LAB 2. CHARGE

Problem

- How can an object become electrically charged?
- How do electric charges behave?
- How do charges behave differently in conductors and insulators?

Equipment

Activity 1: Tape, table top.

Activity 2: Tape, foam cup, foam plate, aluminum plate, fur or wool.

Activity 3: Electroscope, plastic rods, balloon, fur or cloth pieces.

Acknowledgements

The “Background,” “Sticky tape,” and “Electrophorus” sections of this lab were copied and lightly adapted from a Harvard University Physics 1b laboratory. The “Electroscope” section was copied and lightly adapted from a University of Colorado at Boulder Physics 2020 laboratory.

Background

Most modern applications of electricity involve moving electric charges or current electricity. Historically, however, the first studies of electricity involved static charges, or electrostatics. You certainly feel the effects of electrostatic charges every time you touch a doorknob in the wintertime and get zapped. When two surfaces touch (like your socks on a carpet) chemical bonds can temporarily form between surfaces, as neighboring atoms share electrons. When the surfaces are made of two different materials, the atoms in one surface often exert a stronger pull on the electrons than does the other surface. As a result, when the surfaces pull apart, electrons are stripped out of the weaker atoms by the stronger. These stolen electrons create a negative charge on one material, leaving positive charge on the other surface. It is strictly the act of one surface touching and then not touching another surface that causes the charge transfer.

Experimenters have established lists, called **triboelectric ser**ies, of the relative tendencies materials have for gaining and losing electrons. By studying these lists, you

Most Positive (readily lose electrons)

Rabbit fur
Lucite
Bakelite
Acetate
Glass
Quartz
Mica
Wool
Cat's fur
Silk
Paper
Cotton
Wood
Sealing wax
Amber
Resins
Hard rubber
Metals
Polyester
Polystyrene (Styrofoam)
Orlon
Saran Wrap
Polyurethane
Polyethylene
Polypropylene
Sulfur
Celluloid
Vinyl (PVC)
Teflon

Most Negative (readily steal electrons)

can learn that rubbing wool on Styrofoam leads to negatively charged Styrofoam (and positively charged wool). Materials with similar properties (e.g. hair, wool, fur) clump together on the list and don't interact strongly. The author of the above list notes that the series is exactly reproducible only in rare circumstances. Cleanliness, humidity, and manufacturing differences affect ordering. Adapted from *Electrostatics and its Applications*, A.D. Moore, Ed., Wiley & Sons, NY, 1973.

Activities

This lab consists of three stations. You may do them in any order.

1. Sticky Tape

1. Stick a piece of plastic adhesive tape (Scotch Magic tape works well) about 40 cm long onto a table top. This is your **base tape**.
2. Cut two 12–20 cm long pieces of tape. Create a non-sticky handle on the end of each piece by folding over a couple cm section. These are your **working strips**.
3. Stick your working strips firmly to your base tape. Make sure they are in full contact with the base tape by pressing them down firmly with your fingers.
4. Grasping their handles, briskly pull your working stripes off of the base tape (imagine you are removing a band-aid). Letting the strips dangle freely, slowly bring the strips together. Experiment with bringing the tape together with the like sides facing each other (non-sticky to non-sticky) and the opposite sides facing each (non-sticky to sticky). What happens? How does the orientation of the tape affect what you see? What do you think is causing this effect?
5. One at a time, pass each of the working strips lightly between your fingers. Try bringing the tape back together again. Is the behavior of the tape different?
6. Carefully stick the two strips of tape together (sticky to non-sticky) so that you have a double thick piece of tape, and run your fingers down the length of the working strips.
7. Grasping one tape tab in each hand, quickly pull the strips of tape apart, repeating step 4 from this new starting configuration. Do the strips behave differently this time? Is the behavior the same or different from step 4?

8. Create four new working strips that are all about 10 cm long.
9. Create two double thick pieces of tape using your 4 new working strips. Use a pen to mark the tabs of the top and bottom stripes in each pair so you can track which strips started on the top and bottom. (The piece with the non-sticky side exposed is the top.)
10. Quickly pull the two pairs of tape apart and test all possible combinations of bottom and top strips as you tested the strips in step 4. What do you discover?
11. At this point you do not know which strips are positive and which are negative. Using two objects from the triboelectric series (like hair and Styrofoam), create a negatively charged object.
12. Test a top and bottom piece of tape with the negatively charged object. How are the top and bottom pieces of tape charged?

2. *Electrophorus*

Alessandro Count Volta is credited with inventing the electrophorus perpetuum in 1775. This practical machine allowed the (apparent) perpetual generation of charge. The principle behind it is simple. Like charge repels like charge. When a neutral object is brought near a negatively charged dielectric, the free electrons in the neutral object flow as far from the charged dielectric as they can get. If the neutral object is than touched with a conductive object connected to ground, those electrons will actually flee the neutral object, leaving it positively charged. If the neutral object is actually touched to the charged source, the electrons on the charged object will flow onto the neutral object, making it negatively charged.

In this part of the lab, you will create your own electrophorus perpetuum in a manner similar to that used by Volta. A regular Styrofoam pie plate becomes a charged dielectric when it is rubbed against your hair or a wool sweater. Combine this with an aluminum pie plate with Styrofoam-cup handle, and you're ready to “create” charge!

1. Tape an upside-down Styrofoam plate to a table or counter top. The tape should only touch the edges of the plate. This is your dielectric.
2. Tape a Styrofoam cup to the inside of an aluminum pie plate. The cup will serve as an insulating handle for moving the charged pie plate.
3. Charge the Styrofoam plate by rubbing it with fur or wool.

4. Charge a balloon by rubbing it with fur or wool. Bring it close to the Styrofoam plate. Is it attracted or repelled? What type of charge is on the Styrofoam plate?

5. Make sure the aluminum pie plate is neutral (uncharged). Touching it with one hand while touching a water faucet with the other hand should work.
6. Holding on to its Styrofoam handle, move the neutral aluminum plate as close to the Styrofoam dielectric as possible without letting them touch! While keeping the plates as close together as possible, momentarily touch a finger to the top surface of the aluminum pie plate, and then raise the aluminum plate.
7. Now while touching only the handle bring the aluminum pie plate near the charged balloon. Is the balloon attracted or repelled by the aluminum plate? What sign is the charge on the aluminum plate? Is this the same or opposite of the charge on the Styrofoam plate?

8. You can recharge the aluminum plate as many times as you want, as long as you don't allow the two plates to touch. The process of charging the plate requires energy, which is introduced by the work done when the aluminum plate is separated from the charged Styrofoam. Try untaping the Styrofoam plate from the table and repeating steps 5 and 6. What happens?

   When you are done, retape the Styrofoam plate to the table.
9. Repeat steps 3, 5–7, but this time firmly touch the plates together but don't touch the metal plate yourself. How does the balloon react? What do you notice about the amount of charge transferred this time?

3. Electroscope

The electroscope consists of a metal plate connected by a metal rod (the stem) to two leaves of aluminum foil. The fragile part of the instrument is enclosed in the glass. Electrons can flow freely within the ball, stem, and foil. The foil leaves are very lightweight and floppy, so that an electrical repulsive force acting to lift them up can more easily overcome the downward force of gravity.

Notes

• Never tilt the electroscope or turn it upside down. This can tear the foil. Just leave it on the table.

• When you bring a charged object near the electroscope, do so from the top. Do not bring any charged object near the glass sides, as this can twist the foil and rip it off.

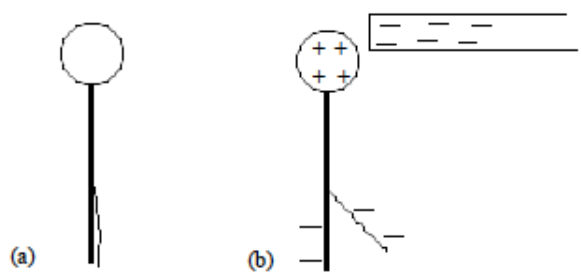
• In order to ground the electroscope (that is, remove all the net charge from it so it's neutral), touch your hand to the top of the electroscope. First be sure that you do not have any charge on your hands.

• Before charging and testing the plastic rods, make sure that they are neutral first. You can ground the plastic rods by covering a water faucet with a damp towel and wipe the rods across the towel. Always test the rod with the electroscope to make sure it is neutral first.

• If you rub two objects together to test the charge on each, make sure you hold the side that was rubbed near to the disk on the electroscope.

Procedure

1. Charge a plastic rod by rubbing it with fur.
2. Make sure there is no charge on the electroscope so that its leaf hangs straight down. Now bring the rod close to (but not touching) the plate of the electroscope, causing the leaves to rise.



(a) If the electroscope is neutral and no charges are nearby, the leaves will hang straight down. (b) A charged rod near the plate causes the leaves to rise.

3. Explain what happens. What forces are acting on the foil?

4. Take the rod away, and bring the fur close to the plate. (Because the charge is spread over the cloth, it is harder to get the leaves to rise this way.) Explain what happens.

5. Using just a neutral electroscope as you did here, can you tell the sign of the charge which is close to the plate? If so, how?

6. Take a charged rod and touch it to the metal plate on the electroscope, then take the rod away. Using one or more diagrams similar to (b) above, explain what happens.

7. Find out and explain how you can increase the amount of charge left on the electroscope. How can you tell that more charge has been left?

8. Now (with the electroscope charged negatively) bring the negative rod close to, but not touching, the plate. Do the same with the positive fur. In each case record and explain clearly, with diagrams, what happens.

9. With the electroscope negatively charged, can you tell the sign of the charge which is close to the plate? If so, how?

10. The electroscope can be charged positively by using a negatively charged rod, as follows: Neutralize the electroscope. Then, holding the rod in one hand, bring it close to (but not touching) the plate. Negative charges on the ball/stem/leaf structure will try to move as

far as possible from the rod. Now, keeping the rod in place, touch the opposite edge of the plate with a finger of your other hand. This allows some negative charge to escape from the plate. Then remove first your finger and then the rod.

11. Explain clearly, with pictures describing each step, why this process of "charging by induction" leaves the electroscope positively charged.

12. What happens now when you bring a negative charge close to the electroscope's plate? What if you bring up a positive charge?

Lab Report

This sheet, with all observations recorded and all questions answered, constitutes the report for this lab.