PIRA DEMONSTRATION BIBLIOGRAPHY

AAPT SUMMER MEETING
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LECTURE DEMONSTRATIONS WORKSHOP

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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**
Turning the World Inside Out	**by Robert Ehrlich**
Why Toast Lands Jelly-Side Down	**by Robert Ehrlich**

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
Ehrlich 1, p. 3	Ehrlich - Turning the World Inside Out
Ehrlich 2, p. 22	Ehrlich - Why Toast Lands Jelly-Side Down

How to use the Physics Demonstration Bibliography

This Demonstration Bibliography contains about 12,000 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/Bib
Excel and PDF versions can be found at: http://www.pira-online.org in the "Resources" section under . the DCS tab.

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 "1" or a "2" has been added to the author prefix when that author has more than one book listed as a reference.
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
Ehrlich 1, p. 3	Ehrlich - Turning the World Inside Out
Ehrlich 2, p. 22	Ehrlich - Why Toast Lands Jelly-Side Down

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.

PIRA 200 - 2014

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

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
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
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
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
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

	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	

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	Pass around to the class some labeled uniform cylinders of different materials.
	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.
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**	
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 cubes. 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.
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 glider 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 glider 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.
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.
Ehrlich 1, p. 3	drop balls of different sizes	1C20.15	Drop balls of different sizes from the same height. Works well unless you use a ball of extremely low density.
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 heavy ball must be dropped from so it hits the floor at the same time as the light ball.
Ehrlich 1, p. 44	freefall and air resistance	1C20.18	Observe the effect of air resistance on objects of different size, shape, density, and orientation. Also, tape a coin to the center of a note card and then a coin to the middle of another card's short side edge. Hold both horizontally and then drop.
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 glider 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.
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 glider 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 glider on an inclined air track with strobe photography.
D&R, M-108	inclined rail and ball	1C20.37	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.
Ehrlich 1, p. 6	ball on an incline	1C20.45	Steel balls are rolled down the grove of an inclined plastic ruler.
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.
Ehrlich 2, p. 32	free fall timer	1C30.10	Drop objects and time their fall through a known distance with a stopwatch.

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.
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.
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.
Ehrlich 1, p. 65	high road low road	1D15.20	Two balls race down incline tracks. One track is straight, one track has a rise at each end.
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.
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	triple 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	1D40.10	A disc with an internal sliding weight has spots painted on opposite sides marking the center of mass in the two cases.
Hil, M-18b.2	throw objects	1D40.10	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	1D40.10	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.
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 glider 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 glider.
Mei, 9-2.3	air track pendulum glider	1D40.50	A heavy pendulum on a light glider.
Mei, 11-1.2	air track pendulum glider	1D40.50	A double pendulum on an air glider has total mass equal to the glider. 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 gliders 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 gliders 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	
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.
Ehrlich 1, p. 72	whirligig	1D50.20	A twirling weight connected to a hanging weight through a tube is used to show angular momentum conservation.
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.
Ehrlich 1, p. 74	conical pendulum	1D50.25	A conical pendulum makes a particular angle with the vertical related to its length and period. Make cones out of cardboard or transparency film to verify.
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 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.
Ehrlich 1, p. 73	carnival ride model - accelerometer	1D50.30	An inexpensive accelerometer is tied to a string. It beeps at a preset value when the correct rotation rate is achieved.
Disc 05-20	roundup	1D50.30	A toy person stands on the inside wall of a rotating cylinder.

D&R, M-370	carnival ride variation - carry a ball	1D50.33	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.
TPT 24(5),295	carnival ride variation - carry a ball	1D50.33	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. An inverted wine glass whose middle is slightly larger than its mouth will also work. Swirl the glass and the ball will rotate about the inside and climb to the center of the glass. Continue swirling the glass and you can carry the ball anywhere desired.
Ehrlich 1, p. 91	carnival ride variation - ball in a cup	1D50.33	A small ball in a plastic cup can be made to revolve faster and faster or even climb the walls by shaking the cup at the right frequency.
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.
Ehrlich 1, p. 76	pail of water	1D50.40	A pail of water is whirled around in a vertical circle. How slow can you go before your head gets wet.
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.
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.
TPT 33(3), 173	ball on a hoop	1D50.57	A ball on a hoop that is inserted into a hand drill. The ball moves up from the bottom of the hoop to a position that depends on the angular velocity.
TPT 33(5), 262	ball on a hoop	1D50.57	A follow up to the March TPT article that states that there is a minimum angular velocity that must be achieved before the ball will start to move up from the bottom of the hoop.
AJP 68(3), 271	balls in a hoop	1D50.57	A grooved track or V shaped aluminum channel is made into a circular track of about 20 cm in radius. Place two balls in the track and rotate it about its vertical axis. The balls will rise to positions that depend on the angular velocity. An offset axis of rotation may also be explored.
AJP 73(4), 366	balls in a hoop	1D50.57	A grooved circular track with one inch ball bearings in it is rotated about its vertical axis. First and second order phase transistions can be demonstrated.
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.
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.
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	A Plexiglas tank is placed on a turntable. Spin the turntable and observe the parabola.
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.
Ehrlich 1, p. 66	water parabola	1D52.20	A paraboloid shape is made when a clear container of water is rotated on a phonograph turntable.
Disc 13-17	paraboloid 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.
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.
Ehrlich 2, p. 22	broken ring	1D55.10	A ball is rolled around the inside of a plastic circular ring with a gap. The ball goes off on a tangent when it hits the gap.
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.
Ehrlich 1, p. 78	falling off the merry-go-round	1D55.30	A turntable is rotated until a row of pennies start to slide off.
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 glider.
TPT 12(3),177	howitzer and tunnel	1D60.10	A description of a ball launcher mounted on an air track glider. 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.
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.
Ehrlich 1, p. 4	monkey and hunter on incline	1D60.31	A simple effective version using rolling balls on an inclined table. Works regardless of the slope of the incline.
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.
Ehrlich 2, p. 30	monkey and hunter	1D60.34	The classic "Monkey and Hunter" demonstration done using a transparency on the overhead projector.
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.
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.
Ehrlich 1, p. 8	parabolic trajectory on incline	1D60.55	Steel balls leave a trail of dots when rolled on an inclined table that is vibrating. Use carbon paper.
Ehrlich 2, p. 87	parabolic trajectory on incline	1D60.55	Balls are rolled across a tilted overhead projector. The ball follows a predictable parabolic trajectory.
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.
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.
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.
Ehrlich 2, p. 64	stick on a wheel	1E10.31	A ruler placed on the top of a rolling wheel or soda can moves twice as fast as the wheel or can.
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	More Phil Johnson humor. "Complicated. Look it up". The description would read: A complicated mechanical apparatus to show two X-Y axes systems, one stationary and one on a moving cart. "Cord" vectors are painted with fluorescent paint and viewed in black light as the cart is moved at constant velocity.
	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.
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.
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	
Ehrlich 1, p. 80	Coriolis ball on turntable	1E30.28	Roll a ball across a rotating turntable that has been covered with carbon paper.
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**	
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.
Ehrlich 1, p. 30	inertia balls	1F20.10	Break the string on the bottom or top of a suspended mass.
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.
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.
Ehrlich 1, p. 30	hit the stake on your chest	1F20.22	A very heavy steel stake is placed against your chest and hit with a hammer. No pain or damage results.
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	
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.
Ehrlich 1, p. 21	coin/card snap	1F20.34	Shoot a penny at the bottom of a stack of pennies knocking the bottom penny out without disturbing the rest of the stack.
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.
Ehrlich 1, p. 21	pennies on your arm	1F20.38	Place a row of 10 to 20 pennies on your forearm. Quickly swing your arm forward and catch all the pennies in midair.
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.
Mei, 8-2.1	inertia stick	1F20.40	A long stick is horizontally supported from rings of filter paper at each end. Break the filter paper with a pull on the middle of the stick or the stick with a jerk.
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 glider on the air track.
UMN, 1F30.10	persistence of motion (air track)	1F30.10	A single glider 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.
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**	
Ehrlich 2, p. 23	net force	1G10.05	Estimating the net force on a book as you move it in several types of motion.
Ehrlich 2, p. 25	net force	1G10.05	Use a simple force indicator made from index cards to observe the connection between force and acceleration.
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 glider pulled by a falling weight.
Mei, 7-1.5.7	acceleration air glider	1G10.10	Accelerate a glider on a track with a mass on a string over a pulley.
Hil, M-7b	glider, mass, and pulley	1G10.10	An air track glider 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 glider 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 glider to the pan.
Mei, 11-1.5	acceleration air glider	1G10.11	Air glider with a string over a pulley to a mass. Vary mass on both glider and hanger.
Mei, 10-2.1	acceleration air glider on incline	1G10.12	A glider 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 glider is accelerated up an inclined track by the string, pulley and mass system. A newton scale is included on the glider 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 bungee loop	1G10.15	
UMN, 1G10.15	roller cart and bungee loop	1G10.15	A student standing on a large roller cart is pulled by another student with a loop of bungee cord. Pulling so that the bungee cord maintains a constant length gives a slow acceleration to the cart.

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	
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.
Ehrlich 1, p. 29	mass on a scale	1G10.30	Hang a mass on a spring scale. Moving the scale up and down will give readings that permit a quantitative test of Newton's second law.
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.
Ehrlich 2, p. 58	Atwood's machine - high friction	1G10.45	A high friction Atwood's machine made by wrapping the string around a smooth horizontal rod or cylinder.
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.
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	
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.
Ehrlich 2, p. 183	leaky pail drop	1G20.30	Drop a water filled cup with two holes near the bottom of it. The water does not run out of the cup when it is in free fall.
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.
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.
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	Hold one end of a Slinky high in the air so the other end is not touching the ground and is clearly visible. Let go of the top end and watch as the lower end remains in place untill the whole spring has contracted to its minimum length. Note that the top end of the Slinky falls faster than "g".
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.
Ehrlich 2, p. 28	deep knee bends	1G20.63	Do deep knee bends on a bathroom scale as a simple test of Newton's second law.
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.
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.
Ehrlich 1, p. 31	float accelerometer	1G20.76	A fishing float or a Ping Pong ball is anchored to the bottom of a water filled jar. Move the jar suddenly and observe the motion of the float.
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.
Ehrlich 2, p. 48	accelerometer	1G20.79	A simple accelerometer for use on the overhead projector made from a clear box, small washer, and a 1 inch ball bearing.
Ehrlich 2, p. 50	accelerometer	1G20.79	A simple accelerometer for use on the overhead projector made from a concave lens and a small steel ball bearing.
Ehrlich 2, p. 52	accelerometer	1G20.79	A ruler hangs over the end of a table like a diving board. Place a penny on the end of the ruler and pluck it. When you hear the penny clatter, the acceleration has exceeded 1 g.
Ehrlich 2, p. 57	accelerometer	1G20.79	A 1000 g accelerometer. Drop steel balls onto a piece of soft wood and determine the acceleration during impact by measuring the depth of the dents.

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.
Ehrlich 2, p. 38	hourglass on a scale	1G30.30	A demonstration equivalent to the weight of an hourglass. The weight of water flowing from one bottle to another shows an increased scale reading while the water flows.
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.
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.
Ehrlich 2, p. 27	pick yourself up	1H10.05	Show that you can not "pick yourself up by your bootstraps" unless an outside force can give you an upward acceleration.
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 glider. 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	
Ehrlich 2, p. 109	helicopter rotor	1H10.25	A propeller on a stick can generate enough lift to rise vertically when twirled.
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	CO2 provides the pressure to blow a cork out of a cannon on wheels.
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.
Ehrlich 1, p. 34	bent straw	1H11.44	A bent straw recoils like a lawn sprinkler when air is blown through it. The author states that no recoil is observed when air is sucked into the bent straw. This statement is retracted in his second book "Why Toast Lands Jelly Side Down", p. 71. See 1Q40.85.
Ehrlich 2, p. 34	bent straw	1H11.44	A bent straw recoils like a lawn sprinkler when you blow through it. No recoil is observed if you place the straw in a plastic sandwich bag.

	STATICS OF RIGID BODIES	**1J00.00**	
	Finding Center of Gravity	**1J10.00**	
TPT 22(8),535	center of mass	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.
Ehrlich 2, p. 66	center of mass	1J10.09	Roll a magnetic marble toward another magnetic marble to make a glancing collision. The two marbles rotate about their center of mass when they stick together.
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.
Ehrlich 1, p. 49	meter stick on fingers	1J10.30	Slide your fingers together under a meter stick and they will meet at 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	
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.
Ehrlich 1, p. 38	leaning tower of Lire	1J11.20	Stack meter sticks stairstep fashion until the top meter stick protrudes out beyond any part of the bottom meter stick.
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.
Ehrlich 1, p. 39	instability in flotation	1J11.30	Place 20 pennies in a Styrofoam cup and close with a lid. Float this cup in some water and see how many pennies you can place on top of the lid, thereby raising the center of mass, before the cup turns over.
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.
Ehrlich 2, p. 43	human center of gravity	1J11.40	Stand with your back and heels against a wall and keep your feet flat on the floor. You can not bend and pick up an object on the floor in front of you.
	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	
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.
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.
Ehrlich 1, p. 34	tension in a spring	1J30.22	Pull on two spring scales connected together to show they will read the same value.
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.
Ehrlich 1, p. 22	chain and three students	1J30.25	A chain with demonstration scales on each end and a 10 pound weight in the middle. No matter how hard you pull on the scales you can not make the chain completely horizontal.
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.
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.
Ehrlich 1, p. 23	force table	1J30.50	A force table suitable for use on an overhead projector.
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 glider with a sail.
AJP 40(4),626	sail against the wind	1J30.60	A sail is mounted on an air track glider. 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	
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.
Ehrlich 2, p. 36	weight of a pendulum	1M40.12	Swing a mass attached to a large demonstration spring scale by a 1 meter string.
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.
Ehrlich 1, p. 48	torque beam	1J40.20	Balance a ruler with pennies on it to show torques about its center.
Ehrlich 1, p. 83	torque beam	1J40.20	A 6 foot long beam is balanced on a knife edge. Pennies are place on one arm of the beam. The angular acceleration is proportional to the applied torque.
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.
Ehrlich 2, p. 75	toast lands jelly side down	1J40.24	A variation of the "walking the plank" demonstration in which the toast with jelly on one side is slowly pushed out over the edge of a table and allowed to fall off. Complete analysis as to why it always seems to fall on the floor with the jelly side down.
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.
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. The steelyard is a graduated metal bar with a fulcrum near one end. Hang an unknown weight from the shorter arm. A sliding weight is moved along the longer arm until equilibrium is achieved. The arm is graduated to directly read the value of the unknown weight.
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.
Ehrlich 2, p. 60	ladder against a wall	1K10.20	A plastic ruler, clay, and vertical notebook pad used to do the ladder against a wall demonstration.
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.
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.
Ehrlich 2, p. 65	walking the spool	1K10.30	A spool can be made to move either backward or forward 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.
Ehrlich 1, p. 46	rolling uphill	1K10.50	A loaded Styrofoam disc or sphere can be made to roll uphill, downhill, or remain at rest on an incline.
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.
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.
Ehrlich 1, p. 41	friction blocks	1K20.10	Pull bricks or blocks across the lecture bench with a spring scale.
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.
Ehrlich 1, p. 42	friction blocks	1K20.13	Launch a sliding block with various initial velocities. Measure its stopping distance and calculate the coefficient of friction.
Ehrlich 1, p. 43	sliding cylinder	1K20.13	Slide cylinders with different height to diameter ratios so they come to a stop. Only those cylinders with a ratio less than the reciprocal of the coefficient of kinetic friction will not tip.
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.
Ehrlich 2, p. 44	static vs. sliding friction	1K20.32	Use the coefficients of sliding and static friction to study the avalanches that occur in a plastic sandwich bag half filled with sand.
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.
Ehrlich 2, p. 45	angle of repose - constant velocity	1K20.36	A vibrating electric razor will slide down an incline at a constant speed for a certain range of angles.
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.
Sut, M-48	angle of repose	1K20.39	The standard inclined plane and blocks + an interesting towel on a glass tube demo.
Ehrlich 2, p. 54	angle of repose - magnetic marbles	1K20.39	A row of marbles on an incline. The number of marbles that can stay magnetically connected depends on the angle of the incline.
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.
Ehrlich 2, p. 74	falling keys capstan	1K20.70	A set of keys and a matchbook are tied to opposite ends of a 1 meter long string. Drape the middle of the string over a pencil and hold the matchbook end horizontal. Let go of the matchbook end and the keys do not 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.
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.
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.
Ehrlich 1, p. 13	gravitational well - rubber diaphragm	1L20.10	A potential well made from and embroidery hoop and clear plastic wrap for use on an overhead projector.
Mei, 8-8.1	gravitational well on overhead projector	1L20.12	Making a Lucite 1/R surface for use on the overhead projector.
ref.	gravitational well on overhead projector	1L20.12	See 8B40.35.
Ehrlich 1, p. 14	gravitational deflection on overhead projector	1L20.12	Draw a straight line on an overhead transparency. Tape the transparency into the shape of a cone and note that the original straight line is now a curve. The massive object that causes the curved space-time distortion is assumed to lie at the apex of the cone.
Ehrlich 1, p. 17	gravitational acceleration on overhead transparencies.	1L20.13	Special transparencies are used to show that particles accelerate due to the curvature of the "time" dimension.

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.
Ehrlich 2, p. 66	orbits in a hemisphere	1L20.17	A steel ball bearing rolling in a transparent plastic hemisphere will precess in a predictable manner.
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	1L20.20	A ball placed in a rotating potential well demonstrates the path of a satellite. Use a variable speed motor to show escape velocity.
Ehrlich 2, p. 133	rotating gravitational well	1L20.20	A ball placed in a rotating parabolic potential well can oscillate only up to a critical angular 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.
Ehrlich 2, p. 64	circular orbit - many impacts	1L20.67	A ball traveling in a straight line can be made to move in a circular orbit by delivering many impacts at right angles to its direction of motion with a pen.
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**	
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.
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 glider 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 glider 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.
Ehrlich 1, p. 76	accelerometer pendulum	1M40.12	An inexpensive accelerometer is the pendulum bob. When swung through an angle of 90 degrees the accelerometer shows 3 g's at the bottom of the swing.
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.
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.

Ehrlich 2, p. 96	stopped pendulum	1M40.15	A pendulum started at a marked height reaches the same height when a nail or peg 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.
Ehrlich 1, p. 57	loop the loop on an incline	1M40.22	A ball is rolled down a loop the loop track that is resting on a gently inclined flat plate. The ball completes the loop the loop only when released above a certain height.
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	
Ehrlich 1, p. 62	energy well trough	1M40.25	Make a one dimensional double well potential from flexible grooved rubber sheet to illustrate the conservation of energy. The transition from order to chaos may also be observed.
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.
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.
Ehrlich 1, p. 53	big yo-yo	1M40.50	A large wheel hung from bifilar threads wrapped around the axle will descend very slowly. Can also be shown by running the wheel on its axle down inclined meter sticks.
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.
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.
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.
Disc 03-08	spring ping pong gun	1M40.65	A spring gun shoots standard and loaded ping pong balls to different heights.
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.
Ehrlich 2, p. 89	spring jumper	1M40.67	Compress the spring of a retractable ballpoint pen to a tabletop. Release and observe the spring launch the pen upward.
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.
TPT 52(2), 88	air track glider and springs	1M40.73	Energy analysis of a damped mechanical oscillator. A dynamics cart may also be used for this demonstration.
Mei, 11-1.12	air track glider and falling mass	1M40.74	A mass m attached to a glider 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	
Ehrlich 1, p. 71	rattleback	1M40.90	A piece of carved wood will reverse its direction of spin only when spun in one direction.
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.
Ehrlich 1, p. 63	high bounce paradox	1M40.91	Cut a rubber ball in half and flip inside out. Drop it from a low height and watch it bounce to a much higher height.
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.
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.
Ehrlich 1, p. 32	egg in a sheet	1N10.20	Throw an egg full force into a sheet held by two students.
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 glider.
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 glider. 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.
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 glider rocket thrust	1N10.85	A device (diagram) measures thrust of a gas propelled air glider. 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.
Ehrlich 1, p. 84	rolling ball on balance beam	1N20.11	A ball rolls in the groove on a balance beam. The ball exhibits oscillatory motion for only precisely determined initial conditions.

TPT 10(9),531	rolling ball on air glider	1N20.12	A ball rolls down a small inclined plane mounted on an air trackglider. 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.
Ehrlich 2, p. 82	car on a rolling board	1N20.15	A spring wound toy car on a ruler which is placed on rollers.
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 glider.
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 gliders 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 gliders 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.
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 gliders	1N20.22	Two gliders with magnets set to repel are tied together with string on an air track. The gliders start at rest, the string is burned so that they fly apart, and a measured distance for each glider to traverse is timed.
D&R, M-554	repelling carts	1N20.22	Two carts, one spring loaded, are placed together. Starting at rest, the spring is triggered, the carts fly apart, and a measured distance for each cart to traverse is timed.
Ehrlich 1, p. 59	repelling balls	1N20.22	A variation with balls inside an embroidery hoop being driven apart by a sharp blow with the handle of a table knife. Where they collide is dependent on their mass ratio.
Ehrlich 2, p. 81	repelling balls	1N20.22	Two balls on a grooved ruler have a folded index card between them. When released the index card pushes the balls apart with recoil speeds having the inverse ratio of their masses.
AJP 41(1),136	magnetic release	1N20.23	The magnetic release for the spring apart air track gliders.
Ehrlich 2, p. 35	recoiling magnets	1N20.24	Equal mass horseshoe magnets are held together with like poles touching. When released they will fly apart into a symmetrical configuration.
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 center of mass collision	1N20.60	An inelastic air track collision with a glider and a spring coupled glider 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 glider.
F&A, Mi-4	ballistic air glider	1N21.30	A .22 is fired into a block of wood mounted on an air glider.
Mei, 7-1.5.6	ballistic air glider	1N21.30	A .22 rifle shoots a bullet into a glider on a track.
Mei, 11-1.11	ballistic air glider	1N21.30	Shoot a .22 into a block on an air glider.
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	
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 glider until the glider 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.
Ehrlich 1, p. 33	water rocket	1N22.20	A water rocket, rocket balloon, or balloon powered helicopter is used to demonstrate Newton's second and third laws.
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 glider.

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.
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.
Ehrlich 2, p. 93	collision balls	1N30.10	An executive toy style Newton's cradle is used to investigate coefficient of restitution.
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.
Ehrlich 1, p. 57	colliding balls	1N30.15	Balls of the same and different masses colliding on a grooved plastic ruler.
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.
Ehrlich 1, p. 51	collision balls	1N30.22	Two ball inelastic collisions of pendula with the same mass on bifilar supports. The center of mass of the two balls after the collision will be one fourth the initial height of the first ball.
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 a 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.
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 gliders, 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 gliders 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 gliders 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 glider 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 gliders with bumper springs.
Mei, 11-1.1	air track collision gliders	1N30.33	A small glider hits a big one elastically. The big one is placed so that after the collision both gliders hit the ends simultaneously. The gliders 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 glider clamp	1N30.43	Design of a simple rubber clamp for stopping Ealing air gliders.
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 gliders 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.
Ehrlich 1, p. 27	rebounding pendula balls	1N30.50	A pendulum made from a Super Ball and another made from a lead or steel ball embedded in clay swing into an upright block of wood. Only the Super Ball pendulum will knock the block over.
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.
Ehrlich 2, p. 91	ball - pendulum collisions	1N30.51	Inelastic collisions are investigated using the executive toy style Newton's cradle and a piece of clay.
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	
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.
Ehrlich 1, p. 60	double ball drop	1N30.60	Stack a small Super Ball on top of a large Super Ball or a Super Ball on top of a basketball and drop them.
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 glider 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.
Ehrlich 2, p. 84	shooting pool - coins	1N40.15	Shoot one coin into a second stationary coin to make a quantitative test of the law of conservation of momentum in a two dimensional collision. Different size coins can be used.
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.
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.
Ehrlich 1, p. 55	vibrating table collisions	1N40.24	Observe collisions of balls on a vibrating plate covered with carbon paper.
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.
Ehrlich 1, p. 87	inertia rotator	1Q10.12	Steel or lead weights are inserted into a hula hoop. The hula hoop can be rotated most easily when the axis of rotation is closest to the weights.
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.
Ehrlich 1, p. 52	ring, disc, and sphere	1Q10.30	A ring, disc, and sphere 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.
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	
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 spool 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 glider 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.
Ehrlich 2, p. 97	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. The rolls will hit the floor at the same time if their initial heights have a specific ration.
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.
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.
Ehrlich 1, p. 82	faster than "g"	1Q20.50	A meter stick with a row of pennies on it falls while remaining supported at the 0 cm end. Only the pennies up to the 66 2/3 cm mark remain in contact with the meter 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 derotator	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.
Ehrlich 1, p. 69	drop objects on a rotating disk	1Q30.40	A clay dumbbell is dropped onto a rotating casserole cover. Move the clay balls on the dumbbell closer together and drop again.
Ehrlich 1, p. 81	drop a jug on a rotating platform	1Q30.40	Swirl a jug of water and then place it on a turntable that can rotate. Loss of angular momentum of the water results in a gain of angular momentum of the turntable.
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.
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.
Ehrlich 1, p. 67	rotating stool and weights	1Q40.10	A rotating platform made from plywood and a large Lazy Susan ball bearing plate.
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 skis 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.
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.
Ehrlich 2, p. 73	counter spinning	1Q40.44	A light portable fan is placed horizontally on the overhead projector. Turn on the fan and it will rotate in a direction that is opposite of the direction of blade rotation.
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.
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.
Ehrlich 2, p. 69	Hero's engine	1Q40.80	A simple Hero's engine made from a soda can.
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.
Ehrlich 2, p. 71	the Feynman inverse sprinkler	1Q40.85	An inverse sprinkler demonstration made from a soda can, one inch ball bearing, large nail, string, duct tape, and a bucket.
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.
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.
Ehrlich 1, p. 77	suspended gyroscope	1Q50.23	A spinning gyroscope is supported by a string at each end of the axle. Cut one string and observe the 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.
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	A model that illustrates precession of the Earth's axis.
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.
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.
Ehrlich 2, p. 183	tippy top	1Q60.30	A tippy top is used to illustrate the two states of electron spin.
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.
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 ellipsoid	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 reach 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.
Ehrlich 2, p. 72	Spin a penny	1Q60.85	Spin a new penny on a smooth hard surface. The slight weight imbalance favoring the heads side of the coin means it will come to rest tails side up more than 80 percent of the time.
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.
	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.
Ehrlich 2, p. 53	suspended Slinky	1R10.15	The spacing between turns of a Slinky suspended vertically under its own weight can be used to test Hooke's law.
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	Hang a mass from a spring, 1/2 mass from two springs in series, and 2 masses from two springs in parallel.
	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.	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.
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.

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.

	SURFACE TENSION	**2A00.00**	
	Force of Surface Tension	**2A10.00**	
Ehrlich 1, p. 110	water filled cup	2A10.05	Many pennies can be dropped into a "filled" cup of water before it overflows.
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.
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.
Ehrlich 1, p. 111	pepper and soap	2A10.40	Sprinkle pepper onto the surface of a cup of water. Add a drop of soap in the middle of the pepper and observe.
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.
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.
Ehrlich 1, p. 111	liquid catenoid	2A15.21	Three liquids of different densities form a catenoid when the top and bottom layer are connected.
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.
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	
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	
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	Humor from Phil Johnson as he wrote" Diagram. Complicated and delicate. The actual description is a labor intensive device using mercury to calculate the decrease in total volume of water upon compression.
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	
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.
Ehrlich 1, p. 101	suction cups	2B30.36	The power of atmospheric pressure can be demonstrated by pressing two plungers together to remove the air between them and then trying to pull them apart.
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'.
Ehrlich 2, p. 102	soda straw contest	2B30.40	4 situations where a person can not suck water up through a straw.
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.
Ehrlich 1, p. 102	inverted glass	2B30.45	Fill a bottle with water and place a stiff card over the opening. Invert the bottle and the card stays in place due to atmospheric pressure.
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.
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.
Ehrlich 1, p. 104	weigh submerged block	2B40.10	A weight hanging from a spring scale is lowered into a bucket of water. The scale reading is reduced by the amount of the buoyant force.
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.
Ehrlich 2, p. 102	finger in a beaker on balance	2B40.15	Place a cup of water on a scale. Insert your finger into the water and observe the scale reading.
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	
Ehrlich 1, p. 97	board and weights float	2B40.18	The amount of weight needed to sink a block of known weight which is floating in water is determined by the density of the block.
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.
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.
Ehrlich 1, p. 96	Cartesian diver	2B40.30	A Cartesian diver made from a soda bottle and a medicine dropper or a piece of soda straw.
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.
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.

Ehrlich 2, p. 136	weight of air	2B40.45	Place a 1 inch steel ball bearing in a balloon, blow it up, and tie it to a large rubber band. The ratio of the oscillations of the balloon when blown up and when empty will allow you to calculate the density of the air in the balloon.
Ehrlich 2, p. 111	weight of air	2B40.45	A balloon is weighed when fully inflated and when it is empty on a digital scale. An estimate can be made as to the air pressure inside the inflated balloon.
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	
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).
Ehrlich 1, p. 103	lifting power of balloons	2B40.70	Hang the appropriate amount of weight from a helium filled balloon to achieve neutral buoyancy.
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.
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.
Ehrlich 2, p. 104	siphon	2B60.24	A demonstration to show that the maximum height of a water siphon is about 10 meters under usual conditions.
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.
Ehrlich 1, p. 98	velocity of efflux	2C10.10	Water streams from holes drilled in the top, middle, and bottom of a bottle. The hole in the middle shoots water the farthest.
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.
Ehrlich 1, p. 99	uniform pressure drop	2C10.20	The range of water streaming from a hole in the bottom of a can decreases linearly with time as the can empties.
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	
Ehrlich 1, p. 100	bottle water velocity	2C10.26	Find the pressure you need to squeeze a plastic bottle filled with water to achieve the maximum range of the water stream.
Disc 13-11	syringe water velocity	2C10.26	Squirt water out of a syringe. The water moves faster through the constriction.
Ehrlich 2, p. 107	falling water stream	2C10.30	A water stream from a faucet narrows as it falls allowing you to calculate the flow velocity and the flow rate.
	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.
Ehrlich 1, p. 109	atomizer	2C20.20	An atomizer made from a plastic straw in a water filled cup.
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.
Ehrlich 1, p. 105	ball in a funnel	2C20.35	A Ping-Pong ball is supported by air that is blown through an inverted funnel.
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.
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 on the table a few inches in front of a coffee cup, give a puff, and the coin jumps into the cup.
Ehrlich 1, p. 106	blow coin into cup	2C20.44	Blow over the surface of a coin to get it to jump into a tilted 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.
Ehrlich 1, p. 107	attracting sheets	2C20.45	A fan blows upward between two sheets of paper. The top edges of the paper will show 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.
Ehrlich 1, p. 105	magnetic Ping-Pong ball	2C20.48	A Ping-Pong ball on a string brought near a falling stream of water will appear to be sucked into the stream.
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.
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 glider. 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.
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.
Ehrlich 2, p. 40	terminal velocity coffee filters	2C30.65	Drop coffee filters from different heights and measure their terminal velocity.
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	
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 in 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.
Ehrlich 1, p. 108	ring vortices in liquid	2C50.21	A straw containing food coloring is dipped into a cup of water. Tap the straw to expel a drop of food coloring and produce a vortex ring.
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.
Ehrlich 1, p. 70	tornado vortex	2C50.30	Swirling a water filled jug that has a hole in its cap creates a tornado vortex that lasts a long time.
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.
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.

	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.

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.
Ehrlich 2, p. 122	other symmetrical shaped pendula	3A15.10	The frequency with which you swing your arms while walking is that of a physical pendulum of the same length.
Ehrlich 2, p. 123	physical pendulum	3A15.10	A physical pendulum made from a meter stick.
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 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.
Ehrlich 2, p. 124	rocking stick	3A15.13	A ruler is balanced on a cylinder or soda can and set into oscillation.
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.
Ehrlich 2, p. 126	truncated ring	3A15.40	Any partial ring regardless of its fraction of the entire ring will oscillate with the same period if they have the same radius.
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.
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 glider is attached to a single horizontal coil spring.
UMN, 3A20.30	air track glider and spring	3A20.30	An air glider 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 glider 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.
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.
Ehrlich 2, p. 142	burn a candle at both ends	3A20.75	A long candle free to pivot in the middle is lit at both ends. The candle oscillates with a predictable frequency.
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	
Ehrlich 2, p. 130	ball on a track vs. pendulum	3A40.25	A ball oscillates in a track made of plastic rulers that has an approximate parabolic shape. The simple harmonic motion displayed is compared to that of a simple pendulum.
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.
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.
Ehrlich 1, p. 90	mass-spring accelerometer	3A40.53	An accelerometer is suspended from a spring to show the acceleration at the end points of the simple harmonic motion.
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.
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 glider	3A50.40	One end of two long springs are attached to each end of the air track. The other end of the springs is then attached to a glider in the center of the 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 glider 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 glider 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.
Ehrlich 2, p. 121	Barton's pendula	3A60.30	Several pendula of different length are hung from the same bar. Small movements of the bar at the right frequency will exite large amplitude oscillations in the pendulum of your chosing.
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.
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.
Ehrlich 1, p. 93	driven mass on spring	3A60.40	A mass on a spring is gently shaken from the top of the spring to find the resonant frequency.
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.

Ehrlich 1, p. 92	resonance reeds	3A60.51	A tin can has vertical strips of varying lengths cut on each side. Pluck a strip on one side and cause a strip of the same length on the other side to resonate.
Ehrlich 2, p. 128	resonance reeds	3A60.51	A plastic ruler held against a block at its midpoint. Pluck one end and the other end will resonate.
Ehrlich 2, p. 129	resonance rings	3A60.51	5 circular paper rings of different diameters are attached to a base. The frequency at which you shake the base will determine which ring vibrates with the greatest amplitude.
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.
Ehrlich 2, p. 134	inverted pendulum - ruler	3A60.61	An inverted pendulum with a vibrating platstic ruler as the driving oscillator.
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.
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.
Ehrlich 1, p. 89	Wilberforce pendulum	3A70.10	Make a Wilberforce pendulum from a spring, a steel rod, a ball or clay, and a straw.
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.
Ehrlich 1, p. 94	coupled pendula	3A70.20	Two pendula hung from a horizontal rod or taut horizontal string will transfer energy back and forth between them.
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.
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	
Ehrlich 2, p. 153	oscillating magnets	3A70.50	Tape magnets to the 4 corners of a long note card with like poles all pointing up. Fold the note card in half and time the oscillations of the unit with a metronome.
TPT 18(1),39	oscillating magnets	3A70.50	Original Phil Johnson humor is shown in this statement: "You really have to see the picture of this to believe it". The official description is: Three rectangular magnets arranged so that the inner edges of the outer two magnets are suspended in mid air. Tap one so that it oscillates and the energy will be transferred to the other.
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.
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.
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 glider 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.
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.
Ehrlich 1, p. 35	a chaotic pendulum	3A95.52	A chaotic pendulum made from two disk magnets with a pendulum made from a steel bob or paper clip. Make this from acrylic for use on an overhead projector.
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.
ref.	fire hose instability	3A95.85	See 1N22.51.

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.
Ehrlich 1, p. 126	pulse on a spring	3B10.10	Stretch a helical spring or a rubber hose to show transverse and longitudinal waves.

Ehrlich 1, p. 134	pulse on a spring	3B10.10	Excite standing waves in a long spring to show that the frequencies of the harmonics are multiples of the fundamental frequency.
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.
Hil, S-2a.2	Slinky on the table	3B10.20	Students stretch a Slinky and send longitudinal waves down from one end.
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.
Ehrlich 1, p. 135	Slinky in a circle	3B10.23	Longitudinal standing waves are generated in a Slinky wrapped around a cylinder and joined end to end.
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.
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.
Ehrlich 1, p. 128	water waves	3B10.60	Water waves in a long trough to show wave pulses and sinusoidal waves. Use a mass on a spring to oscillate in and out of the water at one end to generate the waves.
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**	
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.
AJP 57(10),949	wave cutoff with a hanging Slinky	3B20.15	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.
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.
Ehrlich 1, p. 138	transverse waves in a rod	3B22.40	Excite the fundamental transverse standing wave in a rod with a karate chop to the middle.
Sut, S-135	vertical steel bar Melde's	3B22.41	A steel bar is clamped vertically and driven mechanically through the first three harmonics.
Ehrlich 1, p. 138	horizontal vibrating rod	3B22.41	A rod is clamped horizontally. Higher harmonics are produces with a mechanical vibrator.
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	
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.
Ehrlich 1, p. 142	soap film standing waves	3B22.70	Immerse a large frame in soap bubble solution. Shake the frame to create large amplitude standing waves.
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.
Ehrlich 1, p. 129	traveling and standing wave models	3B22.90	A standing longitudinal wave is simulated by two cylinders made from transparencies.
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.
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**	

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.
Ehrlich 2, p. 138	speed of sound by echo	3B30.25	A metronome, hammer, and a metal pipe are used to find the speed of sound using the echo from a building about 80 meters away.
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.
Sprott, 3.7	bubbles and trumpet - clarinet - saxaphone	3B30.45	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.

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.
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.
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.
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.
D&R, W-020	coat hanger on a string	3B39.30	Hang a coat hanger in the middle of a 3 foot long string. Loop the ends of the string over your fingers and then place your fingers in your ears. Swing the coat hanger to strike a table or other object. A booming sound is heard.
TPT 31(7), 400	coat hanger on a string	3B39.30	Mathematical analysis of the coat hanger on a string and why it produces sounds like Big Ben.
TPT 30(4), 239	coat hanger on a string	3B39.30	Adapting the coat hanger on a string demonstration to a large classroom using a microphone and rubber stopper.
D&R, W-020	cup telephone	3B39.40	Each end of a long string is run through tin cans or plastic cups and secured with a big knot. Pull the string taut and talk into one cup while someone listens at the cup on the other end.
Mei, 18-8.11	multiple wave types	3B39.50	A machine demonstrates transverse, longitudinal, and water wave motion. Picture. Construction details in Appendix, p.636.
Hil, S-2j	seismograph	3B39.60	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.
Ehrlich 1, p. 143	Doppler buzzer	3B40.10	A beeper tied to the end of a string is whirled in a horizontal circle.
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.
Ehrlich 1, p. 144	Doppler spear	3B40.20	Excite a "singing rod". Move the rod toward or away from the listener.
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.
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**	
Ehrlich 2, p. 139	Doppler effect - shock waves	3B45.05	Shock waves can be shown by equally spaced pins on a square wooden dowel being dunked into a long water tank. The angle at which you hold the dowel while dunking determines whether you see a shock wave pattern or a Doppler pattern.
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.
Ehrlich 2, p. 141	shock waves - coins	3B45.25	A penny is flicked into a second penny being held down with your finger causing another penny in contact on the other side to fly off due to the created shock wave.
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.

Ehrlich 1, p. 139	ripple tank - standing waves	3B50.13	Standing waves are generated in a ripple tank by holding a mechanical vibrator against the edge of the tank.
Ehrlich 1, p. 140	ripple tank - standing waves	3B50.13	Long wavelength standing waves are created in a ripple tank by moving the tank back and forth in simple harmonic motion.
Ehrlich 1, p. 141	ripple tank - standing waves	3B50.13	Circular standing waves are created in a ripple tank by dunking a pencil in the middle of the tank at the right frequency.
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.
Ehrlich 1, p. 192	ripple tank	3B50.20	A ripple tank constructed from a clear plastic storage box, a ruler, clay, paper clips, and a block of wood. An old comb is used to construct a multiple point source.
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.
Bil&Mai, p 348	Moire pattern	3B50.40	Moire patterns from two sheets of semicircular ruled transparencies form a double slit representation.
Ehrlich 1, p. 186	Moire' pattern transparencies	3B50.40	Superimpose transparencies of circle patterns to simulate interference and diffraction of waves from point sources.
Ehrlich 1, p. 191	Moire' pattern	3B50.40	Interference effects that can be shown with silk fabric, a coiled spring, or inexpensive commerciallly available Moire' patterns.
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 interference pattern from two rectangular aperture megaphones hooked to the same source.
Ehrlich 1, p. 199	interference	3B55.11	Two source interference demonstrations can be shown with a piezo buzzer placed at the center of a hollow tube.
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.
Ehrlich 2, p. 171	baffle and speaker	3B55.30	A cassette tapr recorder is connected to a small speaker. The sound intensity from the speaker increases if a piece of cardboard with a hole is placed in front of the speaker.
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 - interference / Quinckes' tube	3B55.40	A speaker drives two tubes, one variable , that come together into a common horn.
UMN, 3B55.40	trombone - interference	3B55.40	A speaker drives two tubes, one variable , that come together into a common horn.
F&A, Sg-4	trombone - interference	3B55.40	A horn driver is connected to tubing that splits into two variable path lengths and is recombined at a horn.
Mei, 19-5.3	trombone - interference	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 - interference	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.
Ehrlich 1, p. 196	diffraction - carpet tubes	3B55.51	Piezo buzzers are placed in one end of a 4 inch diameter carpet tube and a 12 inch diameter carpet tube. Sweep the tubes across the room and hear appreciable diffraction from the 4 inch tube but very little from the 12 inch tube.
Ehrlich 1, p. 195	diffraction with a fan	3B55.53	A high frequency piezo buzzer is placed in front of a spinning fan. The listener behind the fan hears a warbling sound.
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.
Ehrlich 1, p. 199	diffraction around objects	3B55.58	A 12 inch diameter carpet tube with a piezo buzzer in the end is moved from above to below a desk creating a noticable drop in sound intensity. Doing the same thing with a lower frequency source shows no appreciable drop in sound intensity.
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.
Ehrlich 1, p. 200	diffraction fence	3B55.60	A piezo buzzer in the end of a tube with equally spaced holes creates an acoustic diffraction grating.
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.
Ehrlich 1, p. 145	beat forks	3B60.10	Two tuning forks which have frequencies that differ by several Hz. A beat frequency is produced when they are struck.
Ehrlich 2, p. 140	beat forks	3B60.10	Listeners can hear beats if you hold a vibrating tuning fork while walking away from sound reflecting wall.
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.
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	
TPT 52(2), 77	eardrum model	3C10.15	A model eardrum is constructed using a wave generator, speaker, membrane, mirror, and a laser. An audio amplifier may also be needed.
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.
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.
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.
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	
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.
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	
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	vertical 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.
Ehrlich 1, p. 131	open tube resonance	3D30.14	A variable length tube excited by a beeper.
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.
Ehrlich 1, p. 132	freq tube	3D30.35	An open tube of corrugated plastic is blown like a whistle or whirled around.
PIRA 1000	Helmholtz 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	Helmholtz 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.
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.
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 with holes	3D32.10	
Sut, S-126	organ pipes with holes	3D32.10	Show open and closed pipes of various lengths and one with holes bored in the side to give the diatonic scale.
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.
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.
Ehrlich 1, p. 132	soda straw oboe	3D32.18	Snip pieces off the end of a straw to produce a double reed. Adjust the frequency by cutting the straw to different lengths.
TPT 23(9), 566	soda straw oboe	3D32.18	How to make a soda straw oboe.
PIRA 1000	organ pipes	3D32.20	
Hil, S-7c.1	organ pipe	3D32.20	An organ pipe is connected to the house air.
Sut, S-57	pipes and whistles	3D32.20	A simple discussion listing organ pipes and whistles.
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.
Hil, S-4d.3	open and closed tubes	3D32.25	Some very nice adjustable open and closed resonance tubes.
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.
PIRA Local	baritone - Euphonium	3D32.41	Functions of a large brass instrument and it's parts are explored.
PIRA Local	tuba - Sousaphone	3D32.42	Functions of a large brass instrument and it's parts are explored.
PIRA Local	trombone	3D32.43	Explore the unique functions of the trombone slide.
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.
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.
Ehrlich 1, p. 137	singing rod	3D40.20	Put some no-slip spray or gel on your fingers. Stroke an aluminum rod to excite longitudinal standing waves.
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.
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 - Gong - Cymbals	3D40.34	Something about nondegenerate normal-mode doublets in vibrating flat circular plates.
AJP 50(3),271	Chladni plates - Gong - Cymbals	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.
Ehrlich 1, p. 135	musical goblet	3D40.50	Rub the rim of a wine glass with a moist finger.
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.

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.
TPT 30(7), 341	spouting bowl	3D40.51	Three demonstrations of ancient chinese bronzeware. The transparent bronze mirror or magic mirror, water spouting basin, and the faith bell.
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.
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.

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.

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.
Ehrlich 1, p. 114	hopping discs	4A30.40	Warm bimetallic 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.

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.
ref.	faith bell	4A40.12	A bell that gives a dull sound at room temperature and a rings at high temperature. The opposite of the lead bell. See 3D40.51 or TPT 30(7), 341.
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, rubber 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.
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.

Ehrlich 1, p. 113	hot metal into water	4B10.26	Known masses of metal are heated in boiling water and then transferred into calorimeters containing a known mass of water. Specific heats are computed.
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.
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.
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.
Ehrlich 2, p. 118	convection currents	4B20.40	An immersion heater is placed at the bottom or the top of a cup of water. Temperature rise vs. time is much faster when it is placed at the bottom of the cup.
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.
Ehrlich 1, p. 120	thermal conductivity of Styrofoam	4B30.13	Measure the rate that the temperature of water in a Styrofoam cup decreases to determine the thermal conductivity of Styrofoam.
Ehrlich 1, p. 121	thermal conductivity of uninsulated objects	4B30.14	Study the parameters that determine the rate of temperature decrease of hot uninsulated objects.
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	
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.
TPT 52(2), 102	electrical analog of heat flow	4B30.59	Several simple resistor circuits may be used to model conductive heat loss from most homes.
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 H_2O, 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.
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.
Ehrlich 1, p. 119	thermal strips on a plate	4B40.53	Thermal strips glued to plates of wood and aluminum are used to show the thermal conductivity in those materials.
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.
Ehrlich 2, p. 116	black and silver thermometers	4B40.60	The rate of heating and cooling for black and silver bodies can be studied by placing a black thermometer probe and a silver themometer probe on an overhead projector. Take them out of boiling water for the cooling observation.
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 glass 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.
Ehrlich 1, p. 118	boil water in a paper cup	4B50.20	A flame is applied to the bottom of paper and Styrofoam cups filled with water, sand, and copper shot. Also a piece of paper wrapped around a metal cylinder does not burn when a flame is applied.
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.
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.
Ehrlich 1, p. 123	dropping lead shot	4B60.10	The mechanical equivalent of heat can be determined from the temperature rise of a bag of lead shot that is dropped many times.
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.
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.
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.
Ehrlich 2, p. 101	floating ice cubes - iceberg	4C20.25	Float ice cubes in a cup of water filled to the very top. The water does not overflow when the ice cubes melt.
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.
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 - fire extinguisher	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.
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.
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.
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.
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.
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 TiO_2 suspension	4D10.33	A TV camera looks through a microscope at a water suspension of TiO_2.
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.
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.
Ehrlich 1, p. 117	radiometer	4D20.10	The radiometer and sunlight or a bright light source.
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 N_2 demo.
AJP 54(9),776	Crookes' radiometer backwards	4D20.12	Use liquid N_2 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	
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.
Ehrlich 1, p. 116	molecular motion simulator	4D30.20	BB's bouncing in a hand agitated frame on an overhead projector show temperature and pressure effects on volume.
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.
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 CO2	4D50.21	When the porcelain cup is surrounded by CO2, 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 - CuSO4	4D50.60	
F&A, Hi-5	diffusion of liquids - CuSo4	4D50.60	Concentrated CuSO4 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.
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.
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 glider 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	
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.
Ehrlich 1, p. 124	time reversal	4F10.10	A line of food coloring in a glycerin filled plastic box will appear to mix or unmix when the box is rotated.
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.
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.

	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.
AJP 29(12),857	discharges in gases	5A10.19	Rub various tubes with plastic foil to see spectacular discharges produced by the static electricity.
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.

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.
Ehrlich 2, p. 146	Coulomb's law with pith balls	5A20.20	Test the inverse square distance dependence of the electrostatic force using a pair of pith balls as the point charges.
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.
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.
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.
Ehrlich 1, p. 149	can attracted to charged rod	5A40.20	An aluminum soda can rolls toward a charged object.
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.
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.
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.
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.
Sut, E-39	electric chimes	5B10.30	A small metal ball hangs on a thread between two bells attached to an electrostatic machine.
AJP 69(1), 50	electric chimes	5B10.30	Franklin's Bells are used to demonstrate and measure charge transport in the laboratory.
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 - cotton	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.
D&R, E-060	electrostatic ping pong	5B10.35	Suspend a metal hemisphere, bell, or ball between two parallel plates that are connected to an electrostatic generator.
Mei, 29-1.13	electrostatic ping pong ball	5B10.35	Insert a metalized ping-pong ball between two highly charged metal plates.
Disc 16-24	electrostatic ping pong balls	5B10.35	Conductive ping pong balls bounce between horizontal 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.
Ehrlich 1, p. 148	electric field	5B10.40	Show electric field lines between two electrodes using a high voltage power supply and grass seed.

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.
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.
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.
Ehrlich 1, p. 174	radio in a cage	5B20.35	A wire mesh will eliminate reception of a radio just as effectively as opaque aluminum foil demonstrating that radio waves must have a wavelength longer than that of visible light waves.
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 potential	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.
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.
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.
	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.
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.
Ehrlich 2, p. 149	generator and capacitor	5C30.38	A small hand crank generator charges a 1 farad capacitor. When you stop charging the capacitor the handle of the generator will continue to turn in the same direction when you release the crank until the capacitor is discharged.
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.
	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.
Ehrlich 1, p. 148	human resistance	5D10.30	Measure your own resistance by holding the probes of a multimeter.
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.
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.
Ehrlich 1, p. 167	Eddy current tube	5D20.25	A disc magnet is dropped through tubes of copper or aluminum. Drop a nonmagnetic disc through for comparison.
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.
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.
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.
Ehrlich 1, p. 147	human battery	5E40.20	A copper sheet electrode and a zinc sheet electrode are connected to a voltmeter. Place a hand on each electrode and observe the voltage (you are the electrolyte).
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	
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.
Ehrlich 1, p. 146	lemon battery	5E40.25	A lemon with zinc and copper electrodes inserted will run a low voltage piezo buzzer.
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.
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 $BaTiO_3$ 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 $BaTiO_3$) 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.
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.
Ehrlich 1, p. 152	electrical equivalent of heat	5F15.10	Submerge an immersion heater in a Styrofoam cup of water. Measure the voltage, current, time, and temperature rise of the water.
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	
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 clothesline 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.
Ehrlich 1, p. 149	series and parallel light bulbs	5F20.50	Three similar wattage light bulbs connected to a 6 volt lantern battery. Bulbs in series, parallel, or a combination of both can be shown.
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	
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.
Ehrlich 2, p. 147	wire combinations - 3-4-5 triangle	5F20.56	A 3-4-5 triangle made from nichrome wire is used to show series and parallel resistance combinations.
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.
Ehrlich 1, p. 150	capacitor and light bulb	5F30.10	A one farad capacitor is charged with a 6 volt lantern battery. Discharge the capacitor through miniature light bulbs.

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.
Ehrlich 1, p. 151	RC time constant on voltmeter	5F30.15	Discharge a capacitor through a voltmeter to measure the time constant and observe exponential time dependence.
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.
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	
Ehrlich 2, p. 151	magnets	5G10.10	Place disc magnets the same pole down on the overhead projector. Watch the motion of one of the magnets as you push another magnet close to it.
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.
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.
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	
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.
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.
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.
Ehrlich 1, p. 153	superconductivity	5G50.50	Levitate a small magnet above a superconducting disc that is cooled to liquid nitrogen temperature.
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	
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	
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.
Ehrlich 1, p. 157	magnetic field around a wire	5H15.10	Iron filings are used to map the magnetic field of a straight wire passing through a piece of Plexiglas.
Ehrlich 1, p. 159	magnetic field around a wire	5H15.10	Iron filings are used to map the magnetic field of 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.
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.
Ehrlich 2, p. 150	inverse cube law - magnetism	5H20.31	A transparent compass and a small disc magnet on the overhead are used to verify the inverse cube relationship of the magnetic field on distance.
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	
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	A compass needle is placed in the center of a large coil oriented in the plane of the Earth field's magnetic meridian. The current in the coil is proportional to the tangent of the angle through which the needle is deflected.
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.
Ehrlich 1, p. 160	field of a magnet	5H10.30	Place a transparent plastic dish on top of a magnet. Sprinkle iron filings in the dish to show the magnetic field of the magnet.
Ehrlich 1, p. 161	cathode ray tube	5H30.10	The beam of a cathode ray tube is deflected when a magnet is brought near.
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.
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.
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.
Ehrlich 1, p. 156	interacting coils	5H40.15	Two coils are free to move on a cylinder made from a transparency sheet. The coils repel when connected to a battery.
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.
Ehrlich 1, p. 161	vibrating lamp filament	5H40.23	The flexible filament of a light bulb will vibrate when a magnet is brought near if the bulb is powered by AC.
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	Take apart an old speaker saving the magnet assembly and the coil/cone assembly. Place the coil cone assembly over or into the magnet assembly. The coil/cone will jump out of the magnet when energized with a battery.
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.
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	
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	A tap switch energizes both coils at the same time. The coils are initially wired so that the current flows in the same direction in each coil.
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.
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.
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.
Ehrlich 1, p. 165	galvanometer, coil and magnet	5K10.20	Move a magnet through a coil that is connected to a galvanometer.
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	
Ehrlich 2, p. 149	coil and LED, magnet	5K10.25	Move a magnet into and out of a coil connected to two different color LED's which are installed with opposite polarities. An upgraded version of this would use a single bi-colored LED.
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.
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 glider 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.
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.
Ehrlich 1, p. 166	Eddy current pendulum	5K20.10	A bar magnet is tied to a string and swung as a pendulum over a sheet of copper.
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.	plates and magnets, the Osheroff demo.	5K20.24	A demo direct from a presentation by Nobel Prize recipient Doug Osheroff. 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.
Ehrlich 1, p. 165	Faraday repulsion coil	5K20.26	Move the pole of a bar magnet in and out of a coil of wire on a bifilar suspension.
Disc 20-19	Faraday repulsion coil	5K20.26	Thrust the pole of a magnet in and out of a copper ring on 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.
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.
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.
Ehrlich 1, p. 164	vertical transformer	5K30.30	A secondary coil attached to a light bulb is placed over the core of a vertical transformer.
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.
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.
Ehrlich 1, p. 162	DC motor	5K40.10	A simple motor constructed from a "D" cell battery, disc magnet, paper clips, and some varnish coated copper wire.
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.
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.
Ehrlich 1, p. 169	coupled motor/generator	5K40.45	Two small DC motors are connected together. Turning one motor by hand will drive the other motor connected to it. Motors as generators and vice versa.
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.

Ehrlich 1, p. 170	hand crank generator	5K40.80	Crank a hand powered generator to light a bulb.
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.
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.
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.
Ehrlich 1, p. 153	blinky whirligig	5L30.20	Alternating current from a wall outlet is shown when you twirl a neon lamp on the end of a line 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.
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	RL and RC filters	5L30.36	A RLC parallel configuration with each component individually switched is used to show the effect of each component on audio frequencies. RL is an example of a low pass filter and the RC is an example of a high pass filter while the RR configuration shows no filtering and only attenuation.
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 is 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 glider 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.
TPT 52(2), 94	LED - Light Emitting Diodes	5M10.55	An article describing how LED's are now used in almost every unit of a general physics course and not just for electronics applications.
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	
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.
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.
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.
Ehrlich 1, p. 175	directional antenna	5N10.65	A radio tuned to an AM radio station is pointed in different directions to show the transverse nature of radio waves.
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.
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.

	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.

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.
Ehrlich 1, p. 179	corner cube	6A10.30	Three mirrors mutually perpendicular are taped together to form a corner cube.
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.
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.
Ehrlich 1, p. 178	angled mirrors	6A10.40	An object placed between variable angle mirrors forms multiple images. The number of images seen depends on the angle of the mirrors.
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.
TPT 15(6), 360	candle in a flask - Pepper's ghost	6A10.60	The illusion of a candle burning in a flask, a modern version of the Pepper's ghost illusion done in the 1860's.
TPT 22(9), 591	Pepper's ghost	6A10.60	Description of several optical illusions including Pepper's ghost with diagrams.
TPT 49(6), 338	Pepper's ghost	6A10.60	Historical description of Pepper's ghost illusion with diagrams.

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.
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.
TPT 30(5), 295	chinese magic mirror	6A10.80	The decorative pattern on the back of a bronze mirror is revealed when light is reflected from the polished front side onto a screen.
TPT 30(7), 327	chinese magic mirror	6A10.80	Comments on the TPT 30(5), 295 article.
TPT 31(7), 325	chinese magic mirror	6A10.80	More comments about the TPT 30(5), 295 article.
TPT 32(7), 329	chinese magic mirror	6A10.80	A second look at how the magic mirror produces the reflected image.
TPT 35(9), 536	chinese magic mirror	6A10.80	How the magic mirror is used to teach optics principles in physics classes.
ref.	chinese magic mirror	6A10.80	The decorative pattern on the back of a bronze mirror is revealed when light is reflected from the polished front side onto a screen. See 3D40.51 or TPT 30(7), 341.
	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.
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.
Ehrlich 1, p. 184	convex mirror - focal length	6A20.55	The focal length of a convex mirror is found using a meter stick.
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.
Ehrlich 1, p. 182	apparent depth	6A40.11	A water filled jar is placed over a transparency on the overhead projector which is focused until the lettering is clear. Slide a pencil along the outside of the jar until the point is also in sharp focus to show apparent depth.
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.
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.
Ehrlich 2, p. 163	disappearing beaker	6A40.30	A small beaker disappears when placed into a larger beaker filled with baby oil.
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.
Ehrlich 2, p. 164	mirage - superior mirage	6A40.47	A focusable flashlight beam passing through a tank of water begins to deflect when heat lamps above the tank are turned on.
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	
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	
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.
Ehrlich 2, p. 159	refraction - number of objects	6A42.44	An object is placed in a transparent tank of water near the corner. Look through the corner at the object and you will see multiple images of the object.
TPT 25 (7), 440	refraction - number of objects	6A42.44	A tank of water with a single fish in it. Look through the corner of the tank and see multiple fish.
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.
Ehrlich 2, p. 157	stick in water	6A42.45	A pencil inserted into a glass of water appears bent or broken. This can be used to calculate the index of refraction of the water.
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
Ehrlich 1, p. 180	fiber optics - ulexite	6A44.37	Ulexite or "TV rock" is a naturally occuring mineral that consists of parallel optical fibers. Place a sample of this on a written page and read the lettering at the top of the rock.
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.
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.
ref.	steal the signal	6A44.42	See 7A50.10.
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.
Ehrlich 1, p. 181	water stream light pipe	6A44.45	Shine a flashlight down a stream of water flowing from a hole in the bottom of a clear plastic cup.
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.
Ehrlich 1, p. 180	oil and water/alcohol initerface	6A44.53	Total internal reflection occurs at an oil and water/alcohol interface.
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.
Ehrlich 2, p. 157	silver soot ball	6A44.55	A soot covered metal ball appears silver when suspended underwater.
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.
	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.
Ehrlich 1, p. 183	rainbow	6A46.10	A rainbow is produced by shining a flashlight at the side of a jar of water.
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	
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.
Ehrlich 2, p. 161	image with lens - cover half lens	6A60.31	Form an image on a screen with a converging lens. Cover half of the lens with a piece of cardboard. The image just gets dimmer.
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.
AJP 48(11),990	flat flames as lenses	6A60.55	More of the original Phil Johnson humor = I haven't figured this out and have to go home to eat, so maybe some other time. The description would be: Using large flat oxyacetylene flames as lenses to focus a laser beam.
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.
Ehrlich 2, p. 167	pinhole imagery	6A61.22	Varying the size of the pinholes will change the fuzziness and brightness of an image in a predictable way.
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.
Ehrlich 2, p. 168	negative pinhole image	6A61.35	A small sphere or screw head is place between a circular fluorescent light and a screen. A negative image of the light appears on the screen.
	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.
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.
Ehrlich 1, p. 177	fillable air lenses	6A65.52	A variety of objects that can be used as convex and concave lenses, prisms, or mirrors which can be filled with water or air and used in a tank of water with some powedered milk or dairy creamer added for visibility. The overhead projector is used as a light source.
Ehrlich 2, p. 161	water lens	6A65.52	Add some water to a transparent plastic globe to make a plano-convex water lens.
Ehrlich 2, p. 162	rotating water lens	6A65.52	Add some water to a transparent plastic globe to make a plano-convex water lens. Place this on an overhead projector and give it a spin. Observe the change in the focal length.
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.
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.
Ehrlich 1, p. 179	Fresnel lens	6A65.70	A large plastic Fresnel lens is shown to have the focusing properties of conventional lenses.
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.
Ehrlich 1, p. 154	inverse square law with a light meter	6B10.20	A light meter, meter stick, overhead projector, and large piece of opaque cardboard are used to plot light intensity versus distance. Equate this to an electrical field point charge. See 5A20.20.
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.
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.
Ehrlich 2, p. 165	grease spot photometer	6B10.35	A piece of paper with a grease spot is moved between two light sources until the spot disappears. Use bulbs of different wattages to test the inverse square law.
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.
Ehrlich 1, p. 114	hole in a box	6B40.20	A hole in a box painted white on the inside is a good example of a blackbody.
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.
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.
Ehrlich 1, p. 202	adjustable single slit	6C10.21	An adjustable single slit made from two razor blades. Look at an unfrosted light bulb with a linear filament.
AJP 33(3),245	adjustable single slit	6C10.21	Look through a vernier caliper toward a monochromatic light 5 to 10 m away.
Ehrlich 1, p. 201	eyelid slit	6C10.22	Looking at the filament of an unfrosted light bulb while squinting allows you to see a diffraction pattern.
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.
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.
Ehrlich 2, p. 176	Poisson's spot	6C20.10	Poisson's spot with an unfrosted light bulb, pinhole, 1cm focal length lens, and a spherical headed pin.
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	
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.
Ehrlich 1, p. 204	pinhole diffraction	6C20.30	Look at an unfrosted light bulb 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**	
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.
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.
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.
Ehrlich 1, p. 203	measure wavelength with a grating	6D20.26	Look through a plastic grating at several different line sources to observe their spectra and measure their wavelengths.
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.

Ehrlich 2, p. 172	measuring wavelength with a ruler	6D20.31	A laser beam is diffracted at a grazing incidence off the rulings of a 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.
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.
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.
Ehrlich 1, p. 205	soap film interference	6D30.20	An interference pattern of stripes in thin films is observed using soap bubbles.
Ehrlich 2, p. 173	soap film interference	6D30.20	Long lasting soap bubbles are made on the mouth of an Erlenmeyer filter flask partially filled with water.
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.
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**	
Ehrlich 2, p. 187	Michelson - Morley simulation	6D40.05	The basic Michelson - Morley experiment is illustrated on the overhead projector using 1 inch diameter ball bearings, note cards, and some thick cardboard.
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.
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.
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.
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.
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.
Ehrlich 1, p. 206	halos	6F40.80	Look at an unfrosted light bulb through a fog you have exhaled onto a glass slide.
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.
Ehrlich 1, p. 172	Polaroids on the overhead	6H10.10	Two sheets of Polaroid on the 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.
Ehrlich 1, p. 173	polarization - mechanical model	6H10.30	A long spring passing through a vertical slit is used to demonstrate polarization of transverse waves.
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.
Ehrlich 1, p. 171	Brewster's angle	6H20.10	Plate glass, a Polaroid filter, a protractor, and a focusable light source are used to demonstrate Brewster's angle.
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.
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.
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 CS_2 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.
Ehrlich 1, p. 174	calcite and Polaroid on the overhead	6H35.15	A calcite crystal shows two images of whatever is placed beneath it. Use a Polaroid filter to shut off one image or the other.
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.
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	6H35.52	Interference colors are shown with a quartz wedge in red, green and white light polarized light.
Mei, 35-6.13	quartz wedge	6H35.52	A setup to show the spectral analysis of the colors of a quartz wedge.
Mei, 35-6.14	various crystal thicknesses	6H35.52	Various crystals are placed between crossed Polaroids including etchings.
Mei, 35-6.17	sign on crystals	6H35.52	A setup using a quartz wedge or sensitive plate to determine the sign of crystals.
PIRA 1000	butterfly, etc.	6H35.53	
UMN, 6H35.53	butterfly, etc.	6H35.53	
Sut, L-136	butterfly	6H35.53	Mica, cellophane, etc. cut into specific shapes and thicknesses are placed between crossed Polaroids.
F&A, Om-14	color with mica	6H35.54	Rotate a mica sheet between crossed Polaroids.
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 refracting 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.
Ehrlich 1, p. 171	polarization by scattering	6H50.10	Use a sheet of Polaroid to show the polarization of light scattered by 90 degrees from light passing through a tank of water with powdered milk or dairy creamer as the scattering particles.
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.
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.
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**	
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.
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.
Ehrlich 1, p. 205	hologram eyeglasses	6Q10.10	A pair of eyeglasses with holographic images of eyeballs.
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.
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.

	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.

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.
Ehrlich 1, p. 146	solar cells	7A10.40	A small fan is powered by a solar cell and a bright light source.
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.

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.
Ehrlich 2, p. 182	frustrated total internal reflection	7A50.10	Frustrated total internal reflection demonstrated using a glass of water. This is an analog to quantum mechanical tunneling or barrier penetration.
ref.	frustrated total internal reflection	7A50.10	See 6A44.42.
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.
	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.
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.
TPT 38(3), 168	Quantum Levitation - Flux Pinning	7A70.25	Press a magnet into a superconductor. The magnet is pinned by the impurities in the superconductor giving great stability.
TPT 28(4), 205	Quantum Levitation - Flux Pinning	7A70.25	A explanation of how flux pinning works in a Type II superconductor.
AJP 77(9), 847	Quantum Levitation - Flux Pinning	7A70.25	A demonstration of levitation, suspension and movement of a superconductor over a magnetic track.
AJP 74(12), 1136	Quantum Levitation - Flux Pinning	7A70.25	Variational theory used to explain the high stability observed in magnetic force experiments with strongly pinned superconductors.
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.
Disc 25-01	emission spectra	7B10.10	Four spectral tubes and white light through a grating.
PIRA 1000	flame salts	7B11.11	
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	A spectral chart showing emission spectra of several gases.
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.
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.
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 reflection 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	fluorescence	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.
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 gliders. Vary the mass of the "nucleus" glider.
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.
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.
ref.	Bohr model	7B50.11	See 3D40.50, Ehrlich 1.
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.
TPT 52(2), 115	radioactive dating - carbon dating	7D10.23	Use the count rates from a new Cobalt 60 source and older Cobalt 60 sources which have manufacturing dates stamped on them to demonstrate how radioactive dating works.
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.
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**	
Ehrlich 2, p. 179	marble chain reaction	7D20.05	A chain reaction simulation made from rows of marbles on an inclined board. Start an avalanche with a single marble.
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	
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.
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.
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.
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.
Ehrlich 2, p. 185	tachyons	7E10.60	The hypothetical faster than light abilities of tachyons is explored using transparencies on the overhead projector.
	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.
Ehrlich 2, p. 184	time dilation simulation	7F10.30	A folding carpenters ruler is used to simulate the effects of time dilation in a "bouncing light pulse clock".
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.
Ehrlich 2, p. 191	relatavistic length contraction	7F10.32	The "pole in a garage" paradox is demonstrated using a collapsible pointer and two cardboard boxes.
AJP 56(10),941	relativistic length contraction - simple diagrams	7F10.32	Simple diagrams for representing relativistic length contraction and time dilation.
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

	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	

	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.
ref.	Foucault pendulum	8A10.45	See 1E20.10.
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 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.	Geochron	8A10.80	See 1A10.41. 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.
TPT 35(3), 167	apparent motion of the Sun	8A10.90	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.
	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.

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	The Earth is a pinhead and the moon is a piece of 30 gauge wire. These are placed in a Styrofoam block 1-1/4 inches apart.
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.
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.
	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**	
	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.
	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.	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.	greenhouse effect	8A70.40	See 4B50.60 for demonstrations of the greenhouse effect.
ref.	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, CO_2, 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.	culvert whistlers	8A70.70	See 3B25.67 for acoustical examples, demonstrations, and comparisons to ionospheric whistlers.
PIRA LOCAL	planetary density model	8A70.75	Place 10 cm cubes of aluminum, wood, foam, and hollow foam with a steel ball inside in 4000 ml beakers of water.
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	

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	Drop ball bearings into a pan of glass beads. Illuminate with a lamp from the side of the pan to provide contrast.
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	Mix sand and snow in a pan. Add some water and mix some more. Form a muddy snow ball with a knotted end of a string at its center. Place this in a beaker of liquid nitrogen to harden and then swing the "comet" around your head.
PIRA LOCAL	Ed's comet	8A80.10	A Styrofoam ball with a tail of turkey feathers is attached to a string. Swing this around your head.
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	A 60 watt bulb represents the sun. Use with a globe of the Earth.
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	
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	
Ehrlich 2, p. 180	stellar / nuclear fusion	8B10.80	A model for the overhead using a transparent grooved plastic ruler, two magnetic marbles or spheres, and a piece of folded index card.
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 glider, 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	
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	A 12 volt, 15 watt lamp is plugged into a Pasco digital function generator-amplifier. Set the generator at about 1 Hz. and observe the intensity change.
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	A flashbulb is placed on the lecture bench hidden behind some "innocent" barrier. The instructor sets it off at an "appropriate" moment.
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 - fiberglass or plastic	8B40.20	
UMN, 8C20.10	black hole surface - fiberglass or plastic	8B40.20	A large fiberglass black hole potential surface from some museum in Philly.
D&R, M-822	black hole surface - fiberglass or plastic	8B40.20	A potential well made of a clothes basket and rubber sheet. Also large and small commercial models of 1/R cones.
TPT 28(8), 575	black hole surface - fiberglass or plastic	8B40.20	A cardboard funnel constructed to give results similar to fiberglass or plastic models found in science museums.
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.
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.	potential well/hill	8B40.35	See 1L20.12.
ref.	gravity well	8B40.40	See 1L20.10. 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.
Ehrlich 2, p. 189	expanding universe	8C10.30	A simulation of the expansion of the universe using two transparancies with random dot patterns on the overhead projector.
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	
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

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.
PIRA LOCAL	space debris	8D10.80	

TELESCOPES 8D20.00

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 43(7), 452	satellites	8D30.50	The effect of atmospheric drag and temperature on satellite orbits.
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.
TPT 23(8), 466	slingshot effect	8D30.70	A simple explanation of the "slingshot effect" or "gravity assist".

ASTRONOMY TEACHING TECHNIOUES 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.

	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	A handheld light pointer unit with arrow image and focusing ability.
	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.

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.

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.

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.

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?)

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?)

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 glider 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.

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 glider 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 glider 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 glider 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.

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.

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.

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.

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.

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.

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.

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.

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 gliders 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.

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.

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 - CO_2
.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
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.65 half silvered mirror box
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.45 half wave plate
.53 butterfly, etc
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11 Physiology
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.20 in class holograms

20 Physical Optics
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7A QUANTUM EFFECTS

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.35 photoelectric threshold
.40 solar cells
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.10 Millikan oil drop
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.20 diffraction model
.30 electron "Poisson spot"
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.60 ripple tank Bragg diffraction
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.10 Josephson junction analog
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.15 line spectra with large grating
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.05 triboluminescence
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.25 Stern-Gerlach crystal model
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.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

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.10 nixie Geiger counter
.15 thermal neutron detector
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.20 Rutherford scattering animation
.30 Thompson model
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.20 fundamental particles software

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.25 foam rubber roller
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.35 local zenith

20 Earth - Moon Mechanics

.70 pinhead earth

30 Views from Earth

.10 horizon astronomy model
.20 Cinhelium

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.10 globes

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60 Planetary Properties - 3

70 Planetary Properties - 4

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.20 comet orbit

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.65 pulsar model
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.37 expanding universe on white board
.40 bubble universe
.50 galaxy model

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

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8E ASTRONOMY TEACHING TECHNIQUES

30 Astronomy Teaching Techniques

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

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.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
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38 Video & Computer Projection

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.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
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9B ELECTRONIC

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.10 eosin mister