

## EXPERIMENT II FURTHER EXPLORATION WITH YOUR ELECTROSCOPE

If you have already thought up an experiment to do in lab, great! Do it. If it doesn't work, that's OK. We'll have fun figuring out why. Remember, the lab is for thinking, not for following instructions to get the “right” answer. No ideas yet? Read on. You may want to try variations on the four experiments suggested below, which anticipate physics that you will be learning more formally over the next two weeks.

You will find it helpful to think about your calibrated electroscope (now an electrometer) as a high-voltage meter and as a very sensitive charge meter. Remember, the deflection of the foil indicates the amount of excess charge on the lower part of the electrode which is directly proportional to the potential difference between it and ground. You can also think of the electroscope as a capacitor that stores charge – but this charge can leak off through any conducting path to ground, as it will do in the first experiment suggested below.

### 1. Leakage Paths and the Rate of Charge Leakage

Some of you have already experienced the effects of charge “leaking” off the electrode---through a poorly placed insulating Teflon strip or some other path to ground. If your electroscope is “leaking”, the foil collapses quickly after you charge the electroscope. If this is still a problem, make sure the Teflon strip is well placed between the stopper and the aluminum tube, and that it and the rubber stopper are CLEAN.

Basically, if charge can spread out, it will—just because of the repulsive electric force between similar charges. So it tries to get to ground and spread out over the Earth. All materials conduct electric charge to some extent, but there is a huge range in the *conductivity* of different materials (and hence also in their *resistivity* = 1 / conductivity). To observe leakages on the scale of seconds, rather than femtoseconds, you must study poor conductors (insulators, rather than metals).

In the lab you will find the following materials to use as “poor” conductors to discharge your electroscope slowly :

- Wood, in the form of meter sticks.
- Paper, in the form of pages in your notebook.
- Oxide-coated Mylar film, in the form of audio recording tape.

Connect the electrode of your electroscope to ground via one of the poor conductors. Charge up the electroscope, and note the deflection of the foil as a function of time. The two angle scales which you aligned and fastened on each face of the electrometer will enable you to measure the foil angle more accurately by minimizing parallax.

The angle of deflection is proportional to the electric potential,  $V$ , of the electroscope. Since the electroscope can be regarded as a capacitor with an capacitance  $C$  (that depends on exactly how you have connected the electroscope to ground via the poor conductor), the charge  $Q$  stored on the electroscope can be written as  $Q = V C$ . Because the poor conductor provides a path to ground through a large resistance  $R$ , the electroscope discharges with current  $I = V/R$ , according to Ohm's law. But since  $I = -dQ/dt$ , we obtain the differential equation  $dQ/dt = -Q/RC$ , whose solution is  $Q = Q_0 e^{-t/RC}$ . This analysis predicts that the voltage on your electroscope obeys  $V = Q/C = V_0 e^{-t/RC}$ , where  $V_0 = Q_0/C$ . The "time constant"  $RC$  is a suitable measure of the leakage time of the electroscope + conductor. During each interval of time  $RC$ , the charge and voltage drop by a factor of  $1/e \sim 1/3$  from their values at the start of the interval.

**Measurements.** Explore the leakage time constant of materials in various conditions.:

- How does the leak rate depend on the *length* of the leakage path?
- How does the leak rate depend on the *cross sectional area* of the leakage path. This can be changed by adding more paths of the same kind. (The audio tape is handy for this experiment as are two wooden rulers.)
- What happens if you moisten the leakage material? Try this with a piece of string.

As you vary the conditions, you may be varying one or both of resistance  $R$  and capacitance  $C$ . To help understand how the capacitance could be varying, consider experiment 2.

## 2. Capacitance and Geometry

Build a parallel-plate capacitor out of a 30 cm square conducting plate (the aluminum plate which was used for the electrophorus last week) and the grounded foil on your lab bench. When you deposit charge  $Q$  on the conducting plate, it takes on electric potential  $V = Q/C$ , where  $C$  is the capacitance of your capacitor. Connect your electrometer to the conducting plate via a good conductor (before charging the capacitor) to measure the voltage  $V$ . Vary the gap height  $h$  between the conducting plate and ground, and observe the electrometer reading. If no charge is leaking off the capacitor, your results can be interpreted as determining the relation between capacitance  $C$  and the gap height  $h$  of the capacitor. Perhaps you can also devise an experiment to determine the relation between capacitance and the area of the capacitor.

## 3. Dependence of Electric Force on Distance

Make a pair of small conducting balls, perhaps from Al foil, and suspend them by strings (or thread) from a horizontal rod. Charge up the balls and note the deflection of the string from the vertical as a function of separation of the balls. Use your results to characterize the dependence of electric force on distance.

You may need to use the Van de Graaff generator to provide the balls with enough charge to have measurable deflections.

## 4. Image Charge

Suspend a small charged ball from a string such that the ball is close to a vertical, grounded conducting plane (maybe an electrophorus). Note the behavior of the ball as a function of its distance from the plane. Interpret the results in terms of a "image" charge.

PRINCETON UNIVERSITY

Physics Department

Name: \_\_\_\_\_

PHYSICS 104 LAB

Week #2

Date/Time of Lab: \_\_\_\_\_

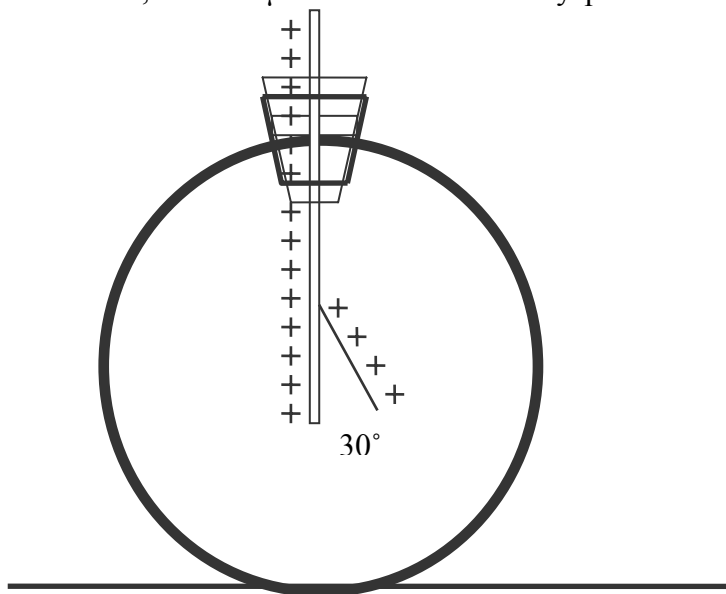
## EXPERIMENT II

## PRELAB PROBLEM SET

- 1 The electrode of a charged electrometer is connected to one end of a wooden meter stick whose other end is connected to ground. Explain what happens to the charge over time.

- 2 Suppose electrostatic repulsion causes your electrometer leaf to deflect by  $30^\circ$ . Consider a simple (“toy”) model in which the force on the leaf is directed horizontally and acts at the center of the leaf. What must the Coulomb force be?

The leaf is approximately 2.5 cm long, 0.64 cm wide, and  $13 \mu\text{m}$  thick. It is mostly plastic (Mylar) and has a density of  $1.5 \text{ g/cm}^3$ .



- 3 Suppose the horizontal force found in part 2 were due to two equal point charges that are separated by 1 cm. How large is each charge in Coulombs? How many electrons make up this much charge? (Note that  $\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 \text{ m}^{-2} \text{ N}^{-1}$ .)