LAB 1
Electric Charge

OBJECTIVES
1) Identify the two different kinds of electric charge.
2) Discover some of the effects of static electricity.
3) Investigate charging by friction, charging by contact, and charging by induction.
4) Quantify the electrostatic force by determining the number of electrons responsible for common electrostatic phenomenon.

EQUIPMENT
Gray (PVC) and clear (acrylic) plastic rods, fur, wool, pith balls, packing tape, electric pompoms, water stream, balloons, pie plates, voltage source, voltmeter, conducting spheres, conducting wand, electrophorus, and Van de Graff generator.

THEORY
We charge things by transferring electrons from one place to another. We do this by physical contact, as occurs when substances are rubbed together or simply touched. We can also redistribute the charge on an object simply by putting a charged object near it. This is called *induction*.

Charging by friction occurs when electrons are transferred from one material to another by rubbing the two materials together. One object will gain electrons and the other will lose electrons. Electrons can also be transferred simply touching two materials together. For example, when a negatively charged rod is placed in contact with a neutral object, some electrons will move to the neutral object. This method of charging is called *charging by contact or conduction*. If the object is a good conductor, electrons will spread to all parts of its surface because the transferred electrons repel one another. If it is a poor conductor, it may be necessary to touch the rod at several places on the object in order to get a more or less uniform distribution of charge.

If you bring a charged object near a *conductor*, you will induce electrons to redistribute in the material even though there is no physical contact. This method of charging is called *charging by induction*. However, when a charged rod is brought near an *insulator*, there are no free electrons that can migrate through the insulating material. Instead, there is a rearrangement of charges within the atoms and molecules themselves. One side of the atom or molecule is induced into becoming more negative (or positive) than the opposite side. The atom or molecule is said to be *electrically polarized*.

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 class**.**

Keys to all lab activities: ground everything before proceeding with an activity, always make a comparison with a neutral object first, then followed with a charge object. Many parts of this lab will be improved if everything is first "dried" with the hair dryer.

1) Charged Rods and Pith Balls

a) Charge the gray plastic (PVC) rod negatively by rubbing it with wool or a paper towel. *Explain how the rod becomes electrically charged.*

b) Using some black string and some aluminum foil (4cm x 4cm), create an aluminum ball at the end of the string. Hand it by taping one end of the string.

c) Bring the rod close to but not touching a hanging pith ball. *Explain the behavior of the pith ball and draw a diagram showing the distribution of the electric charge on the rod and pith ball.*

d) Now let the rod touch the pith ball so the ball is repelled from the rod. *Explain the behavior of the pith ball and draw a diagram showing the distribution of the electric charge on the rod and pith ball.*

e) Now charge the clear plastic (acrylic) rod by rubbing it with wool. Bring it near a pith ball that has been previously charged as in step d. *What happens to the pith ball? What does this tell you about the charge of the glass rod?*

2) Charged Balloon

a) Rub a balloon on your hair and put it against a neutral wall. *What do you observe? Draw a sketch showing the charges in the balloon and the wall when the balloon is stuck against the wall.*

b) Rub a balloon on your hair again, but this time put the opposite side (i.e. not the side that you rubbed) of the balloon against a neutral wall. *What do you observe? What does this tell you about the balloon?*

3) Charged Rod and Stream of Water

a) <u>*Make a prediction*</u>: *what will happen to a small neutral stream of water when a charged rod is brought near? Why?*

b) Rub the gray plastic (PVC) rod to charge it and observe its effect on a water stream. *What happens and why?*

c) <u>*Make a prediction*</u>*: what will happen if you do the same thing with the clear plastic (acrylic) rod? Try it out. What happens and why?*

d) *How is this similar to the balloon and the wall? Explain.*

4) Fun with the Van de Graff Generator

a) Put several small pie plates on top of the Van de Graff generator. Before you turn on the Van de Graff, predict what you think will happen when the generator is switched on.

b) Predict what will happen when the metal pie plates are replaced with insulating coffee filters. After your prediction, run the experiment. *What was your prediction? What happened and why? Explain.*

c) Hold a small piece of animal fur near the Van de Graff generator and then let it go. See if you can get to animal fur to bounce back and forth between your hand and the generator – it's pretty cool! *Explain the behavior of the fur.*

d) Tape an electric pom pom on top of the Van de Graff generator. Predict what you think will happen when the generator is switched on. After your prediction, turn on the generator. *What was your prediction? What happened and why? Explain.*

e) Eventually, the strings of the electric pom pom will fall down. *How long does it take the electric pom pom to discharge? Explain how this happens.*

5) Are We Charged?

Ground yourself by touching a large metal object. Place your hand close to the **E-Field Detector** to verify that you are not charged.

Experiment with different ways of charging yourself: rub your hands together, scuff your feet across the floor, touch the Van de Graff generator, ... *Report on several of the ways that worked and what charge you acquired in each case.*

6) Electrophorus

a) Charge the square piece of gray (PVC) plastic by rubbing it with wool. Charge the entire square and then do not charge it again. Touch the round metal plate to the square. Then touch the electric pomp pom with the metal plate. *Explain what happens and why. Did the plate become charged? Why or why not?*

b) Put the round metal plate back on the charged plastic square and then touch the metal plate with your finger. Now touch the electric pomp pom with the plate again. *Explain what happens and why. What charge is the plate? Explain how the plate becomes charged.*

c) Repeat step b numerous times. *How many times can you charge the round metal plate?*

7) Charged Packing Tape

a) Determine the charge on a piece of packing tape. *Is the tape positively or negatively charged? How did you determine the charge?*

8) Conductors and insulators

Use a small power supply, a small light bulb and some wires to build a basic circuit to light the bulb. Study the bulb carefully, and be sure you see exactly how the current is able to flow completely around the circuit. (The word *circuit* comes from *circle.*)

a) *Draw a sketch of your circuit. If you open the circuit* ***at any point****, what happens?*

b) Use your simple circuit to test the following items, and others you may wonder about, to see if they can conduct electric current so the power supply can light the bulb. If so, then we call them *conductors.* If not, they are *insulators.*

Make a prediction before you try each one.

	Prediction	*Observation*
Plastic spoon	________________	________________
Metal fork	________________	________________
Fresh water	________________	________________
Salt water	________________	________________
Eraser	________________	________________
Pencil 'lead'	________________	________________
Aluminum foil	________________	________________
Your finger	________________	________________

Try some other things too:

c) *What determines whether something is a conductor or an insulator?*

d) *Is your body a conductor or an insulator? Why is this an important question?*

9) Quantifying the Electrostatic Force

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.

a) *Draw a Free-Body Diagram (FBD) of the situation and calculate the electrostatic force using Coulomb's law.*

Assumptions and estimations:

Electric Charge assumption: assume the wall is polarized such that it has approximately the same magnitude of charge as 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.

b) *Calculate the total number of transferred electrons (i.e., the extra charges) on the balloon using:*

$$\text{Number of transferred electrons} = N_e = \frac{q_{\text{transferred electrons}}}{q_e}$$

c) 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.*