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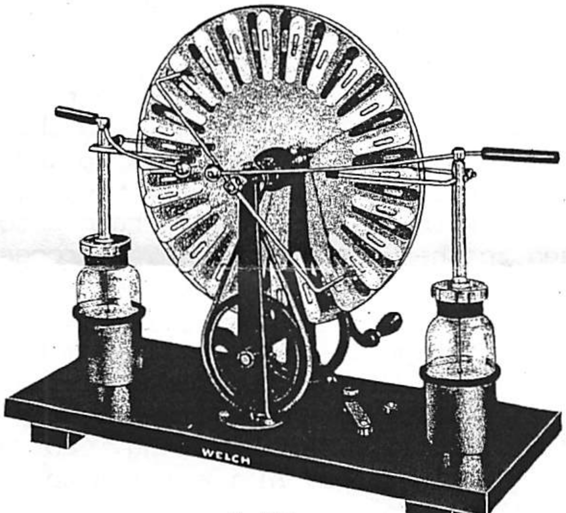
The Wimshurst machine - was developed in 1883 by Englishman James Wimshurst. It superseded all other electrostatic machines of that time and still retains its importance as an outstanding tool for teaching introductory electricity; few high school or college physics departments are without it. Pictured (1.) is the classic Welch Scientific version, the all-time best seller, with its contra-rotating discs and sectors and Leyden jar capacitors. It charges by induction rather than friction. Determine which movable electrode (arm) is negative and label it. Two 24" long leads with alligators clips on both ends are also required. What follows are a number of fundamental, historic demonstrations once performed by their founders; they are instructive and entertaining.

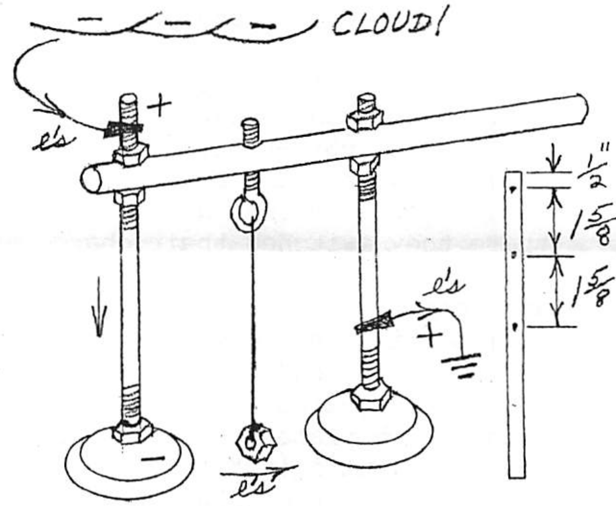
Diagrams:

1.



No. 1912.

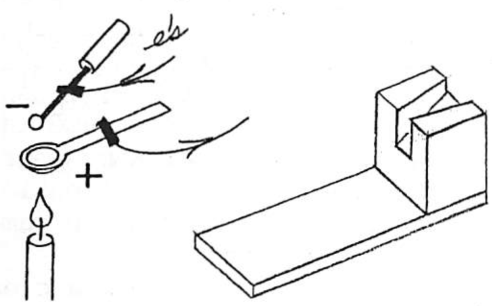
2.



We start with three demos used by Ben Franklin (1755?) to promote his new ideas about electricity. Besides all of his other accomplishments, he was a master showman. You'll see why as you replicate these demos. Perform them in any order that you wish.

2. Ben developed an early warning system to go with his lightning rod. With a little effort, you can make a working replica of his "chime" system. First, try to obtain two "door" bells (2½" dia.?) from old equipment to produce a nice "ring". See the diagram and adjust dimensions as necessary. Select a 3/4" dia. solid PVC rod 7½" long as the key insulator and holder for the apparatus. Drill 3 holes in the rod as per diagram. The "bell" bolts are #10-24, 5" and 4½" long and require 13/16" passing holes. The eyebolt hole in the center must be threaded for the fine adjustment of the clapper, merely a #10-24 alum nut on a nylon thread. The eyebolt is #8-32 x 1" and requires a #29 drill hole for the #8-32 tap; carefully thread the hole. Attach the bells to the bolts and the bolts to the rod with stop nuts; the bells must be even. The longer bolt's tip becomes the "lightning rod". Tie an alum. nut on one end of a nylon thread and the other end on the eyebolt as close as possible to the needed length. Final adjustment depends on the threaded eyebolt. Attach the apparatus to a ringstand with a right angle clamp. Attach a lead from the Wimshurst to the "lightning rod" and another lead from the second bell to the ground. Start cranking. (Grab the kite and run!) Of course, the "clapper" nut is transporting charges from one bell to the other and eventually to the ground safely via the "path of least resistance", the main function of the grounded lightning rod. Note also the slow discharge of the Wimshurst's Leyden jar capacitors when you stop cranking.

3.



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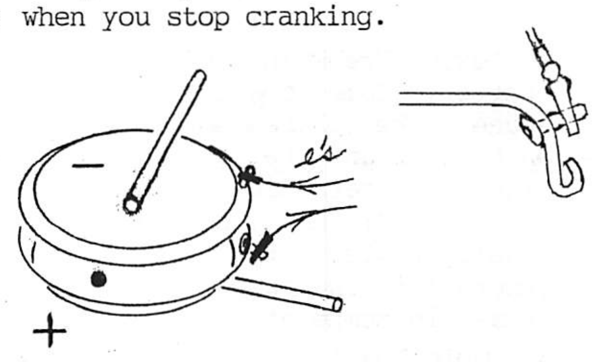
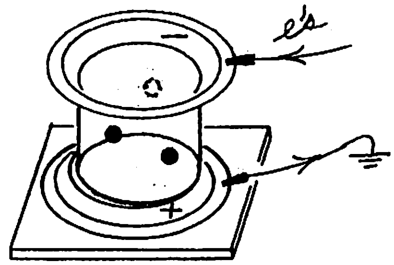


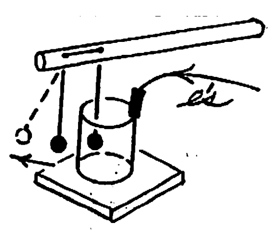
3. After a candlelight dinner party, Ben would carefully heat up a spoonful of brandy over a candleflame. With a Leyden jar's charge, he would generate a spark that would jump to the edge of a grounded spoon and light the alcohol fumes rising above the heated brandy producing that beautiful blue flame; in effect, he had created the first spark plug. (He had also invented a crude electrostatic generator for his work that used friction.)
Select a candle with a good flame, an old, metal teaspoon, some brandy, and an insulated metal probe. A spoon holder on a piece of wood is recommended so you don't spill the brandy while you hold the probe near the edge of the spoon and crank the Wimshurst. Practice heating up the brandy before the demo. Warning: if you hold the spoon too close, the candleflame may set the fumes on fire. If you heat the brandy too long, most of the alcohol may have evaporated away. If not heated enough, not enough fumes may be present to ignite. Once the fumes catch fire, the flame lasts for many seconds. I keep a small, 200 ml bottle of brandy on hand for this demo and sore throats.

4. Another of Ben's favorites was his electrical "jumping jacks", little "pith men" caught between horizontal parallel plates. Seems that pith could be carved into the shape of little men who were placed on the bottom plate. As the plates charged up and the electric field between them grew stronger, the little charged men stood up and then followed the electric field lines upward until they collided with the oppositely charged top plate; there they switched their charge and returned to the bottom plate. The process was repeated at a rapid rate, thus, the appearance of "jumping jacks", very entertaining to see and hear.
I simplified this demo by using a single ½" dia. graphite-coated styrofoam sphere instead of the "pith men". I also modified two heavy Al, 9" Mirroware, "camp" plates. Using my thumbs, I applied pressure to the center of each plate to shape them slightly parabolic. Attach each plate with a FH screw to a 3/4" dis. solid PVC rod 9" long. For details, see "Static electricity" (4.). Add a 1/8" dia., ¼" grip range, Al pop rivet to the backside outer edge of each plate for the leads with alligators clips.
With right angle clamps, attach the plates to ringstands; the "concave" plates should be level and facing each other. Attach the leads between the plates and the Wimshurst. As the Wimshurst charges up the plates, watch for the sphere to float up and start its "jumping". Note that the faster you crank, the faster the jumping. The slightly parabolic shape of the plates keeps the sphere bouncing near the center. When the cranking stops, notice the lingering action as the Leyden jars and the plates slowly discharge, displaying the main function of capacitors, storing up charge for later use. This demo by Ben illustrated the importance of parallel plates and their future, significant role in electronics. Some 150 years later, the core of Robert Millikan's "oil drop" apparatus to determine the charge on an electron was its parallel plates and the controlled, potential difference (voltage) they possessed. The all-important uniform electric field concept had begun, probably unknowingly, with Ben's parallel plates.

5.



6.

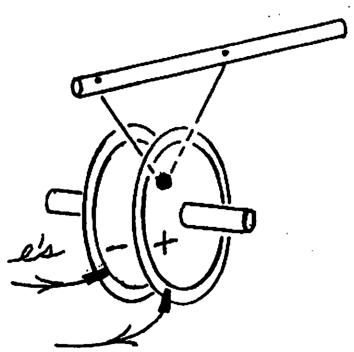


5. Following Franklin's experiments with parallel plates, Italian "Count" Ales. Volta of "battery" fame took them one step further; he injected several spheres into a confined space. The spheres not only oscillated up and down between the plates but collided with each other and the walls of the container, resulting in considerable, random motion, much like the interaction among air molecules. The experiment or demo became known as Volta's "hailstorm"; hail, of course, is tossed up and down in the upper atmosphere until it finally falls to the ground. Also, as Franklin discovered, if the potential difference (energy) is increased, the spheres move faster and hit harder, much the same as an increase in temperature (ave. kinetic energy) does to air molecules.
A simple "hailstorm" apparatus can be made with a pair of pie plates, a clear enclosure,

several ½" dia., graphite-coated styrofoam spheres, and an insulated "base". The insulated "base" could be an 1/8" sheet of Plexiglas. The clear enclosure could be the glass globe of a gas lantern or a clear cylinder resulting from removing both ends of a soda bottle (21.?). Some easy-to-remove masking tape will hold the apparatus together. Connect the leads and crank up the Wimshurst.

6. Here's another Franklin experiment that would stimulate further thinking (study) about charged objects, in this case cylinders. When Ben charged up a cylinder, he found no electrical effect inside the cylinder, only on the outside. Puzzled, he discussed it with his brilliant friend, Joseph Priestley,in 1775(?). Priestley, familiar with Newton's <u>Principia</u>, suggested that it was similar to Newton's conclusion about gravity inside a <u>hollow sphere</u>, that the force field was zero (all forces canceled out each other). Some 30 years later, Michael Faraday would devise his famous "ice pail" experiment, that would show that the charge on the pail only resided on the outside. Since like charges repel and thus try to get as far away from each other as possible, they naturally migrate to the extremity of a conductor leaving the inside charge-free or neutral. From this series of steps came the fundamental concept of electrical shielding (Faraday's "cage"), a major factor in protecting electronic systems from harm.
The apparatus required is any metal cup or can on an insulated base (Plexiglas?) and <u>2</u> ½" dia., graphite-coated styrofoam spheres suspended on nylon thread from a ½" dia. dowel 7" long with two small, drilled holes 3/4" apart for the thread. With a right angle clamp, attach the dowel to a ringstand, and make sure neither sphere inside nor out, touches the cup. Clip one lead from the cup to the Wimshurst, and slowly crank it up; watch the spheres. You've just repeated Ben's experiment and can now understand why you are safe staying in a car during an electrical storm. (But don't go looking for one to see if it's true!)

7.



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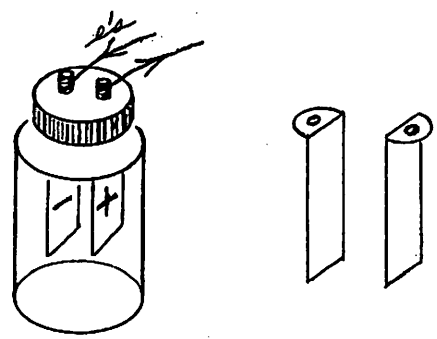

7. For a simple alternative to Ben's "Early Warning System" (1.), see "Static electricity" (6.) where parallel plates replace the bells and a lead from the Wimshurst clips directly on the edge of a plate. Always make sure that the other plate is grounded. Start cranking; you'll know when you have electricity present just as Ben did.

8. In today's world, we are striving for clean air, to remove as many harmful impurities as possible. One method utilizes the electrostatic precipitator, a very simple, but efficient device. Making one is easy. Select a large, clear glass, coffee jar with a plastic screw top. Drill two holes in the top for long bolts to hold the two alum. "electrodes" that attract the impurities (smoke particles). Make the electrodes out of heavy alum. that can be scrubbed clean after use. Thinner roof flashing may be used in a pinch. Attach the electrodes to the inside of the top with long bolts whose ends protrude out of the top for the alligator clip leads. See "The vortex box ...." about using cigarette smoke in this demo. Introduce smoke (particles) into the jar, screw the top on quickly, clip on the leads to the Wimshurst, and crank. All of a sudden the smoke swirls, and the air clears, like magic! Seems that most smoke particles are charged (ionic) and thus, are attracted to the electrodes where they attach themselves leaving the air clear. If you use cigarette smoke, the electrodes are instantly coated with a film that is discolored and has a greasy appearance. You can show your students how the lungs of a smoker look inside - pretty ugly! You will have to remove the electrodes after some use and scrub them clean to restore their efficiency (like any "filter").