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

Electroscopes are used to detect the presence or absence of electric charge. They come in various forms, but a picture of a typical electroscope is shown in Figure 1.1. Inside the electroscope a metal needle pivots on a wire support shaped something like a paper clip. This structure inside the electroscope is connected to the outside by a metal rod passing through a plastic insulator. The metal disk on top simply allows charge to be detected more efficiently; otherwise its geometry is not too important. The term "electrostatics" refers to charges that are basically stationary, rather than continuously moving as in a wire carrying an electric current. 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, a small fraction 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 rubber and glass are essentially fixed in place.
- The positive charges in 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, a glass rod acquires a net positive charge on its surface by giving up electrons to the silk, which has a stronger affinity for electrons.
- The plastic (polyvinyl-chloride, or PVC) acquires a net negative surface charge when rubbed with wool by "stealing" electrons from the wool.

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 the glass rod, the plastic tube, and the wool and silk fabrics any more than necessary. Their electrostatic properties are degraded by moisture and oil from your hands.

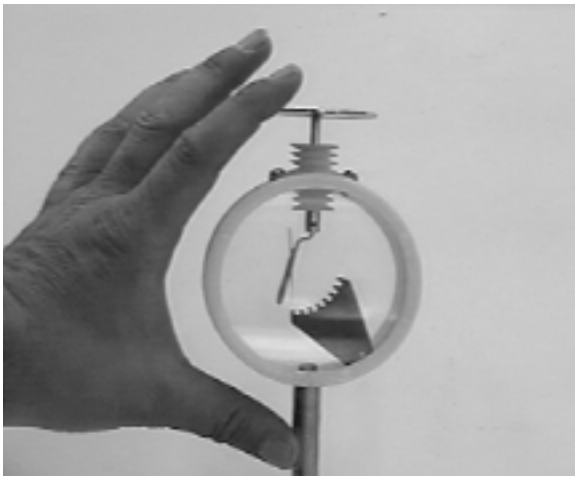

Figure 1.1. "Grounding" the electroscope.

Holding a charged rod close to the electroscope plate

Ground the electroscope as illustrated in Figure 1.1. This works because your body can absorb or give up small amounts of charge without suffering any ill effects. You could use a wire connected to the earth (or ground, hence the term "ground"), but your body is handier in this case. To charge the glass rod, hold the silk cloth by the edge so that it hangs below your hand and stroke the hanging silk with the glass rod. This procedure keeps moisture from your hand from damping the silk. Then position the part of the glass rod that touched the silk just above the circular disk on top of the electroscope without touching the disk with the rod.[1] 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 case of the electroscope with your finger.

[1]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 more than half the distance up the scale, you have probably produced a spark. Sparks transfer charge to the electroscope. The effect of transferred charge will be studied below.

The case is not connected to the top plate. Tapping the case will not affect the charge on the plate or needle.

Repeat the same sequence with the plastic tube after rubbing it with wool. The wool cloth is thicker than the silk, and is less susceptible to moisture. The best procedure is to put to wool in the palm of your hand and rub it against the rod. Take care to avoid sparks, as described in the footnote above. Again record your observations.

Now explain your hypothesis with the aid of some simple "cartoons"—a series of pictures with words of explanation; your TA will have some helpful suggestions for making simple drawings. 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.

Charging the electroscope by direct contact

Ground the electroscope again. This time touch the charged glass rod 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 the charged glass rod near the disk at the top of the electroscope but 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. By using the scientific method we hope to reach the correct explanation in the end. If the behavior is repeatable, then make another hypothesis to explain your observations and test it again. To double check your understanding, bring the plastic tube close to (but not touching) the electroscope that was touched at the outset with the charged glass rod and observe what happens. Is your hypothesis consistent with these additional observations? Explain with the aid of another cartoon sequence.

Repeat the entire process outlined in the previous paragraph, but start this time by touching the initially uncharged electroscope with the charged plastic tube.

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? Summarize your findings for this exercise.

Charging the electroscope by induction

Ground the electroscope again, as in Figure 1.1. 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 up close to the the other 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 sure that it is repeatable. 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. Modify your hypothesis as necessary. Explain your reasoning with another cartoon sequence.

Now beginning with the charged plastic tube repeat the process described in the previous paragraph. Summarize your results for this section.

Effect of lit match 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 match is burning. Hold the burning match about 2 cm above the disk. (Hold the match at least 1 cm from the plate.) Try it with the electroscope initially uncharged, positively charged, and negatively charged. Explain in detail your procedure, results, reasoning, and conclusions. More cartoons are needed here.

Summary

Summarize your findings concisely. Provide a brief explanation of your most important observation in each experiment.

Before you leave the lab please:
- Straighten up your lab station.
- Report any problems or suggest improvements to your TA.