

Lab 1. Charges and Electrostatics

INTRODUCTION:

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.

In this lab you will be introduced to an instrument called an *electroscope*, which is used to measure electric charge. By the end of this lab you should understand how the electroscope physically works, you should know how to use it to measure electric charge, and you should be able to use it as a tool to discover some electrical properties of various plastic materials.

THE ELECTROSCOPE:

The instrument that you will use in this lab is called an electroscope, shown in Figure 1. The electroscope consists of a metal ball connected by a metal rod (the *stem*) to a very thin leaf of gold foil. The fragile part of the instrument is enclosed in a protective case. Electrons can flow freely within the ball, stem, and gold leaf. The leaf is very lightweight and floppy, so that an electrical repulsive force acting to lift it up can more easily overcome the downward force of gravity.

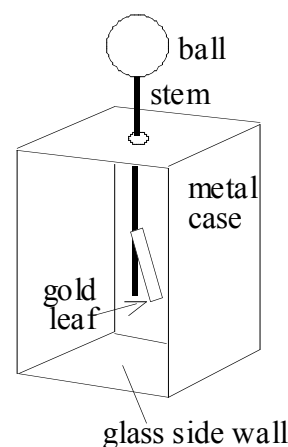


Fig.1. Electroscope

PRECAUTIONS & NOTES:

- Never tilt the electroscope or turn it upside down. This can tear the foil off. 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 gold 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 the metal grounding plate to the metal ball 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 the plastic rods, make sure that they are neutral first. You can ground the plastic rods by covering the metal grounding plate with a damp towel and wipe the rods across the cloth. 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 metal ball on the electroscope.

PART I: USING THE ELECTROSCOPE

The simplest way to obtain an electric charge is to take almost any two materials and rub them together. Often, one of the materials becomes negatively charged and the other positively. 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 – to get rid of these, just touch the nearest doorknob or metal bookcase. A similar effect occurs if you rub a teflon rod with a woolen cloth; the teflon rod acquires a negative charge and the wool acquires an equal amount of positive charge.

We know that all matter contains positive and negative charges. The positive charge is deep inside each atom on the atomic nucleus, while the negative charge is on the electrons that orbit outside the nucleus. In normal, neutral matter the amounts of positive and negative charge are equal, and we are unaware of either. Given any two different materials, it usually happens that 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. For example, teflon has higher electron affinity than wool; when they are rubbed together the teflon captures a few electrons from the wool; the teflon therefore acquires an excess of electrons and is negatively charged, while the wool is left with a deficit of electrons and is therefore positively charged.

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 on insulators (like cloth or plastic rods). The preceding paragraph applies to insulators in this lab.

Make sure there is no charge on the electroscope so that its leaf hangs straight down as in Fig. 2a. Now rub the teflon rod with the wool and bring the rod close to (*but not touching*) the ball of the electroscope, causing the leaf to rise. Using Fig. 2 as a guide, explain what happens.

What forces are acting on the leaf?

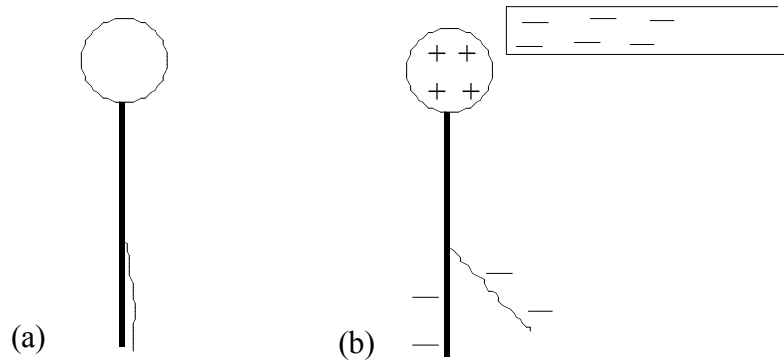


Fig. 2. a) If the electroscope is neutral and no charges are close by, the leaf will hang straight down. b) A charged rod close to the ball causes the leaf to rise.

Take away the teflon rod, and bring the wool cloth close to (but not touching) the ball. (Because the charge is spread over the cloth, it is harder to get the leaf to rise this way.) Draw a diagram similar to Fig. 2b and explain what happens.

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

Take a charged rod and touch it to the metal ball on the electroscope, then take the rod away. Using one or more diagrams similar to Fig. 2b, explain what happens.

Charge the electroscope negatively by touching the ball with the negatively charged rod. 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?

Now (with the electroscope charged negatively) bring the negative rod close to, but not touching, the ball. Do the same with the positive wool. In each case record and explain clearly (with diagrams like Fig. 2) what happens.

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

The electroscope can be charged positively by using a negatively charged teflon rod, as follows:

Neutralize the electroscope. Then, holding the teflon rod in one hand, bring it close to (but not touching) the ball. 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 ball with a finger of your other hand. This allows some negative charge to escape from ball/stem/leaf. Then remove first your finger and then the teflon rod.

Explain clearly, with several pictures (at least 4...) describing each step, why this process of "charging by induction" leaves the electroscope positively charged.

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

PART II: COMPARISON OF ELECTRON AFFINITY

On your lab table, you should have about 6 different pieces of plastic. The shapes and colors of the rods all differ, but the important thing is that they are all composed of different materials. Therefore, they should behave differently when you try to charge up each rod. We already know that when rubbed with wool, the plastic become *negatively charged* (the plastic wants to hold these negative charges, so it takes them from the wool). However, what happens when you rub two neutral plastic rods together? The answer will depend on which rod has a higher electron affinity.

Charge your electroscope with negative or positive charge, whichever seems more convenient. *Record which charge you use.* Be sure that the leaf is neither too high nor too low, so that you can see it rise or fall when you bring up other charges.

Choose any three plastic samples, and label them #1, #2, and #3 with masking tape. For each pair of plastic pieces (three pairs in all), *discharge both pieces and check that they are neutral.* Then rub them together to charge them. Experiment a bit to find how to get a good charge, and describe the best technique below. Is it important to press hard? To rub for a long time? Anything else?

For each of the three pairs, use the charged electroscope to find out which is negative and which positive. Be sure to test both pieces. Describe the results of each test.

Trial	(+) charge	(-) charge
#1 vs. #2		
#1 vs. #3		
#2 vs. #3		

From the results listed above, list the three objects in order of increasing electron affinity.

Why do we start with a charged electroscope instead of a neutral one for these tests?

PART III: THE RACE

Once you have determined which plastic rod can hold the most negative charge, challenge another group to a race. Here's how the race goes: if you lay a soda can on its side, you can get the can to roll towards your charged rod. Try it! Line up 2 soda cans and see which one of you can get the can across the table the fastest *without* touching the can with the 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.

Betting on the race is not required, although it is highly encouraged.

POTENTIAL EXAM QUESTIONS:

1. Which of the following statements is/are true?

- a) It is possible to charge up a steel ball *positively* using a *positively* charged plastic rod and a grounding plate.
- b) It is possible to charge up a steel ball *negatively* using a *positively* charged plastic rod and a grounding plate.
- c) Both statements (a) and (b) are true.
- d) Neither statements (a) or (b) are true.

2. In the following diagram, the spheres in each pair are initially in contact, but they are then separated while the rod is still in place. The rod is then removed.

Which of the following is the correct order of the final charge on the spheres, from most negative to most positive?

- a) ABCD
- b) ADCB
- c) BCDA
- d) DCBA
- e) All of the spheres have the same charge

