John B. Johnston, The Faraday Center, 103 Creamery Road, Livingston Manor, NY 12758
(845) 439 - 4706

A list of topics, mostly HS physics demonstrations, on the internet at a Union College (Schenectady) website.
http://minerva.union.edu/vineyarm/john_johnston/john_johnston.html
Also, a link to the Union College website is https//www.tinyurl.com/WS-Johnston

email: denali77@hvc.rr.com

The Darth Vader Disc (center of mass)

The inverse square relationship (3-D model)

The "g" Stick (free-fall and the different values of "g")

Free falling bodies - the hinged board with cup

Vectors - forces and the inclined plane

Vectors - velocities and river crossings

The sail cart - force vectors & sailing

The rotator (electric drill) and accessories

Tension in a pendulum (using a spring scale)

2-D Motion - a teaching model (stick with hanging spheres)

2-D Motion - centripetal force (using Johnston's "Singapore Sling")

Horsepower - a brief essay

Resonance - the hacksaw blade resonator

Resonance Pendulums - a pair of metal pendulums

Measuring the speed of sound (in air and an alum. rod)

An acoustic interferometer (made of PVC pipe)

Wire waves I - a jig for making wire waves & uses

Wire waves II - a second jig for making wire waves & uses

Demonstrations: the eye of a needle and Poisson's spot - actual size wood models

Poisson's spot - a steel ball bearing on a magnetised needle

A wood model of a polaroid filter (and explanation)

The 3 3/8" x ... acrylic container (Prism) - a triangular trough

Dispersion via diffraction & interference - using diffraction gratings

The "To-Infinity" mirror system - reflection via flat mirrors

Light - reflection via the flat-mirror periscope

Light and a real image via reflection - the concave mirror

Light and a real image via refraction - the convex lens

The 5" x ... Acrylic Container - flat-sided box (The "blue beer" demo)

Reflection - a front surface, parabolic, water mirror - using a record player

Total internal reflection in a stream of water

Atmospheric refraction - using "sugared" water

The rainbow - one-drop rainbow and explanation

Dispersion - spectra via reflection and interference (in thin soap film)

A "spectra" comparator - elementary spectroscopy

The hand-held Tesla coil - uses

The "green" comparator - using a 120 VAC (home) powerline meter

Wire Loop I - a jig for making wire "coil" loops as teaching models

Wire Loop II - a jig for making wire "generator" loops as teaching models
The Ring Flinger - a 120 VAC electromagnet as a transformer
The blue sky and ... - Rayleigh scattering in a watertank
Sunspots or relative temps. and colors on the sun's surface
Northern lights or the aurora borealis
The Snowflake - water's polarity and surface tension
Standing Waves in the Hydrogen Atom - a cardboard model
Electromagnetic induction - generators & motors
Self-inductance and mutual inductance - the Thomson apparatus
The monkey and the hunter (2-D motion)
Static electricity (Braun 'scope)
Wimshurst machine (electrostatic demos)
The vortex box ("rings")
Friction - tractor "pulls"
Electricity - Coulomb"s Law (on the OHP)
The Millikan Experiment (washers in film cans)
The Gas Laws - a teaching model
The flame tube - "seeing" sound waves
The Van de Graaff generator (electrostatic demos)
Magnetism and the acrylic tray (magnetic fields)
Demonstrations on the OHP
Crystal packing - dislocation
Critical angle "magic" - internal reflection
The "one-bottle wine cellar" (center of mass)
The rotating platform (many uses)
Acceleration and the HPP liquid accelerometer
Sound and loudness - forced vibrations
Impulse (cushions)
Conservation of Momentum (carts with masses)
Time and timing - stroboscope uses
Electromagnetism (the hand rules)
Kinematics and free fall (examples)
Lenz's Law - induction & retardation
Keepers! I - simple, reliable demos
Conservation of energy (mechanical examples)
Demonstration aids (optical holders)
Interference and historic discoveries ("ether" & DNA)

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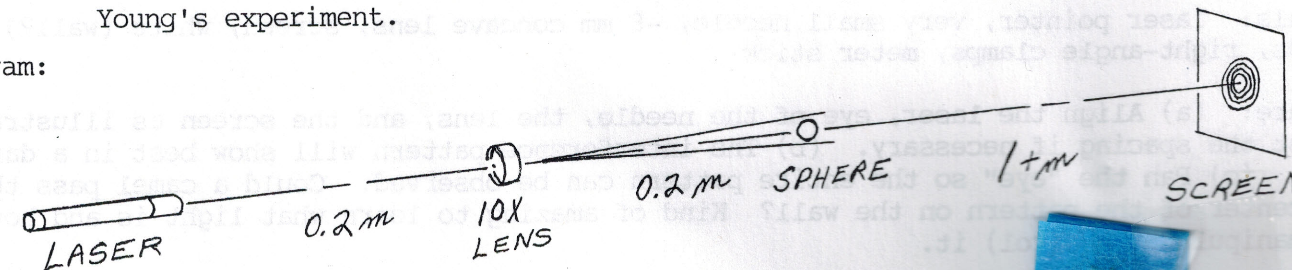
Poisson's spot - long considered one of the great experiments (demonstrations) on the topic of light. It is easily performed today via the use of the laser and some simple materials. But first, a little history to illuminate its importance in the development of our knowledge about the nature of light.

1672 - Newton's corpuscular (particles of matter) theory of light.
1678 - Huygens' wave theory of light (principle).
1803 - Young's double slit experiment (interference pattern) predicted by Huygens' principle.
1819 - Poisson (particle supporter) vs Fresnel (wave supporter). Fresnel's wave (diffraction) equations were solved by Poisson who considered the result reached absurd. It predicted that a bright spot due to diffraction (and interference) would occur behind the center of a small, round, solid object (sphere?) instead of a shadow. Arago (particle supporter) set up the experiment and discovered the spot. Fresnel's reputation and the wave theory were secure. Rarely mentioned is the beautiful interference pattern of concentric circles which adds further credence to the wave nature of light. The pattern is simply an extension of Young's experiment.

Diagram:

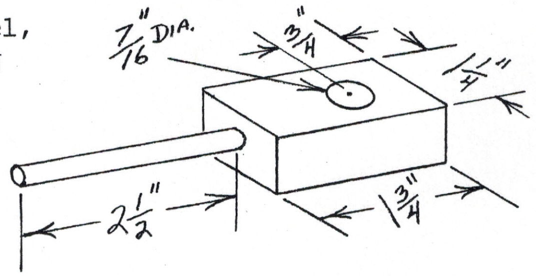


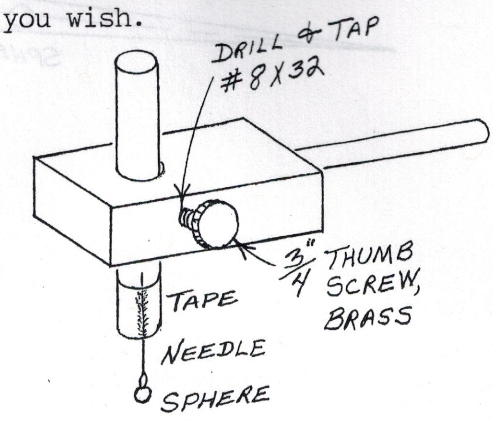
Materials: laser pointer (red or green), 10 x lens (microscope ocular, simple magnifier), ball bearing, steel (3/32"), screen, white (posterboard, classroom wall), ring stands, right-angle clamps, meter stick

A simple way to "suspend" a small, steel ball bearing is on the tip of a steel needle taped onto the end of a small bar magnet; the needle is mostly unobstrusive. Below is my design for a simple, wooden ball bearing holder; you may alter as you wish.

Plan for ball bearing holder:

3/4" pine
3/8" dia. dowel,
3 1/8" long



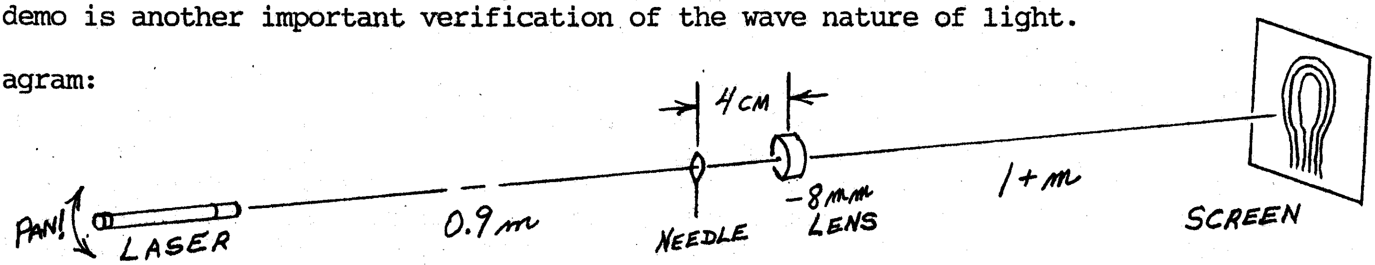


Assembly of bearing holder: (a) Cut out pine block and drill the three necessary holes: 3/8" dia., 5/8" deep for dowel; 7/16" dia. through for 3/8" dia. magnet; and #29 drill bit through for #8 brass thumb screw. (b) Cut the dowel, sand ends, add glue, and tap it into the block with a hammer. (c) Carefully tap the #8 thumb screw hole; add wax or soap to the thumb screw and carefully twist it into the block. (d) Tape a small needle to the end of the magnet with the eye extended about ½". Insert the magnet into the wooden holder and tighten the thumb screw until snug. Don't over-tighten and strip the wooden threads. Fasten the holder to a ring stand with a right-angle clamp. Add the bearing. A small, steel bearing of a different size may be used; experiment. The 10 x lens acts as a beam spreader.

Procedure: (a) Align the laser, lens, bearing, and screen as illustrated in the diagram; adjust the spacing (0.2 m) if necessary. (b) The spot and pattern will show best in a darkened room. Have the students get up close for a better look; they can now see what Arago saw for the first time in 1819. Neat!

Addendum: The eye of a needle - another classic demonstration, closely related to Poisson's spot, is one that can be projected in a large pattern on a classroom wall. The laser's light diffracts around the needle's eye, inside and out, and establishes a tiny interference pattern that is expanded by the diverging lens onto a large screen or wall. The demo is another important verification of the wave nature of light.

Diagram:

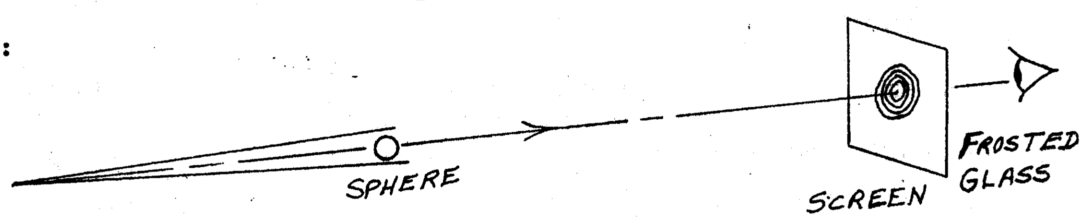


Materials: laser pointer, very small needle, -8 mm concave lens, screen, white (wall?), ring stands, right-angle clamps, meter stick

Procedure: (a) Align the laser, eye of the needle, the lens, and the screen as illustrated; adjust the spacing if necessary. (b) The interference pattern will show best in a darkened room. (c) Pan the "eye" so the entire pattern can be observed. Could a camel pass through the center of the pattern on the wall? Kind of amazing to learn what light is and how we can manipulate (control) it.

Addendum: An alternative screen for both demos. If a darkened room is not possible, try a pane of frosted window glass as a screen and view it from behind. It is safe, and the patterns are clearly visible. I mounted the glass (9½" x 11") in a simple frame so I could easily attach it to a ring stand.

Diagram:



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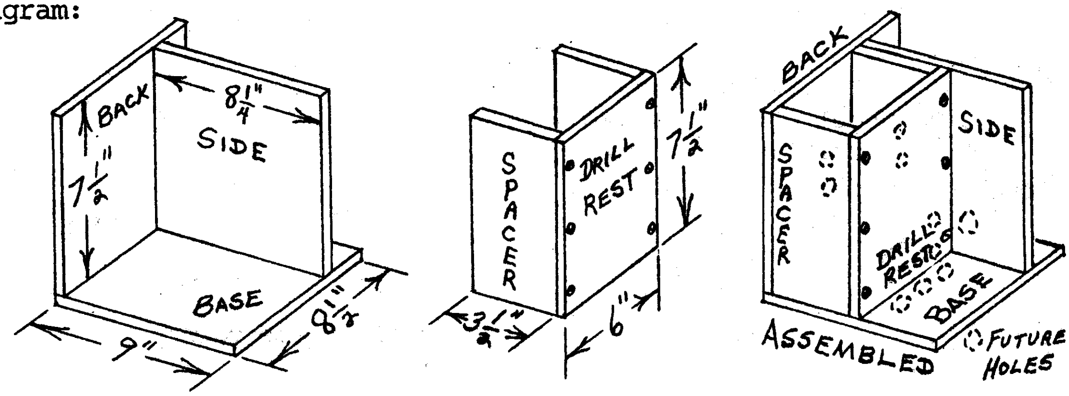
The rotator - has always been a very useful piece of apparatus in the physics classroom, especially in the study of mechanics. However, the commercial versions are quite expensive. A less expensive alternative that may be as useful is presented here. It requires a corded electric hand drill, a Variac, and a homemade, wooden platform. The design and construction are simple so people can easily assemble it. Possible uses will be discussed later.

A lot of corded drills may be available as users transition to cordless; inquire around. Just be sure the bearings are not badly worn. The dimensions of the platform may need to be changed depending on the size of the drill you finally choose. My "rotator" is a 3/8" B&D (2.5 amp., 1-1200 rpm) drill; however, any good 3/8" drill should work well enough.

The platform should be "universal", so the chuck can be horizontal or vertical depending on its use. Most rotators are quite heavy and resist movement. This alternative is lightweight and moves easily; thus, for safety, it must be clamped down. My design offers extra areas on the edges for safe clamping. I have also added "finger holes" as a handle to better hold the platform up in the air for special purposes. 3/4" plywood and coarse-thread #6 x 1 5/8" drywall screws should provide enough sturdiness for the platform's construction. Follow the plan in the diagram.

Diagram:



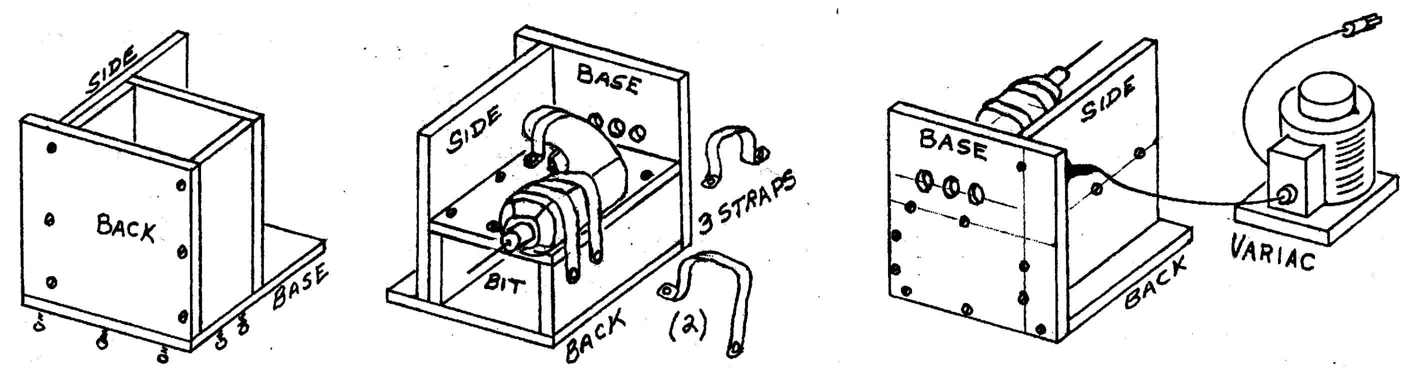
base: 8½" x 9"

back: 8½" x 7½"

side: 8¼" x 7½"

drill rest: 6" x 7½"

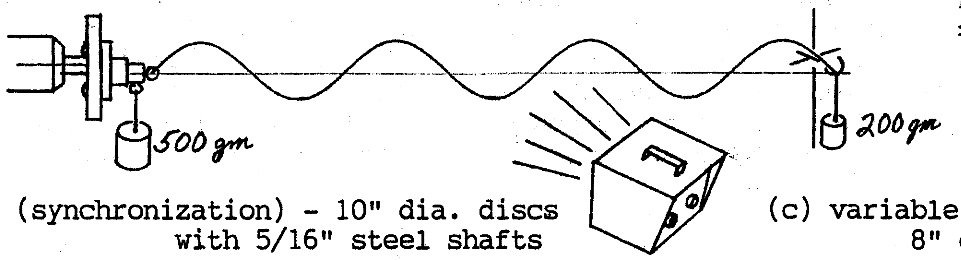
spacer: 3½" x 7½" (2)



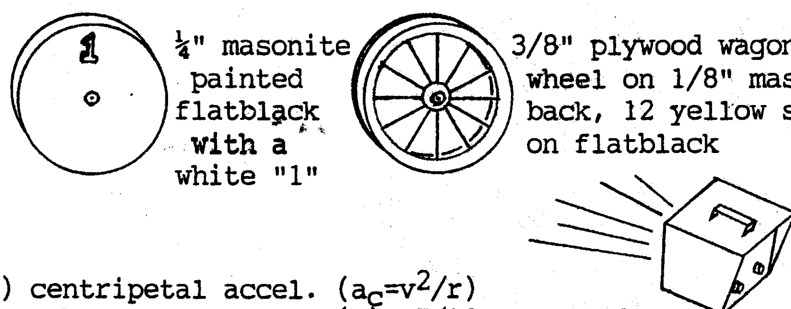
Assembly: Cut out the 6 pieces of plywood; delay the use of glue. Attach the "back" on the "base" with 3 screws. Attach the "drill rest" on the 2 "spacers" with screws. Slide the "drill rest" assembly up against the "back", even with the front of the "base" and add screws. Position the "side" up tight against the "back" and the "drill rest" assembly. Use 3 screws on the long edges to fasten all parts together. Lay the entire platform on its "back" and place the drill (with ¼" bit) on its side on the "drill rest"; align the bit parallel to both sides of the "drill rest". Add a shim (small wood block) under the drill handle so the drill body is flat on (against) the "drill rest". Decide on the cord hole location and its size in the "side". 3 steel straps (3/4" steel hanger strap) are needed to fasten the drill to the "drill rest"; make up the straps as follows. To measure the strap lengths accurately, use a tailor's flexible tape measure. Cut and bend the straps to fit the drill snugly. This may be done by cutting and/or bending the straps a little "short" to provide tension when tightened down. (I add a strip of innertube rubber under the steel strap to protect the drill's finish.) Bend the 4 tips; 2 tips remain straight. With the drill in place, press the straps around it and mark the bolt holes to be drilled. six ¼" x 1¼" carriage bolts are to be used. At the same time, locate the three 3/4" dia. "finger holes" (handles) in the "base", just above the "drill rest" edge; these "holes" allow you to easily hold the rotator upside down for some demos. Neat holes are best drilled on a drill press; back out the screws to free the boards if necessary. Reassemble and bolt down the drill in place. If everything is properly aligned and tight and no further adjustments are needed, you can disassemble and add glue to all joints but only as a final step. You may feel that the glue is unnecessary, that the screws are good enough; that's OK.

Now you have a versatile rotator platform. With the drill's trigger locked in the "full on" position, add the Variac for speed control (rpms). Bring on the clamps and accessories, and let the fun begin! Below are some of my favorite accessories. (P) means "purchased".

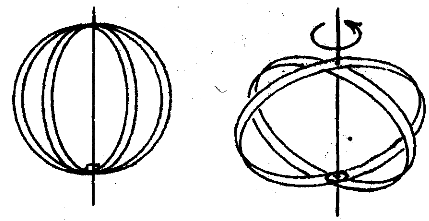
(a) standing waves (harmonics) - an old CENCO eccentric (P) with 7½' of 1/8" dia. braided, nylon rope and a Winsco #E-77 strobe light (P)



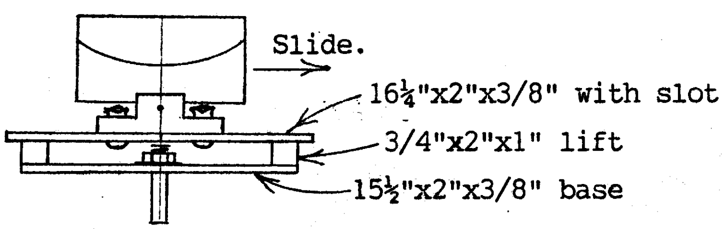
(b) timing (synchronization) - 10" dia. discs with 5/16" steel shafts



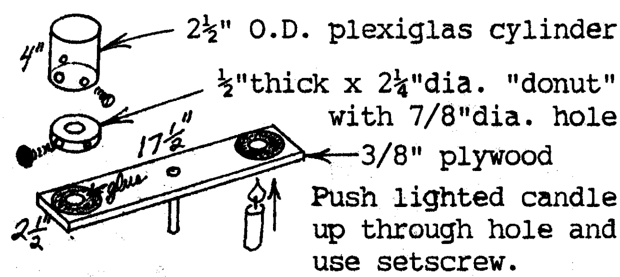
(c) variable g (planetary deformation) 8" dia. hoops on a shaft (P)



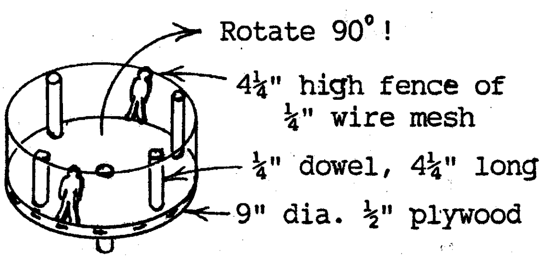
(d) centripetal accel. ($a_c = v^2/r$) the accelerometer (P), 5/16" steel shaft

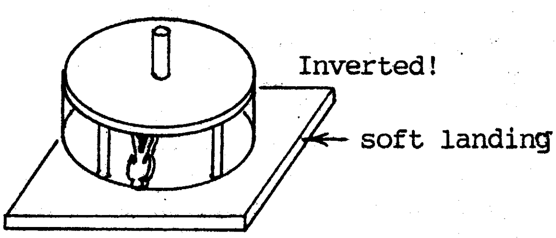


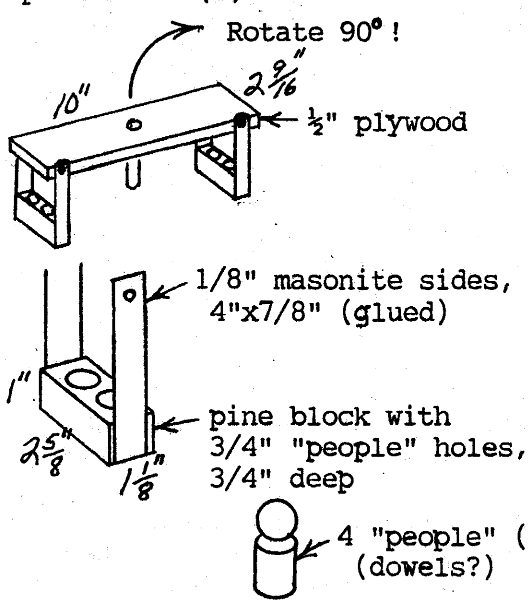
(e) the candle flame paradox usually 2 flames, 5/16" steel shaft

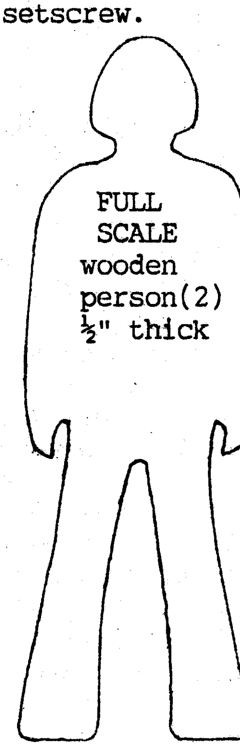


(f) centripetal force ($F_c = mv^2/r$) - amusement park rides (3) 5/16" steel shafts









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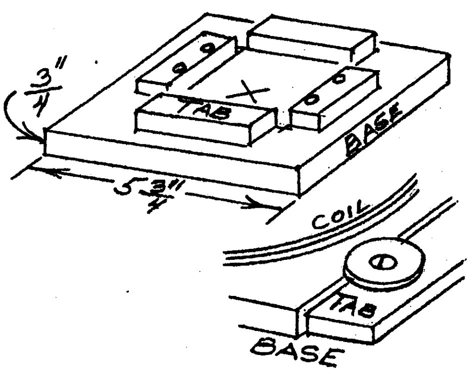
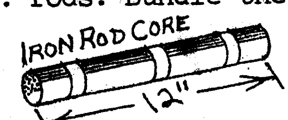
The Ring Flinger - The original Thomson (Dr. Elihu) apparatus provided a series of classic demonstrations in electromagnetism. This apparatus is a simplified version using today's available materials. The air core solenoid* required may be used for a dozen other demonstrations. Be assured, this electromagnet is well worth constructing.

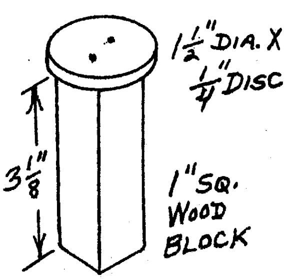
Materials: air core solenoid, welding wire (rod), shop wood, hardware, transparent plastic tubing, masking tape, AC switch box with circuit breaker, patch cord, Johnston alum. ring**

Construction: (a) Base - Cut 3/4" plywood or pine 5 3/4" square and 4 tabs, 2 3/4" x 3/4" x 3/16". Place solenoid on end in center of base; mark position of tabs along the edges, apply glue (Elmer's?),and nail down with brads. With 4 washers and #8 x 3/4" woodscrews, position washers so they overlap the edge of the solenoid's base. Mark and drill screw holes. Screw down the solenoid in place; everything should fit tight.



(b) Core - Buy "mild & low alloy steel welding wire (rod), 3 ft. long, cut to 1 ft. lengths. If 5/32" dia. is used, core requires 74 rods or 25 - 3 ft. rods. Bundle the 74 rods together with masking tape.





(c) Spacer - Make a wooden spacer 3 3/8" long that will just fit inside the solenoid core. Glue and nail a masonite top (disc) to the wood block (round its corners to fit?).

(d) Insert the bundle of rods in the core. Place an 8" long piece of thin transparent plastic tubing (a sheath) over the iron core. Place the Johnston ring over the sheath and iron core. Connect the patch cord to the solenoid's terminals. With the AC switch box unplugged from the AC source and its switch in the "off" position, plug the patch cord into the switch box. Now everything is ready for 120 V.

<u>Warning!</u> This is a 120 V system. Observe all safety precautions. Keep unplugged until all adjustments are made; unplug when not in use. Tape over exposed terminals. This apparatus was designed for experienced teachers. You must add safety features for student use, and you must supervise them.

Presentation: (a) Plug into the AC source. Turn the switch "on"; the ring will pop up and "float" in the electromagnetic field and obey Lenz's Law. Don't leave the switch on long because of overheating the coil's insulation (damage!).

(b) Pull the sheath off and the iron core out of the coil. Insert the spacer, and reinsert the iron core without the sheath. Replace the ring over the iron core. This time when you throw the switch "on", the ring will "explode" upward, high into the air; be ready to catch it! <u>Immediately</u> turn off the switch <u>or</u> the coil will overheat and be badly damaged (ruined?!). Do <u>not</u> repeat many times in a row; the coil must have time to cool off. For more fun, tip the apparatus to a 45° angle and "shoot" the E-M "cannon"; prepare to catch the ring in a cardboard box, etc. to prevent damage to it. A review of 2-D motion? Obviously, this demo is a student favorite.

* air core solenoid #14825 - Science First (207) 701 - 8111 www.sciencefirst.com

** Contact The Faraday Center.

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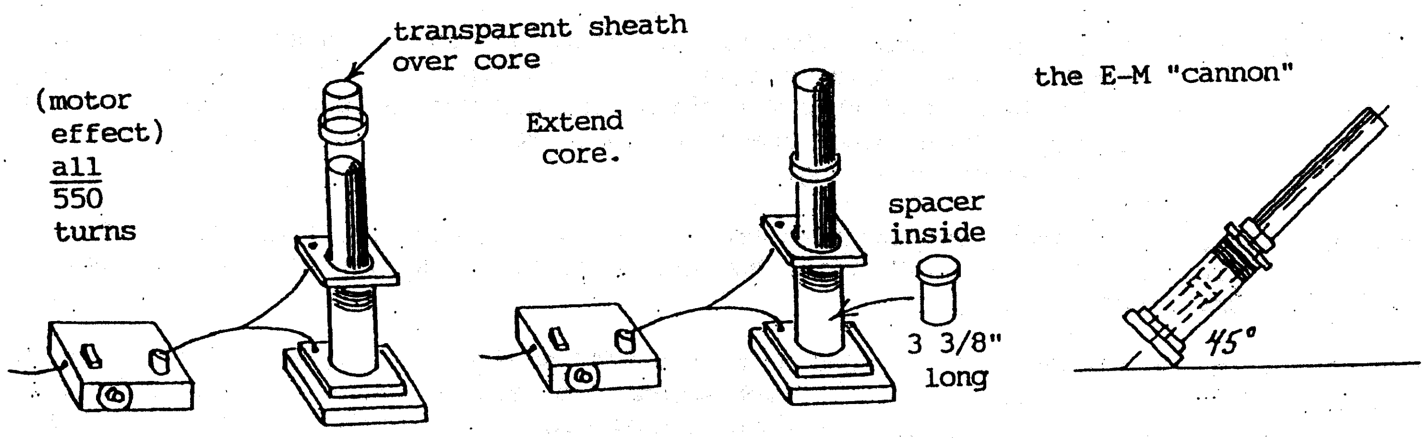

transparent sheath over core
(motor effect) all 550 turns
Extend core.
spacer inside
3 3/8" long
the E-M "cannon"
45°

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The hand-held Tesla coil.* This apparatus has been in our classrooms for over fifty years and still stirs excitement. Originally used to test vacuum assemblies for leakage and for exciting spectrum, Geissler, and other electrical tubes, this unit has additional uses that are fundamental and entertaining.

If you hold the tip of the unit near a grounded metal object, the maximum spark gap is about 2.5 cm (1 in.). The "rule of thumb" is that a 1 cm air gap requires a potential of about 20,000 volts to cross it. Thus, this coil is operating at about 50,000 volts at its maximum. This voltage is enough to ionize air around the coil's tip and produce a "brush" discharge of electricity; it is like the St. Elmo's "fire" seen at the top of the tall masts on the great sailing ships of the 19th century. With this discharge, ozone (O_3) is produced; its odor is strong! Also, the coil can charge up an electroscope, poke holes through paper, start fires, etc. For fun, I reasoned, why not add a pistol grip (handle) to the coil so it looks like a "zap" gun?

I glued two pieces of 3/4" plywood together and attached it to the coil with two 57/82 mm hose clamps. (See the pattern.) I glued cardboard shims to the front of the "cradle" as the front of the bakelite case has a slightly smaller diameter than the rear. I layed out the work according to the diagram and cut out the "cradle" on a table saw <u>first</u>, using the straight edges on each side against the fence. Then do a "rough" cut on a scroll (jig) saw to separate the two pieces. Glue the two pieces together, <u>matching</u> the "cradle" sections. Cut out the <u>final</u> shape on the scroll saw, including the notches. Sand and finish as you like. Make two sharp bends in the hose clamp straps so they fit tightly in the plywood notches. When assembled, use your imagination, and let the fun begin!

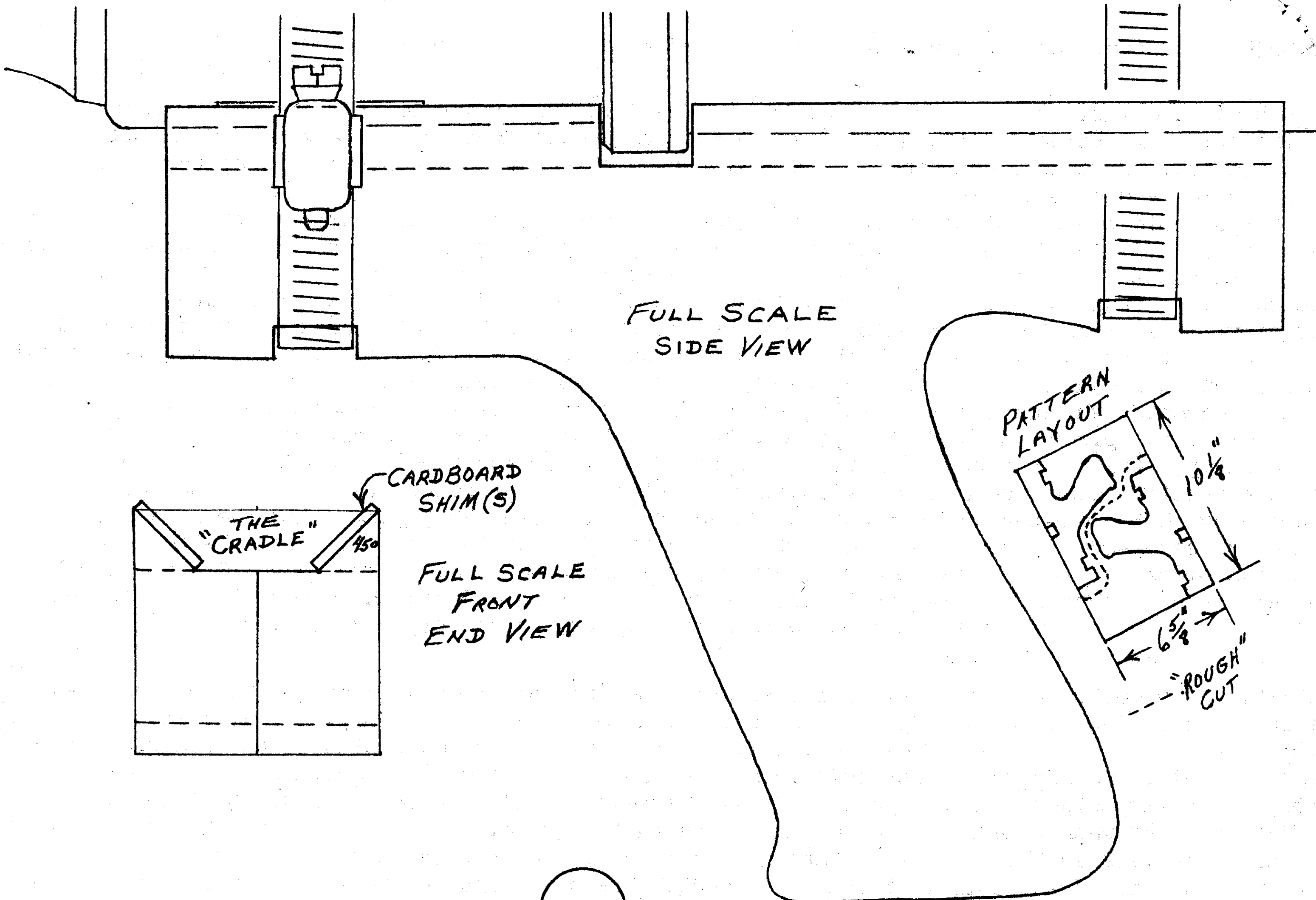
The "Tesla tower". With a little extra effort, you can construct a "zap" gun holder that can turn the coil into a two-way "plasma" globe. With some 3/4" pine or plywood, nine coarse-thread #6 x 1 5/8" drywall screws, and some velcro, follow the "tower" plan in the diagram. The clear 5" dia. incandescent light bulb is mounted on a wood block in a med. base #9063 Leviton pony cleat lampholder with two #8 x 1" RH wood screws. A ¼" x 20 thumbscrew, 1½" long, with a 3/16" and a ¼" washer make up the "clamp". Note that a ¼" shim must be glued to the lower side of the backpiece so the hose clamp screws clear; thus, the "tower" is slightly off-center. Because the tip of the coil must touch the center brass contact in the socket, a 3/8" dia. hole must be drilled up through the wood block and a 3/16" hole drilled up through the plastic (bakelite) lampholder. Assemble the "tower" with the drywall screws.

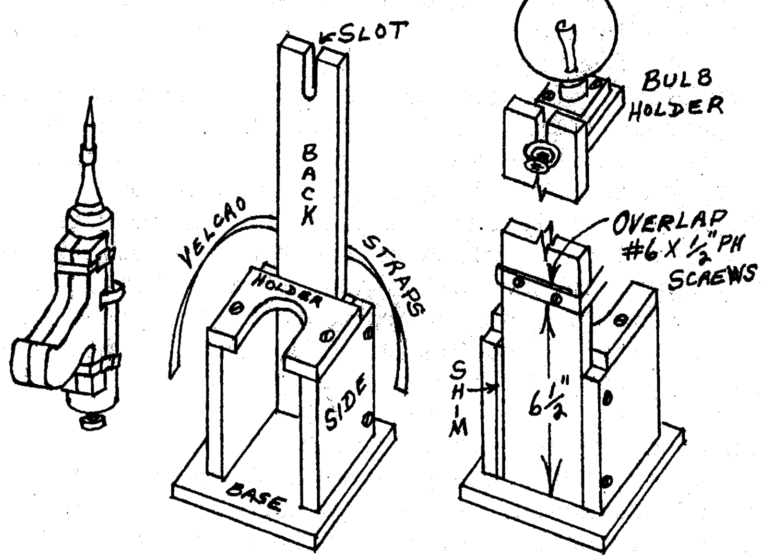
Presentation: With the coil turned up and in place, strapped to the tower, and bulb (globe) holder clamped down in the adjustable slot, plug in (turn on) the coil. Darken the room if possible, and watch the violet discharges in the bulb. Move your finger(s) near and touch the glass. Amazing! I wish I had a good explanation for what is going on here. No one I've met is very sure. Keep asking! Next, unplug (turn off), raise up the globe holder to clear the tip, remove the coil, attach a ground wire with alligator clips to the brass screw on the lampholder, have it lead to any nearby ground, and plug in the coil again. Bring the tip to the glass, and watch the discharge streak to the filament, just the opposite of the previous situation. Still amazing! Whether we understand everything that is going on here or not, there are still lessons to be learned. One is that under certain circumstances, glass can not shield (insulate) us perfectly from all electrical effects. Be careful.

Lighting (exciting) fluorescent tubes can also be instructive and fun. The coil is really an induction coil (a DC transformer) that increases the voltage from 120 V up into the thousands. Fluorescent fixtures have "transformers" (ballasts) in them to supply the needed high voltage. This coil can do what they do; all that is needed for full effect is a "ground" connection. A person on one end of a 4 ft. fluorescent tube becomes that connection. Keep hand(s) on the glass, not the metal! For fun, a teacher I know "swears in" Star Wars Jedi Knights (students) this way! Also, have the person change the hand location on the tube; the tube does not light beyond the hand (ground). As you experiment with the coil, other learning (and fun) situations will arise.

<u>Warning</u>: The high voltage may be dangerous to high-tech equipment. As a precaution, I would stay a safe distance away from all electronic gadgets, computers, etc. to avoid an <u>expensive</u> accident.

* #61157-02 hand-held Tesla coil in a bakelite case from Science Kit of Tonawanda, NY, (800) 828 - 7777, about $200.





Base: 5½" sq.

Back piece: 2½" x 14"

Slot depth: 1 7/8"

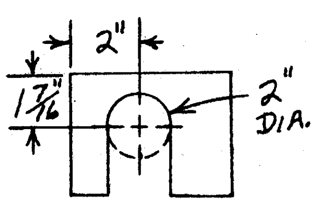
Shim: ¼" x 4 3/4"

Side piece (2): 3½" x 4 3/4"

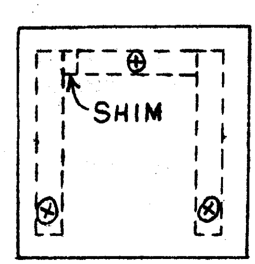
Holder: 2 3/4" x 4¼"

Bulb holder. 2½" sq.

top view of
holder



bottom view of
base (3 screws)



top view of
bulb holder