Name____ Date__________________________

Partner____ Course&Section________________

Lab 1. Electrostatics

Goals

• To understand and verify the behavior of the two kinds of charge, denoted “positive” and “negative”, respectively.

• To understand the response of the electroscope when a charged rod is brought near, so that the electrical charges on the rod interact with charges already present in the electroscope.

• To visualize charge transfer between charged rods, the electroscope, and other objects, and to understand how the electroscope is used to compare the net charges on two objects.

Introduction

Most modern applications of electricity involve electric charges in motion or **current**. Historically, however, the first studies of electricity involved static charges, or **electrostatics**.
The simplest way to obtain an electric charge is to take two materials and rub them together. Given any two different materials, charging occurs when one has a greater attraction, or **affinity**, for electrons than the other. When the two are rubbed together, the material with higher affinity captures some electrons from the material with lower affinity. Thus, one of the materials winds up with an excess of negatively charged electrons and so becomes negatively charged and the other has lost these electrons and so is positively charged.

For example, if you scuff the rubber soles of your shoes along a carpet, you will acquire some of the electrons from the rug. Your body will then have an excess of electrons. It is important to note here the difference between **insulators** and **conductors**: electrons can move freely within conductors (such as metal), but don’t move very easily through insulators (like cloth, hair, or plastic). To get rid of the excess of electrons on your body, just touch the nearest doorknob, metal bookcase, or best of all, earth ground. Although the electrons were transferred initially from the carpet to your feet, your body is a fairly good electrical conductor, so that the electrons can escape through your hands.

In this lab you will get the same effect by rubbing a hard rubber rod on a piece of fur. Rubber has higher electron affinity than hair; so when they are rubbed together the rod captures electrons from the fur; the rod therefore acquires an excess of electrons and is negatively charged, while the fur is left with a deficit of electrons and is therefore positively charged. Once the charges have been transferred from one material to the other, they cannot move freely and escape, since both the materials are insulators.

Electroscopes are used to detect the presence or absence of electric charge. Inside the electroscope a metal-coated needle (or sometimes a foil strip) pivots on a metal support connected directly to the metal disk platform on top of the electroscope. This electrically-conductive assembly is separated by non-conductive plastic insulators from the drum-shaped electroscope housing and base, thereby isolating and trapping any charge applied to or removed from the needle and top plate. The large metal disk on top simply allows charge to be detected more efficiently; otherwise its geometry is not too important here. The term "electrostatics" refers to charges that are basically stationary rather than continuously moving as in a wire carrying an electric current from one place to another. An analogy may be made to water in a bathtub as opposed to a flowing stream of water.

Some important things to remember are:

- Electric charges come in two varieties that are designated positive and negative.
- Charges of the same variety repel one another while charges of the opposite variety attract one another.
- Charges exert greater forces on one another when closer together (Coulomb's law).
- All materials are composed of positive and negative charges.
- In metal objects, some of the negative charge is relatively free to move from one place to another within the object. (This is why metals are called conductors.)
- Electric charges in insulators such as plastic, rubber, and glass are essentially fixed in place.
- The positive charges in any solid materials are in the atomic nuclei and are not free to move.
- Electric charges in static equilibrium have no net force acting on them.
- When rubbed with silk, plastic, or rubber, a glass rod acquires a net positive charge on its surface by giving up electrons to those materials having a stronger natural affinity for electrons.
- The plastic or hard rubber acquires a net negative surface charge when rubbed with wool or fur by "stealing" electrons from the wool or fur.
- In order to ground the electroscope (that is, remove all the net charge from it so it's neutral), touch the metal grounding plate to the metal disk on top of the electroscope. Touching your hand to the top of the electroscope can sometimes work, if you do not have any charge on your hands.
- Before charging and testing rods, make sure that they are neutral first. You can ground the rods by rolling them against the brass grounding plate. 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 end or side that was rubbed nearest to the top of the electroscope.

Caution: The glass rod is brittle. Return it to the tray when not in use. If placed on the table, the rod can roll off and break. Avoid handling any of the experimental materials any more than necessary. Their electrostatic properties are degraded by moisture and oil from your hands.

1. Holding a charged rod close to the electroscope plate

Ground the electroscope by touching the edges of the top plate and base housing simultaneously with your hand. This works because your body can absorb or give up small amounts of charge without suffering any ill effects. The needle or foil should then rest in a nearly vertical position influenced mainly by gravity. If it doesn't, your body may have become excessively charged. You can ground yourself by touching some nearby bare metal conduit, pipe, faucet, outlet cover plate, doorknob, or other bare metal structure fastened to the building. Most effective would be to use a wire connected directly to the earth (literally deep into the soil, hence the term "ground"), but your body is more convenient and usually good enough in this case. If your apparatus includes a metal plate connected by wire to the ground tap on a typical building electrical outlet, use that to neutralize charge on any apparatus and yourself.

Charge the glass rod. Hold the glass rod by its smooth end, and use the exterior of a common plastic storage bag to lightly and rapidly stroke the etched end of the glass rod. (A balloon or piece of silk in place of the bag also works.) **Then position the part of the glass rod that touched the bag just above the circular disk on top of the electroscope without touching the disk**. What do you observe? As the rod is moved away from the disk, what happens? Hypothesize what is happening to the charges. If at any time you suspect that the needle is stuck, gently tap the base of the electroscope with your finger. The base is not connected to the top plate, so tapping the base will not affect the charge on the plate or needle.

Repeat the same sequence with the black plastic rod after rubbing it with fur or wool. The fur or wool is thicker with more surface area than the plastic bag or silk which makes it less susceptible to moisture. The best procedure is to lay the fur face-up on the palm of one hand and with the other hand rub the rod against it lightly and vigorously. Take care to avoid sparks, which occur when charges have enough energy to jump through space, in this case if a charged rod is held too close to the electroscope.

Record all of your observations and justify your hypotheses on the back of this page with the aid of some simple "cartoons"—a series of pictures with words of explanation; your instructor will have some helpful suggestions for making simple drawings. Try to show what the electric charges on the electroscope are doing as the charged rods are brought close and then moved away. You will need a sequence of several cartoon pictures to show the locations of the charges on the electroscope for different positions of each rod. If you can't support your hypothesis by your observations and pictures, you may need to make another hypothesis.

Note: The effectiveness of the charging procedure depends strongly on the ambient humidity and the cleanliness of the glass rod. On a humid day, it may take some time to properly charge the rod. Cleaning the glass with a glass cleaner helps considerably. On a dry day, the charging procedure can produce much more charge. As you move the rod toward the electroscope, stop when you see the needle move. Sparks between the rod and the electroscope will invalidate this part of the experiment. If the needle moves suddenly and stays there after the rod is taken away, you've probably produced a spark. Sparks transfer charge to the electroscope.

2. Charging the electroscope by direct contact

Ground and discharge the electroscope again. The needle should return to vertical. **Touch the charged part of the glass rod firmly to the disk, and then move the rod away.** What happens to the needle of the electroscope? Make a hypothesis about what happened when you touched the disk with the rod using some "cartoons" as visual aids. Without grounding the electroscope, **test your hypothesis by bringing a newly charged glass rod again near the disk at the top of the electroscope but this time without touching it.** What happens to the electroscope needle? Explain whether this observation supports your hypothesis or not. If the observation doesn't support your hypothesis, redo the whole procedure and make sure that the observed behavior is repeatable—an important aspect of the scientific process. Record all your hypotheses, whether they turn out to be correct or incorrect. Once the behavior is repeatable, make another hypothesis to explain your observations. **Double check your understanding, by bring the charged black plastic rod close to (but not touching) the electroscope that was touched and charged by the glass rod** and observe what happens. Is your hypothesis consistent with these additional observations? Explain with the aid of another cartoon sequence.

Repeat the process described above using a charged black plastic rod. Can a net electric charge be left on the electroscope by touching it with the rods? How does the sign of the charge on the electroscope compare to the charge on the rod that touches it? **Again, record all of your observations and justify your hypotheses on the back of this page**

3. Charging the electroscope by induction

Ground and discharge the electroscope again. With your finger still touching the edge of the disk and your thumb still touching the body of the electroscope, bring the charged glass rod close to the opposite side of the disk (away from your finger) without touching the disk. Now remove your finger from the disk first and then move the glass rod away. What do you observe on the electroscope? Make a hypothesis about what happened to the charge in the electroscope and record it. Then test your hypothesis using what you learned so far and verify that the result is repeatable. Modify your hypothesis as necessary. **Repeat the process described above using a charged black plastic rod.** **Explain your reasoning along with another cartoon sequence on the back of these pages.**

4. Effect of a flame on electroscope charge

Using your knowledge of the behavior of the electroscope and the charged rods, determine what variety of charge is released when a flame is burning nearby. Hold a burning match or lighter about 2 cm above the top plate. Try it with the electroscope initially uncharged, positively charged, and negatively charged. Explain in detail your procedure, results, reasoning, and conclusions. More drawings are needed.

5. The Race

If you lay a soda can on its side, you can get the can to roll towards your charged rod. You are allowed to use any tricks and insights that you learned from the lab to make your can go faster, including “preparing” the can before the race. However, once the race starts, you cannot touch the can or blow on it. Now, line up two soda cans and see who can get the can across the lab table the fastest without touching the can with the rod! Describe how you “prepared” your can and summarize your results and conclusions on the back of this page.

Triboelectric Series:

MOST POSITIVE (readily lose electrons when rubbed)

Rabbit's fur
Lucite
Bakelite
Acetate
Glass
Quartz
Mica
Human hair
Nylon
Rayon
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 take electrons when rubbed)