Electrostatics

1 Equipment

In order to investigate very fundamental properties of charge conduction and induction you will need the following equipment:

- Black plastic rod
- Glass rod
- Electroscope
- Fur pelt
- Rubber glove or something similar.
- Very small ball of aluminum foil on string
- Ball of aluminum foil on stick
- Large aluminum sphere on plastic stand
- Sheet of mylar

This lab is pretty elementary . I apologize if its results are so obvious. In order to discuss electrostatics we have to start with the phenomena of electrostatic attraction and repulsion. Otherwise it is all mere assertion.

2 Introduction

You have probably experienced shocks of "static electricity" on dry winter days. We are going to look at aspects of this phenomenon in a more controlled setting. It is important that you perform each of the following tasks described below in the order given. At times you will be asked to describe what you *expect* to see, or evaluate what you *do* see. Take these questions seriously - you will learn the material more thoroughly if you can reason from your own experience, rather than just accept what is stated in the book or in lectures. Most of the questions require quite short answers of just a sentence or two.

You are to work in small groups of no more that five people. You should try to reach a group consensus on each question. Consensus does not mean one person dictates the answers and everyone else copies them down! You should all have input to the process. Answers based on your experience in the lab should take precedence over answers you can recall from books. If you get stuck, please ask for help!

3 Procedure

The electroscope consists of a metal rod mounted on a pivot, sealed in a metal box or ring. The round disk on top of the scope is attached to this rod, but they are both insulated from the outer case. The pivot point in the rod is slightly off center, so that when the scope is discharged, the longer half will point downward. Check that the metal rod inside your electroscope can swing freely, and it points vertically. If it does not point vertically, touch the top disk briefly with your hand. If it is still not perfectly aligned, then be sure to correct for this in your measurements, subtracting this offset from all deflections you measure.

Task 1 Stroke the black plastic rod briskly with the fur pelt for about a dozen strokes. Bring the rod close to the electroscope *but do not touch it*. You should observe some change in the electroscope deflection. (If it does not, then report this to your instructor and you will be issued new equipment.) What happens? Does it persist when you move the rod away?

At this point all we know is that rubbing the rod with the fur produced something, but we don't know what it is, or why the electroscope reacted to it. Since we are starting a unit on electrostatics, you can probably guess that the "what" has something to do with electrical charge. Understanding why the electroscope reacts is part of the task of this lab.

Why does rubbing the rod with fur produce such a charge? To investigate this question in detail would take a long time! We hope you don't mind if we just quote an answer, an answer that can be proved by other experiments:

> "It is known that if you run a plastic comb or pen repeatedly through or a long your hair, or rub it with cotton or wool, the plastic ends up having a negative charge and so repels electrons. Large organic molecules in the plastic and/or your hair break at their weakest bond in such a way that negative ions (positively charged fragments) are deposited on your hair. A similar process occurs when you [rub the rod].
>
> It is probably significant that almost the only materials that can be easily charged by rubbing are those that contain large organic molecules, which can be broken fairly easily. It is typically more difficult to pull single electrons out of atoms or molecules, although we cannot rule out the possibility of stripping a single electron out of a molecule. One of the few inorganic materials that can be charged easily by rubbing is glass (which consists of silicon dioxide). Glass becomes positively charged when rubbed with silk. It may be that positive ions break off the large organic molecules in the silk and are deposited on the glass, or that silk strips single electrons off of glass.
>
> Molecular breakage or electron transfer provides a rough explanation but such details as to why the comb rather than your hair becomes negative are the subject of continuing research by physicists and chemists. Part of the complexity of these phenomena are due to the fact that they are *surface* phenomena. The special nature of the intermolecular interactions at the surface of a solid are generally less well understood that those in the interior. Moreover, unless one takes extraordinary precautions, real surfaces are always 'dirty' with various kinds of (possibly charged) contaminants, which further complicated any prediction about the effect of rubbing, which may remove or deposit charged contaminants.

One thing is certain: *you cannot by rubbing remove nuclei from inside the surface atoms nor remove protons from inside the nuclei of the surface atoms.* Removing protons would amount to transmuting one element into another!"

Sherwood and Chabay, *Understanding Electromagnetic Interactions*

It is worth noting then that the process of electrification through rubbing is not well understood even today. Think about that the next time you scuff your feet on the carpet to shock a sibling.

Task 2: Rub the black rod again, and touch it to the aluminum foil on the stick. Wave the foil ball close to the electroscope as you did with the black rod. Does the scope react? Is the reaction weaker or stronger than it was to when you first tried it with the rod?

React: Yes No

Strength: Weaker Same Stronger

Task 3: Rub the black rod again, and touch it to the aluminum foil on the string. After they have made contact, you should observe that there is now a force between them.

What type of force: Attractive? Repulsive?

We are told that electric forces between two objects act along a line drawn from one object to the other. This may sound a bit obvious to you, but there are forces in Nature for which this isn't the case. You should check this with your ball and string.

Task 4: Dangle the aluminum ball over the edge of a desk. (You may wish to tape it in place.) Rub the black rod again, and touch it to the aluminum foil on the string. After they have made contact, you should observe the force between them. Do you find that the force does indeed act along a line drawn between them? Draw vectors indicating the direction of all of the forces you observe on the suspended ball.

Task 5: You can estimate the force between the two balls of aluminum foil by looking at how far the dangling one is deflected. Draw a rough sketch of how the deflection varies with the distance between the two balls. (Of course, you can't take any measurement at zero deflection!).

Task 6: Again rub the black rod, and this time touch it to the electroscope. What happens to the electroscope needle?

Does it persist after you remove the rod?

What happens if you repeat the process?

We now have a number of observations: rubbing the rod seems to produce charges. These charges can be transferred by contact to a metal. The charges then can be seen to repel each other. Using this information, can you explain why the electroscope needle behaves the way it does when you touch the electroscope with the rod?

Task 7: Touch the electroscope with your finger. What happens to the deflection of the needle? Can you explain why?

So far we have found one type of charge in the world that produced from black plastic rods! The above quote from Chabay and Sherwood indicates that rubbing a glass rod should produce a different charge. Let's check this out.

Task *8:* Rub the black plastic rod and touch the ball of foil hanging from the string. Now rub the glass rod, and wave it near the suspended aluminum ball but do not touch it. Is the ball attracted or repelled from the glass rod?

The ball is: attracted repelled.

Give a rough sketch of how the deflection varies with distance:

Task 9: Rub the black plastic rod and touch the electroscope and then remove it. Now rub the glass rod, and wave it near the electroscope, but do not touch it. Does the electroscope needle deflect more or less when the glass rod is near'?

When the glass rod is near, the electroscope is deflected: more less.

We have now seen two different charges - black plastic rod charges, and glass rod charges. You might imagine that there could be hundreds of different types of charges, one from every material. It turns out that there are only two types of charge, positive and negative. Rubbing the plastic rod charges it negatively; rubbing the glass rod charges it positively. Any other material rod will produce charges like those from glass or like those from plastic. You have shown above that you can transfer charge from one object to another via contact. Such a process is called conduction.

However, we have a puzzle! The electroscope registered a deflection when you brought a charged rod *near* it, but not touching it. You did not conduct any charge to the scope. Why should it react?!

Task 10: This observation is a little subtle, so read the directions carefully. First charge up the black plastic rod. Bring it near the electroscope without touching it. Make sure the electroscope needle shows a deflection. With the rod kept in place, have someone touch the plate of the electroscope. The deflection should vanish. Now the person holding the electroscope should remove their hand. The deflection should still he zero. *Now* remove the black rod from the vicinity of the electroscope. If all goes well, you should now see a deflection!

Charge up both the black plastic rod and the glass rod. One of them should increase the needle deflection (the one with time same charge) and one should decrease it.

Which of the following is true?

- The black rod increases the deflection and the glass rod decreases it so the scope has the same charge as the black rod.

- The black rod decreases the deflection and the glass rod increases it so the scope has the opposite charge as time black rod.

The process you followed above, to charge the electroscope without touching it with the rod, is called induction. Try to figure out how induction works from what you have learned. You need to know a few more pieces of information: a metal has many charges in it which are effectively free to move around; when it is neutral there are just as many positive charges as negative ones.

Task 11: Charge the electroscope with either time black plastic or glass rod. Now strike a match and hold the flame near the electroscope. What is the effect? See whether you can determine experimentally the cause of the observed effect. Is it due to:

(1) Visible light from the flame?

(2) Ultraviolet light from the flame?

(3) Ions (charged atoms or molecules) produced in time flame?

(4) Air currents from time flame?

Try to think how you might test these hypotheses. Some useful facts:

- Glass will partially block UV radiation.
- Ions might be blocked by a grounded metal screen, or by a charged rod.
- The smoke from an extinguished match is cooler than that from a burning one. Devise tests

for (1)-(4), and record your observations. What is your explanation?

4 Questions

1. Have we proven that there are only two types of electrical charge?
2. Sketch a series of images showing how an electroscope can be charged by induction. Take care to demonstrate whether the charge on the electroscope is the same or different from that of time charged rod.
3. Present arguments for exactly what is discharging the electroscope when you bring a flame near it.