LAB 1
Electric Charge

OBJECTIVES
1. Investigate charging by friction & contact, and charging by induction & polarization.
2. Quantifying the Electrostatic Force by determining the number of electrons responsible for common electrostatic phenomenon

EQUIPMENT
PVC and acrylic rods, wool, pith balls, balloons, conductive shapes, Faraday Ice Pail, Electrometer, paper clips, electric pom-poms, pie plates, and Van de Graff generator.

PROCEDURE
This is an “Exploratorium” type lab. There are numerous stations set up around the lab. Experiment with all the equipment at each station and make diagrams that show what you observed. Check at each station to see that your observations are consistent with the concepts developed in lecture.

Part 1: Induction with Pith Balls & Electric Pom-Poms
a. Charge a PVC rod through friction. Explain how the rod becomes electrically charged.

b. Bring a charged PVC rod close to but not touching a hanging pith ball (conductor). If now the rod touches the pith ball, the ball is repelled from the rod. Explain and draw a diagram of the behavior of the pith ball using induction ideas.

c. Scrape the charged PVC rod across the top of the electric pom-pom. Explain and draw a diagram of the behavior of the strings using induction ideas.

d. Touch the top of a charged electric pom-pom with your finger. Explain this behavior.

e. Repeat parts (a) through (c) but this time replaced the PVC rod with an acrylic one.

Part 2: Conductive Spheres & Shapes
Set the voltage of the conductive shape to 3000 V and use the Faraday Ice Pail (see footnote **) setup to measure the charge density. Use the proof plane (or “wand”) to make contact with the conductive shape and transfer it inside the Faraday Ice Pail (without touching the wire cage) to measure the charge density of the conductive shape. For each part, explain your reasoning and draw a picture of the charge distribution.

Two Conductive Spheres
a. Charge up the sphere to 3000 V, touch the surface with the proof plane, and measure the charge density of the sphere using the Faraday Ice Pail. Is the charge positive or negative?

b. Now bring a second neutral sphere close to the charged sphere but not touching it.
   • Measure the charge density of the neutral sphere closest to the charged sphere. (i) Is the induced charged positive or negative? (ii) Is the magnitude of the induced charge greater than, the same as, or less than the charged density on the charged sphere?
   • Measure the charge density of the back side (farthest from the charged sphere) of the neutral sphere. (iii) Is the induced charged positive or negative? (iv) Is the magnitude of the induced charge greater than, the same as, or less than the charged density on the charged sphere?

Conductive Conical Shape
b. Measure the charge density of the conical shape. (v) Is the charge density at the larger rounded end greater than, the same as, or less than the charge density in the tapered area?
Part 3: Polarization with Charged Balloons and Meter Sticks
a. Charge a balloon (dielectric) and put it against a neutral wall (dielectric). Explain and draw a diagram of the behavior of the balloon using polarization ideas.
b. Recharge your balloon but this time rotate the balloon so that the opposite side (i.e. not rubbed) touches the wall. Explain draw a diagram of the behavior of the balloon using polarization ideas.
c. Recharge your balloon and bring it close to but not touching a hanging meter stick. Now rotate the hanging meter stick using the charged balloon. Explain and draw a diagram of the behavior of the meter stick using polarization ideas.

Part 4. Quantifying the Electrostatic Force
a. Pierce an inflated balloon tied-off point with a paperclip. Now charge the top of a balloon and put it against a horizontal piece of white board so that it hangs vertically downwards. Gently hang additional paper clips until the balloon just falls. Measure the mass (kilograms) of this balloon-paper clip system at this point.
b. Which electric charge is responsible for the attractive force between the balloon and the horizontal piece of white board? Explain.
c. Draw a Free-Body Diagram (FBD) of the situation and calculate the electrostatic force using Coulomb’s law.
d. Assumptions and estimations:
   - Electric Charge assumption: assume the wall is polarized such that it has approximately the same magnitude of charge near the balloon that the balloon has.
   - Estimate of distance r: the size of the atom is $10^{-9}$ m (1 nm) and the smallest size that the human eye can see is about $10^{-4}$ m (100 μm). Estimate a range for the spacing between the balloon and the wall when in contact.
e. Calculate the total number of transferred electrons (i.e., the extra charges) on the balloon using
   \[
   \text{Number of transferred electrons} = N_e = \frac{q_{\text{transferred electrons}}}{q_e}
   \]
f. An estimate of the total number of electrons that are in the rubber of the balloon is $10^{22}$ electrons. Calculate the percent of transferred electrons relative to the number of electrons in the rubber of the balloon. Using your results, was the number of transferred charges a small or large percent? Interpret your results.

Part 5: The Van de Graaff Generator
a. Explain and identify how a Van de Graaff gets charged.
b. As the Van de Graaff generator becomes charged, you should be able to hear the motor slow down. Explain why the motor slows down.
c. Using the ideas of induction and polarization, explain each of the situations.
   - Place several small pie plates on top of the Van de Graaff generator and turn the generator to a slow speed. Why do the pie plates fly off one at a time?
   - Hold a small piece of animal fur near the Van de Graaff generator and then let it go. Why does the animal fur bounce back and forth between your hand and the generator?

**What is a Faraday Ice Pail?**
The Faraday Ice Pail operates on the principle that a charge placed inside a conducting surface will induce an equal charge on the outside of that surface. The charge can be measured with an electrometer. When a charged object is placed in the grounded ice pail (without touching it), the electrometer indicates the potential between the ice pail and ground. The greater the charge the greater the potential. Thus we can easily measure relative charges by varying the charges in the ice pail and observing the potential indicated by the electrometer.