

# ELECTROSTATICS

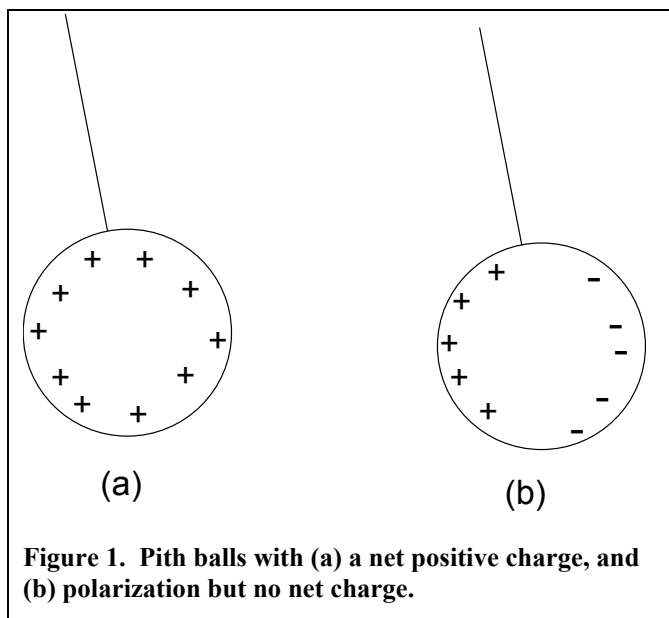
In this experiment we generate electrostatic charge by friction, and explore the different kinds of electrostatic charge and how they interact.

## I. Theory

It is interesting to compare the electrostatic force (the attraction of electric charges for each other) with gravitation (the attraction of masses for each other). In both cases the force falls off as the attracting objects are separated, with the same dependence on the distance between the objects. However, there is one important and intriguing difference. All masses attract all other masses gravitationally. But the electric force is different. Some charged bodies attract, and others repel! The object of this lab is to see what this is all about.

You may know that there are supposed to be two kinds of charge. Like charges repel, and opposites attract. But why are there only two kinds of charge? Over the last 20 years a theory of the force between sub-nuclear particles called *quarks* has been developed. Quarks have a new kind of charge, which comes in *three* kinds, called colors - red, green, and blue. So, being precise about the types of electrical charge might prepare you for a career as a nuclear physicist.

In interpreting the effects observed in this experiment, we will assume that charge is a conserved quantity. This means that the total amount of charge on an electrically isolated, or insulated, object does not change. If positive charge is attracted to one side of a neutral body, negative charge must appear on the opposite side, to conserve charge. You will have to make a lot of drawings in this experiment, showing where the charge is. You can't see it, so you have to make hypotheses. Conservation of charge helps. As an example, figure 1 shows two isolated spheres, one with positive charge uniformly distributed over its surface, and another with no net charge, but with an excess positive charge on one side and an excess negative charge on the other.



In this experiment we will measure the sign of charge using an electrometer. However, the sign of the charge is based on an arbitrary convention. When the first scientific studies of electrostatic charge were made, the charge left on the rubber rod after rubbing it with cat fur was called negative. Negative charge is in fact an excess of electrons, but in this experiment we have no way of relating the charges that we see to elementary particles like the electron. We will use human hair (the hair of the people doing the experiment!) in place of cat fur; the electrostatic charges that result are the same.

## II. Experimental Procedure

**A. Two kinds of electricity.** We will demonstrate the existence of two kinds of electricity and explore their interactions.

1. Bring a hard rubber rod that has been vigorously rubbed with hair or flannel close to a hanging pith ball, but do *not* let the ball touch the rod. Explain why the ball behaves as it does.

**Sign Convention:** You have to start drawing diagrams now. Let us all make the same arbitrary assumption that the rubber rod is charged **negatively**.

2. Let the ball touch the rod. The ball is now charged in the same way as the rod (either an excess or a deficiency of electrons, if we believe the atomic theory of matter). How does the ball behave? Explain.

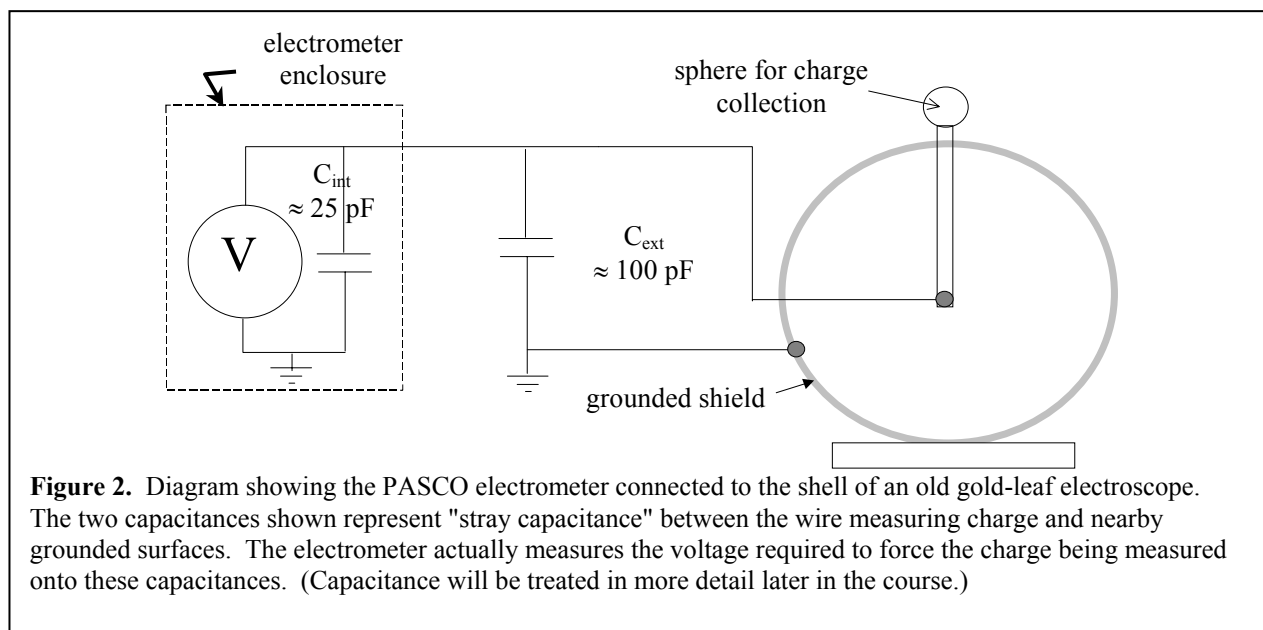
3. Bring a glass rod that has been rubbed with silk near the same ball without touching. What does the ball do?

4. Let the ball touch the glass rod. It is now “charged” in the same way that the glass is charged. Describe the behavior. Next bring the hard rubber rod near the ball. What does the ball do now?

5. By doing test similar to those above, determine if there is electricity on the hair or flannel which was used to rub the rubber rod. (Remember that a *neutral* body may attract a charged body, as you showed in part (1).) Is the charge on the flannel the same as one of the two kinds of charge already put on the pith ball in the preceding steps? An alternative possibility is that a third kind of charge is on the flannel, attracting the other two kinds but repelling itself. Can you rule this out?

### **B. Charging the electroscope by induction.**

**The Electrometer.** Electrostatic charge can be measured directly using the sensitive solid-state electrometer which we have available. (See figure 2 for some details on how the electrometer works.) Connect the electrometer to the inside contact of the metal housing, with a smooth ball on the outside to accumulate charge on. (The instructor will demonstrate.) The electrometer plus ball and housing forms an electroscope, or instrument for measuring charge.



1. Discharge the electroscope with your hands.
2. Bring a charged rubber rod near the electroscope. The meter will indicate a voltage. Why?
3. Holding the rod near, touch the metal strip inside the cylindrical housing with your finger, then remove your finger. Next remove the rod. The electrometer should indicate zero when you touch with your finger, and then deflect again when you remove the rod. Why? What happens if you remove the rod before you stop touching with your finger? Why?
4. After charging by induction, will the charge left on the electroscope be the same or opposite of the charge on the rod that was used? Describe how to verify this conclusion experimentally, and do so. Do the results of your test agree with your prediction?

**C. The electrophorus.** This is a plastic square and a metal disk on an insulated handle.

1. Rub the plastic vigorously with flannel (or hair).
2. Place the metal disk on top of the plate.
3. "Ground" the metal disk by touching it with your fingers (or use the neon bulb, and look for the flash).
4. Remove your fingers, then remove the metal disk from the plastic BY MEANS OF THE INSULATED HANDLE.
5. Determine the sign of charge on the electrophorus and on the disk. How is the disk being charged?

6. Discharge the disk by bringing it close to any grounded object, such as your finger, or one prong of the neon bulb, such that a spark jumps. (With the bulb, you should be able to see a flash in the bulb too.)

7. Repeat the sequence 2. through 6. as many times as you can note a spark or for as long as your patience lasts (and don't be *too* patient!)

8. Explain what happens in each step of the process. Why don't you have to rub the plate each time? Does it matter if you touch the plastic plate at any time? (Try it.)

9. You can apparently keep discharging the metal disk through the neon bulb indefinitely if you return the disk to the plate in between each discharge. Where does the "infinite" quantity of charge come from? (You have already answered this if you answered 8. completely.) Where does the supply of *energy* come from??

**D. Qualitative tests.** Inflate a balloon and tie it off. Rub it on your hair or clothes. Put it near the ceiling. What happens? Why?

Put the balloon near a running stream of water, breaking up into droplets. What happens? Why?

Charge the rubber rod and hang it from a string, using the rod holder. Then bring the charged glass rod near it. See what happens. Bring the plastic plate of the electrophorus and the balloon near it. See what happens.

### III. Equipment

stand and one pith ball  
rubber and glass rods, silk, flannel and fur  
electroscope, with PASCO Basic Electrometer (ES-9078) in place of gold foil.  
electrophorus  
neon bulb  
rod holder and string  
one balloon per student