Experiment 12: Electric Charge

Introduction

There are several ways to give an object a net charge. Protons are “stuck” in the center of atoms and thus cannot generally be moved or removed. The negatively charged electrons are located much more precariously outside of the center of the atom. If some of the electrons are removed from some of the atoms in an object by some outside influence, the object will have more protons than electrons and will be positively charged. If, on the other hand, some electrons are added to an object, it will then have a net negative charge.

Once the outside influence that caused an accumulation of charge on an object is removed, the charge can act in one of several ways. In some types of materials the electrons cannot move away from “their” atom without the outside influence. Therefore the charges will be stuck in place and cannot move from one region of the object to another. Materials like this are called *insulators*. Common examples of insulators are rubber and plastics.

However, there are other types of materials in which the electrons are not fixed to any particular atom and may move about more or less freely. These kinds of materials are called *conductors*. Metals are a common example of conductors.

There is a third kind of material in which the electrons may move from atom to atom, but not very easily or only under certain circumstances. These materials are called *semiconductors* and are of extreme importance in the field of computers and electronics.

Objects may be given a charge in several ways. The first way to give an object a charge is by simply rubbing it. If the right kind of object is rubbed in the right way with the right type of material, some electrons are “scraped” off resulting in a net positive charge. The electrons which are “scraped” off onto the object that is doing the rubbing give it a net negative charge. In this way *both* objects are given a charge. However, since charges are not visible to the naked eye, the direction in which the electrons are transferred is not immediately obvious. The only observable result is two objects, each with a charge of equal magnitude and opposite sign.

A second way of giving a charge to an object is by *conduction*. If a previously charged object is touched to an object with no charge, some of the charge may flow from the charged object to the initially uncharged object. Since the charges have to actually move in this case, this method of charging works best when the charged object is a conductor.

The third way of charging an object is called *induction*. A charged object is brought close to, but not touching, an uncharged conductor. Let's say, for the sake of argument, that the charged object has a negative charge. The negative charges repel the negative charges in the conductor. The positive charges in the conductor are attracted to the negatively charged object, however the positive charges cannot move since they are in the nuclei of the atoms in the conductor. The negative charges in the conductor move away from the charged object leaving an excess of positive charges on the near side. If a grounding wire is now placed on the side of the conductor with the excess of negative charge, (some of) the excess charge will flow through the wire into the "ground" leaving a net positive charge on the conductor. The ground wire and original charged object are then both removed, leaving the conductor with a net positive charge. (Keep in mind that this would work in exactly the opposite way if the charged object were positive rather than negative.)

Since charges are free to move in a conductor, any net charge on a conductor will migrate as far away from "itself" as possible and end up at the surface. Therefore, any net charge on a conductor will always reside at the surface of the conductor. This is not to say that the charge will spread itself *uniformly* across the surface. Charge tends to accumulate at places with very tight turns or points and spreads out more thinly on smoothly curving and flat regions of the surface.

One last item of interest: if one charged particle exerts a force on a second charged particle, a charged *object* will exert a force on another charged object. This is why hair stands up after being combed in very dry weather. The comb rubs some electrons off of the strands of hair when it is pulled across your head. Each strand of hair is left with a positive charge. Each hair exerts a repulsive force on every other piece of hair and tries to get as far away as possible. The only way it can to this is by sticking straight out!

Apparatus

Glass and rubber rods, various types of material (fur, silk, etc.), electroscope, plastic sheet, metal disc.

Experiment

Most of the observations in this experiment will made with an electro-scope, the parts of which are indicated in Figure 12.1. Rub the dark rod with fur. Bring the tip of the rod close to the electroscope probe. Note what happens to the "leaves" as you bring the rod closer. Finally, touch the rod to the probe. What happens to the leaves then, and why? Keep in mind that the leaves of the electroscope are both conductors and are *both* attached to the probe by a conductor.

Remove the rod and observe the action of the leaves. Can you explain this effect? Now touch the

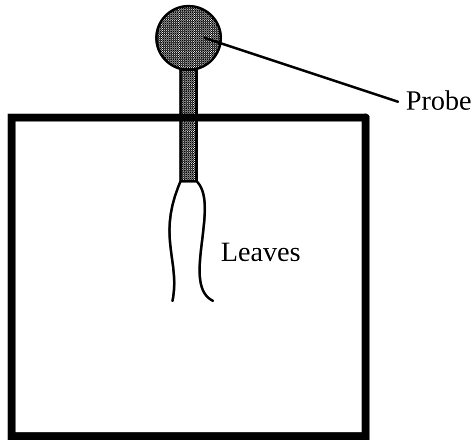

Figure 12.1: The main parts of a simple electro-scope as seen from the front. The *probe* is connected to the *leaves* by a conducting rod which is insulated from the exterior conducting shell.

probe with your (or one of your lab partner's) finger. What happens, and why?

Now perform the same actions except with the glass rod and the black silk fabric. Can you tell from your observations which sign of charge is given to the rubber and glass rods?

Give the rubber rod another charge with the fur. Bring it slowly closer to the electroscope probe, but not close enough to touch. Are the results of the very first part of the experiment repeatable? *Without* touching the probe with either the rod or your finger, take the rod away. What happens now? (And why?)

Bring the rubber rod back close to the probe (rub it with the fur again if it has lost it's charge). This time, while holding the rod close to but not in contact with the probe, touch the probe with your finger. Now what happens to the leaves? Explain this effect.

Charge the electroscope by touching the rubber rod to the probe. Now rub the disc on the piece of plastic. Observe the electroscope as you slowly bring the disc close to the probe. Allow the disc to make contact with the probe. What happens? Why? From these observations, what can you tell about the sign of the charges on the rubber rod and the disc? Can you decide now whether or not the rubber rod becomes positively or negatively charged when rubbed with fur?

Recharge the electroscope and observe it for several minutes. What happens to the leaves as it sits for this period of time? What can you tell about the insulating properties of air from your observations?

Since this experiment consists primarily of qualitative observation rather than quantitative measurements, discussion of sources of error is not required. However, your laboratory notes should include answers to each of the questions posed above with accompanying explanations based on the theory of charges on insulators and conductors presented in the introduction. In answering the questions, you may find it helpful to make sketches roughly showing the arrangement of charges on the objects involved.

Pre-Lab Questions:

1. Why is the grounding wire necessary in the charge-by-induction method of charging an object?
2. Why will charge-by-induction not work with two insulating objects?
3. Do you suppose air will be a good conductor or poor conductor (insulator)?
4. Given your answer to the previous question and the description of the electro-scope in the experiment, what do you predict will happen when you allow the charged electroscope to sit for a long period of time?
5. Would your answer to question 4 change if the air in the room is considered to be very humid?