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Static electricity - was the first electricity that aroused people's curiosity and was easy to generate. Thus, it was the first to be studied and resulted in the first "rules" to be learned. An instrument or apparatus developed for this study was the electroscope, originally the "gold-leaf" type, now the superior "Braun" type*, expensive but worth the price. A matched pair is recommended. What follows is a series of demonstrations that illustrate the principles of modern electricity and makes them easy to understand via the use of the electroscope.

What is electricity? Simply, it's the movement of electrons (e's) from one place to another and the energy they carry with them. Amperage is the number of e's moving and voltage is the energy each electron carries. Amps times volts equals the total amount of energy delivered from point A to point B.

First, of course, we must create polarity, a separation of charge, i.e., usually positive and negative places or terminals. Minutely, we just remove an outer electron or two from the edge of a neutral atom (which requires "work" or energy to accomplish), leaving the atom positive (+) or with more protons than electrons. In chemistry the atom has become a positive ion, a positively charged particle; the removed electrons are "relocated" to what becomes a negative (-) place or terminal.

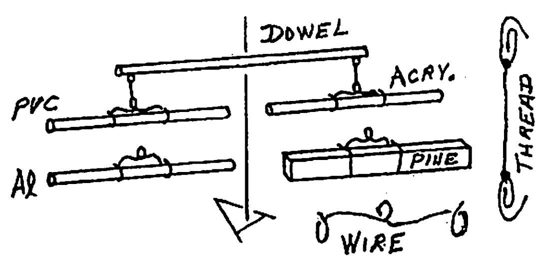
One of the simple beginnings is to pull a PVC rod through a wool felt cloth held tightly around the rod. It has been proven that the charge collected on the rod is negative (-). Alternately, an acrylic rod pulled through the thin plastic (polyethylene?) of a drycleaner's clothing cover produces a strong positive (+) charge on the rod.

Suggestion: 20 - 24" long, 3/4" dia., solid PVC (gray preferred) and clear acrylic rods are highly recommended for all of these demos. If, however, you have the older, hard rubber rods and cat's fur for producing negative charges, stick with them. On the otherhand, the acrylic rod and the right plastic are far superior to the glass rod and silk for producing positive charges.

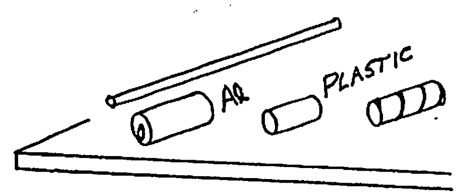
At the moment, we have "static" electricity, i.e., things (rods) charged up but no e's moving (current). Let's put the charged rods to use and get things moving!

Diagrams:

1.



2.



1. Take a 29" long, 3/4" dia. wood dowel, insert a screweye 1" in from each end and set it up as a crossbar with a right angle clamp on a ring stand. See diagram. Make up two "nylon thread-and-paperclip" hangers about 8" long. Take some #16 gauge steel wire and bend it around the 3/4" dia. PVC and acrylic rods as in the diagram; bend the "rod" loops slightly smaller so they will grip the rods quite tightly. (Obviously, you need a second set of rods for this demo.) Work the steel wire rod holders along to the middle of each rod. Hang the rods on the paperclip "hooks"; adjust the rods in the wire holders until they are level (balanced). Notice how frictionless these thread hangers are; they are extremely sensitive, thus, great for these demos.
   Now the fun begins. Move the uncharged hand-held PVC rod near the ends of the uncharged hanging PVC rod. Any motion by the hanging rod? Now charge up both ends of the hanging PVC rod and the the one in your hand. Move the hand-held PVC rod near the hanging PVC rod. It's repelled! You've just learned a "first-rule" in electricity: like charges repel! Quickly charge up the hand-held acrylic rod and bring it near the hanging, negative, PVC rod. It's attracted! Another "first-rule": unlike charges attract! Finish the demo by charging up and "testing" the ends of the hanging acrylic rod. The complete "first-rule", of course, is "unlikes attract", "likes repel".

* Klinger Ed. Prod. Corp., College Point, NY 11356

Incidentally, in the initial experiment when all of the rods were neutral (hadn't been charged up yet), you were also experimenting with the gravitational attraction between the rods which was virtually nil. This demo proves that the electrical forces involved were considerably stronger than the gravitational forces.*

The next step is to learn how e's move from place to place. They can achieve it by direct contact (conduction) or by induction (through space via electric fields).

If we remove one of the hanging plastic rods and replace it with a ½" dia., 24" long alum. rod, we can change it from neutral to "charged" without ever touching it by simple induction. Bring the negatively charged PVC rod near one end of the neutral Al rod. The Al rod is attracted! What happened? Simply, the negative electric field around the PVC rod repelled e's in the Al away from the rod's end, leaving it positive and thus attracted to the negative PVC rod. The Al's e's had been repelled (pushed) toward the other end; thus, a slight dipole had been created in the rod, or it now had temporary + and - ends. Take the PVC rod away, and the e's flow back to where they started, from negative to positive. We've just created an electric current each way and shown that Al is a good conductor.

If we run the same experiment with the positively charged acrylic rod instead, the Al rod is also attracted! How come? This time, the positive field of the acrylic rod attracts e's in the Al to the end near the acrylic rod, making it quite negative and attracted to the positive acrylic rod. Neutral conductors can always be induced to become oppositely charged when confronted by another charged object and thus, forces of attraction will always arise.

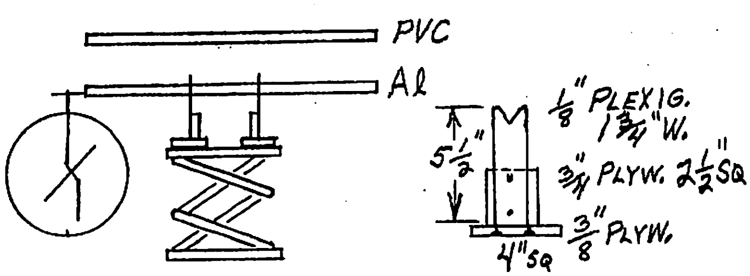
If we remove the other hanging plastic rod and replace it with a 3/4" x 1 3/4" x 24" pine stick, we can also change it from neutral to "charged" without touching it via simple induction. Bring the negatively charged PVC rod near one end of the stick. The stick is attracted! What happened? We don't normally consider wood to be a good conductor like Al. But all wood retains some mositure (H_2O) and H_2O is polar and can thus be attracted. Time out! See "The Snowflake" for a more complete explanation of water's polarity and the demos that go with it. Time in! So any charged object near wood will attempt to attract it. Later, when we get to the study of lightning with its high voltage, we will learn that the moisture in wood makes it a pretty good conductor.

2. Here are some simple "induction" demos that are fun and lead to more learning about the difference between conductors and insulators. Select an undented, empty, soda (beer?) can, a plastic container like a soda can, and a cardboard toiletpaper core, lay them on their sides so they can roll freely, and attract them with a charged rod. You can easily make the soda can roll back and forth by switching the rod's position from side to side, thus making the e's shift their position on the can's surface (a good conductor). If the plastic container is "bare" (no "message"), it shouldn't move. The cardboard toiletpaper core will roll because of its moisture content (polarity).

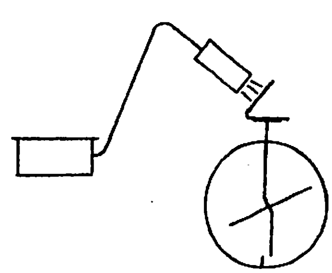
* Another dramatic demonstration of electrical field strength vs gravitational field strength is charging up the down of a cockatoo (Australian parrot) by touching it with the positively charged acrylic rod. Gently pull the charged down away from the rod and gently shake it. The charged down appears like a "ripe" (mature) dandelion flower and almost floats in the air (descends very slowly due to air resistance). Now "tease" the charged down with the charged rod. You should be able to move the down rather freely around the room. Stop for a moment, however, and let the down descend freely in the earth's gravitational field. Then "tease" it upward with the charged rod's electrical field, a clear demonstration that the latter field is stronger than the former. Pet owners and pet stores who have cockatoos can supply you with the down you need because the birds shed frequently. Store the down in small, used pill containers.

Diagrams:

2.



3.

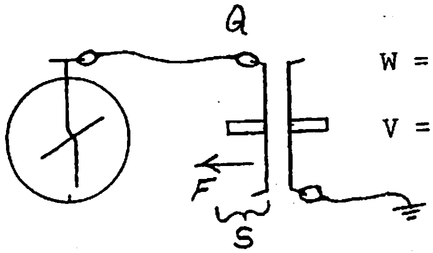


Enter the Braun electroscope and its use in some fine demos. Back to 2., conductors and insulators, for a moment.

Set up a scope with a lab-jack, insulated stands, and the rods shown in the diagram. With the end of a rod touching the scope's top plate (pan), bring a negatively charged rod up close to the far end. Does the scope's vane move away from the stem? Now actually touch the far end. Does the vane extend out even farther? In each case, an Al rod will show vane activity or is a good conductor where e's move freely. The PVC rod, on the otherhand, will show no vane activity or is a good insulator where e's don't move.

3. Before going further, how do we know which rod is truly negative or positive? How can we tell the difference? The answer came with the discovery and explanation (by Einstein) of the photoelectric effect. Using an old PSSC ultraviolet source (lamp), a scope, and a bent, polished Zn strip, you can show skeptical students the truth. The lamp has a small, white-light, mercury bulb which emits a low energy (long λ) ultraviolet ray, strong enough to energize loosely held e's on a Zn surface. Set up the apparatus as in the diagram. A strip of Zn, polished and bent, rests on the scope's pan; tape it down if necessary with masking tape which is easy to remove. Charge up the PVC rod (-) and carefully "wipe" it on the Zn strip until the scope appears fully charged. Bring the mercury lamp up close to the strip. The vane should collapse to zero in a short time as the e's leave the strip. Now charge up the scope with the acrylic rod (+) and carefully "wipe" it on the strip until the scope appears to be fully charged. (You've just attracted a large number of e's away from the scope and strip leaving them positive.) Again shine the lamp on the strip. Nothing happens. No e's are available to be easily ejected. Or you may wish to reverse the order and perform the second part first, your choice. So, calling the PVC rod negative and the acrylic rod positive is correct.

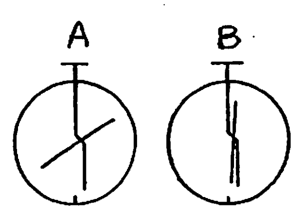
4.



$W = F \times S$

$V = \frac{W}{Q}$

5.



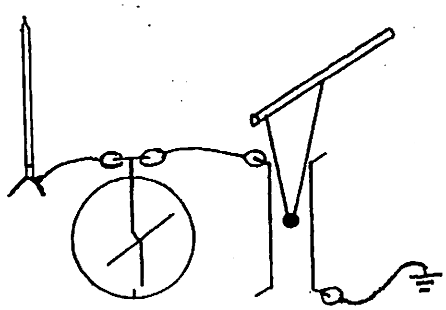
A	B	moving q
-10	0	-5
-10	-5	-2.5
+10	0	+5
+10	+5	+2.5
-10	+10	-10
-10	+5	-7.5
+10	-5	+7.5

4. Besides showing electrical activity, the scope is also a qualitative voltmeter and thus, can simply show the definition of a volt or voltage. Set up a scope with a pair of capacitor (pie?) plates as shown in the diagram, with the further plate grounded. With a 1 cm space between the plates, charge up the scope negatively until the vane is partially extended. Now carefully "pull", with force F, the "scope plate" back away from the grounded plate a distance S. Did the vane extend farther out or collapse inward? The "scope plate" is covered with negative charge Q. By induction, the grounded plate has become equally charged positive. When you "pulled" the negative plate back, you did work W on its charge Q, or the force F you used during the displacement S. The scope vane extended farther out showing an increase in voltage or an increase in potential difference, like stretching a spring. If they could, the plates would really like to snap back together and become neutral again (the vane "collapses"). Carefully move the scope plate back and forth and watch the vane as the voltage increases and decreases.

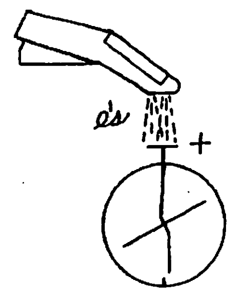
Construction: A nice pair of capacitor plates can be made from the standard, 9" reusable Al pie plate or the excellent, heavy Al, 9" Mirrorware, "camp" plate. Handles can be ½" dia. solid PVC rod, 4" long. A little technique is required for attaching the handles to the plates unless hot glue is used. First, take a scrap piece of oak or hard maple and countersink it on a drillpress for a #10 x 32 x ½" FH screw; everything about the hole must be slightly oversize for the thickness of the Al plate. Then drill a #10 size hole in the center of the plate, and center it over the countersunk hole in the wood. Insert the FH screw through the plate and into the wood. With a hammer, carefully tap the FH screw into the plate. You want the hole in the plate to taper into the shape of the countersunk hole. Tap until the top of the screw is even with the surface of the plate or slightly lower. If tapped carefully, the hole should not tear open and affect the hole's integrity. Last, holding the PVC handles straight up in a vise, drill and countersink holes for the #10 x 32 x ½" screws which will have to be tapped (threaded); center as best you can and drill carefully (slowly?). Carefully tap (thread) the holes and attach the plates; make further adjustments, if necessary. Now these plates have removable handles for easy storage. See "The Wimshurst machine" for more demos that use these special plates; they are well worth making.

5. A very instructional study of difference of potential can be performed with a matched pair of good scopes and good judgment by the observer. It will destroy the myth that e's travel only from - to + positions (terminals). To start, fully charge up scope A negatively (-10). Pick up scope B (0), and touch A's top pan. Both scopes swing to ½ or (-5). Result: -5 e's (q) moved from higher potential -10 (A) to lower potential 0 (B) until they both arrived at a potential of -5 or a difference of 0. Now recharge A up to -10; touch -5 B to A. Result: both scopes swing to 3/4 or -7.5, thus, only 2.5 e's (q) moved from A to B this time, but e's did move from one negative to another negative position because they were at different potentials. Now change to a full positive charge (+10) on A and 0 on B; repeat the sequence. This time e's (q) moved from B to A until the +5 potential was reached on both scopes, no potential difference left. You have just learned that any imbalance between charges will result in e's moving (an electric current or amps). Go on down through the chart; it's a good lesson!

6.



7.



6. A simple version of B. Franklin's "Early Warning System" with his lightning rod. Set up the capacitor plates and scope as in the diagram with a space of about 3 cm between the plates. Suspend a bifilar pendulum with a ½" dia. graphite-coated styrofoam sphere in the middle of the space. A 3/8" dia. dowel 16" long will hold the sphere and fit in a right angle clamp. Be sure the outside plate is grounded. Connect a small Al rod, serving as a "lightning rod", to the scope. Charge up the rod negatively; observe the scope's reaction, and wait to listen for the sphere to start swinging from plate to plate, passing e's to the ground. The sound from the banging was Ben's warning of an approaching electrical storm. (Get out the kite?) For a more dramatic presentation, use a Tesla coil to provide the "lightning". As a bonus, a capacitor's ability to store charge may be shown. When the system is fully working (charged), remove the charging rod and/or Tesla coil. Watch and listen as the plates slowly discharge back to neutral; it's not instant. Bigger plates would take longer.

7. This demo may not be possible if you can't locate an electronic static eliminator. This device existed when LP vinyl records were popular. It seems that a stylus (needle) which "drags" through the grooves of a phonograph record strips off e's leaving the grooves positively charged and prone to attract and hold unwanted dust. The eliminator is a piezoelectric device; when its trigger is squeezed, it "sprays" e's from a sharp point out onto a charged record to neutralize it, to discourage dust collection. So charge up a scope positively, hold the working tip above the charged plate (pan), and squeeze the trigger; it may take some practice. If the charge and distance are right, the scope should drop dramatically to zero (neutral). However, if you hold the eliminator too close, you may overpower it with excess e's, and the scope will switch to a negative charge which you don't want.