LAB 18. ELECTRIC 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: Balloon, fur, thread
Activity 2: Cellophane tape, table top
Activity 3: Balloon, fur, working water faucet, bubble soap, aluminum can
Activity 4: Tape, foam cup, foam plate, aluminum plate, fur or wool.
Activity 5: 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.

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)

Experimenters have established lists, called **triboelectric ser**ies, of the relative tendencies materials have for gaining and losing electrons. By studying these lists, you 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 five stations. You may do them in any order.

1. Charge-Charge Forces

1. Charge a balloon suspended by a thread by rubbing it with fur. Hold another balloon in your hand and charge it in the same manner. Slowly bring the balloon in your hand toward the suspended balloon. What happens?

2. Re-charge the suspended balloon by rubbing it with fur. Remove the fur piece and then slowly bring it toward the balloon. What happens?

3. Rub a balloon in your hair (if, unlike your teacher, you have hair). Slowly pull the balloon away from your head. What happens?

2. 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 pieces of tape 12–20 cm long. 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 strips off of the base tape.
5. 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?

6. 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?

7. 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 its length. Grasping one tape tab in each hand, quickly pull the strips of tape apart.
8. Do the strips behave differently this time? Is the behavior the same or different from step 5?

9. Create four new working strips that are all about 10 cm long. Make them into two double thick pieces of tape. 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 5. 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?

3. Electric Charge Polarization

1. Charge a balloon by rubbing it with fur.
2. Hold the charged object near a thin stream of falling water. What happens?
3. Blow soap bubbles in air. Bring the charged balloon near the bubbles. What happens?
4. Place an empty aluminum can on its side on a level surface, so that it can roll freely. Bring the charged balloon near the side of the can. What happens?

4. 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 conductor is brought near a negative charge, free electrons in the conductor flow as far from the charge as they can get. If the neutral conductor is then grounded, those electrons will actually leave the neutral conductor, leaving it positively charged. If the neutral conductor actually touches the charged source, some electrons on the charged object will flow onto the neutral object, leaving 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 Styrofoam slab becomes a charged dielectric when it is rubbed against fur or wool. Combine this with an aluminum pie plate fitted with a Styrofoam-cup handle, and you're ready to “create” charge!

1. Place a Styrofoam slab on a table or counter top.
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 slab by rubbing it with fur or wool.
4. Charge a balloon by rubbing it with fur or wool. Bring it close to the Styrofoam slab. Is it attracted or repelled? What type of charge is on the Styrofoam slab?
5. Make sure the aluminum pie plate is neutral (uncharged). Touching it with one hand while holding a water faucet with the other hand should work.
6. Holding on to its Styrofoam handle, bring the neutral aluminum plate to the Styrofoam slab without letting them touch. While holding the plates as close together as possible, momentarily touch a finger to the edge of the aluminum pie plate, then release the finger, and finally raise the aluminum plate.

7. Now while holding only its 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 as or opposite the charge on the Styrofoam slab?

8. You can recharge the aluminum plate as many times as you want, as long as you don't allow it to touch the slab. 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.
9. Place a Styrofoam plate on the table and charge it by rubbing it with fur or wool. Repeat steps 5 and 6 using the plate in place of the slab. What happens?

10. Ground the aluminum plate, then, holding it by its foam handle, touch it to the charged Styrofoam slab. Do not touch the metal of the plate. How does the balloon react to the metal plate? What do you notice about the amount of charge transferred?

5. 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 move freely within the conducting plate, stem, and foil. The foil leaves are very light, so that an electrical repulsive force acting to push them apart can easily overcome the downward force of gravity.

Notes

• Never tilt the electroscope or turn it upside down. This can tear the foil.

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

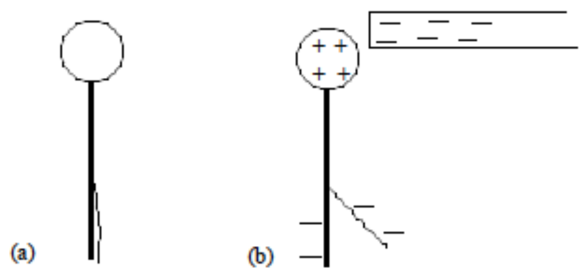
• In order to ground the electroscope (that is, remove all the net charge from it so it is neutral), touch your hand to the top of the electroscope. You may want to ground yourself to a faucet first.

• Before charging and testing the plastic rods, make sure that they are neutral. 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 charge them, make sure you hold the side that was rubbed near the plate of the electroscope.

Procedure

1. Charge a plastic rod by rubbing it with fur.
2. Make sure there is no charge on the electroscope (its leaves will hang 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 leaves?

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

5. Using 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. Touch a charged rod and to the metal plate on the electroscope, then take the rod away. Using one or more diagrams similar to those above, explain what happens.

7. Find out and explain how you can increase the amount of charge loaded on the electroscope. How can you tell that there is more charge?

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 brought close to the plate? If so, how?

10. The electroscope can receive a positive charge by using a negatively charged rod, as follows. Ground the electroscope. Then, holding the rod in one hand, bring it close to (but not touching) the plate. Keeping the rod in place, touch the opposite edge of the plate with 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.