Stern-Gerlach crystal model
.45 Mossbauer model

**30 Ionization Potential**
.10 ionization potential of mercury
.40 excited states model

**35 Electron Properties**
.10 discharge at low pressures
.40 Maltese cross
.50 paddle wheel
.75 plasma tube

## 7D NUCLEAR PHYSICS

**10 Radioactivity**
.20 half life with isotope generator
.25 radon in the air
.30 contamination by neutron source
.45 electrical analog of decay
.50 dice on the overhead
.55 coin toss half life
.80 cosmic rays

**20 Nuclear Reactions**
.15 match chain reaction
.20 dominoes chain reaction

**30 Particle Detectors**
.05 Ludlum Detectors
.10 nixie Geiger counter
.15 thermal neutron detector
.25 spark chamber

**40 NMR**
.10 NMR gyro model

**50 Models of the Nucleus**
.20 Rutherford scattering animation
.30 Thompson model
.46 mass defect

## 7E ELEMENTARY PARTICLES

**10 Misc.**
.20 fundamental particles software

## 7F RELATIVITY

**10 Special Relativity**
.10 Lorentz tranformation machine
.20 flow ripple tank - twin source
.25 foam rubber roller
.66 Majestic clockwork

# ASTRONOMY

## 8A PLANETARY ASTRONOMY

**05 Historical Astronomy**

**10 Solar System Mechanics**

.35 local zenith

**20 Earth - Moon Mechanics**

.70 pinhead earth

**30 Views from Earth**

.10 horizon astronomy model
.20 Cinhelium

**35 Views from Earth - 2**

**40 Planetary Properties**

.10 globes

**50 Planetary Properties - 2**

**60 Planetary Properties - 3**

**70 Planetary Properties - 4**

**80 Planetary Properties - 5**

.20 comet orbit

## 8B STELLAR ASTRONOMY

**10 The Sun**

**20 Stellar Spectra**

**30 Stellar Evolution**

.10 stellar magnitude simulator
.40 variable star simulation
.65 pulsar model
.70 pulsar recording
.95 forward and backward scattering

**40 Black Holes**

.20 black hole surface

**50 Stellar Miscellaneous**

## 8C COSMOLOGY

**10 Models of the Universe**

.35 inflating balloon
.37 expanding universe on white board
.40 bubble universe
.50 galaxy model

**20 Gravitational Effects**

.10 Klein bottle
.20 Moebius strip
.30 saddle shape

## 8D MISCELLANEOUS

**10 Miscellaneous**

## 8E ASTRONOMY TEACHING TECHNIQUES

**30 Astronomy Teaching Techniques**

# EQUIPMENT

## 9A SUPPORT SYSTEMS

**10 Blackboard Tools**

.10 compass
.12 protractor
.31 angle templates
.35 sine wave templates

**20 Audio**

.10 wireless microphone
.11 multiple wireless microphones
.15 cord microphone
.16 multiple cord microphones
.20 CD player
.30 audio cassette
.40 phonograph
.50 reel to reel

**30 Slide Projectors**

.05 mobile screen
.10 35 mm projector
.11 two 35 mm projectors
.15 35 mm to go
.20 lantern projector

**34 Film Projectors**

.10 16 mm projector
.20 film loop projector
.30 super 8 projector
.35 8 mm projector
.40 film strip projector

**36 Overhead Projectors**

.10 overhead projector
.15 two overhead projectors
.30 write on film rolls

**38 Video & Computer Projection**

.10 TV table (color)
.11 TV table (B&W)
.15 tripod TV (color)
.16 tripod TV (B&W)
.17 tripod TV (IR)
.20 video projector
.21 LCD panel
.22 color LCD panel
.25 classroom monitors
.26 monitor on cart
.30 video disc
.40 VHS tape deck
.45 3/4" tape deck
.50 IBM clone
.65 Mac

## 9B ELECTRONIC

**60 Light Sources**

.10 eosin mister