An Introduction to Electrostatic Charge and Its Related Forces (approx. 1 h 45 min.)(6/2/13)

Introduction:

All solid materials are composed of atoms or molecules which are bound together by "electrostatic" forces (i.e. the forces between "charged" particles). The charged particles of which atoms and molecules are composed are called protons and electrons. All protons have exactly the same charge, and all electrons have exactly the same charge. The charge of a proton is exactly equal in magnitude to the charge of an electron, but opposite in sign. To be consistent with conventions that were chosen centuries before scientists even knew of the existence of electrons or protons, or even atoms, the charge of the electron is negative. If an object has just as many electrons as protons, it therefore has no "net" (total) charge and is said to be electrically neutral. Otherwise, it is either "positively charged" (more protons than electrons) or "negatively charged" (more electrons than protons).

While all the protons of an atom are bound tightly within the nucleus of the atom by the "strong" force, electrons are generally more spread out and less tightly bound. In many materials, there are electrons that are so weakly bound that they can be removed from the surface simply by rubbing it with another material that has a stronger affinity for electrons. Thus one object becomes negatively charged, the other positively charged.

When an object is not in contact with anything that can effectively add charge to it or remove charge from it, it is said to be electrically "isolated". If a positively or negatively charged object is placed near (but not touching) an electrically isolated, neutral object, an interesting phenomenon called "charge induction" occurs. In part (iii) of the lab you will investigate this phenomenon and try to explain it based on what you have learned about attraction and repulsion forces between charged objects.

Equipment:

- Electrostatic Materials kit which includes:
  - 2 acrylic rods (clear, plastic)
  - 1 glass rod (one end "frosted")
  - 2 nylon rods (black, one end pointed)
  - 1 PVC pipe
  - brass rod holder on string
  - Styrofoam® (i.e. polystyrene) ball on string
  - wool cloth
  - fur cloth
  - silk cloth
- long metal rod (vertical)
- short rod and rod clamp

For class as a whole: thin string and a pair of scissors

For the instructor: Basic Electrometer (ES-9078) with test lead and ground cord, and a Faraday "Ice Pail"

Purpose:

The primary purpose of this lab is to create "charged" objects by rubbing their surfaces with dissimilar materials and to determine whether the charged objects attract or repel one another. The following three activities, summarized below, are aimed at familiarizing you with the nature of electrostatic charge and its related forces:

(i) Repulsion Pairs

- We know that objects can be charged by rubbing them with cloth, thus adding or removing electrons. In this activity we will explore the effects of using various cloths to charge two like objects.

(ii) Attraction or Repulsion?

- Once we have determined the effects of using various cloths to charge two like objects, we will explore attraction and repulsion using rods of two different materials.

(iii) "Sticky" Styrofoam® Balls

- Styrofoam® (polystyrene) is a "funny" material. It tends to become charged easily and "hold on" to its charge better than most materials. Because it does not "conduct" charge well, it tends to remain charged even when part of it briefly contacts another object. For example, Styrofoam® can "stick' to your hand or to a wall when it is charged. If you've ever tried to throw away Styrofoam® packing "peanuts", you know that they tend to cling to your hand. In this experiment, we will explore "induced charge" on electrically neutral polystyrene, then, try to give it a net charge buy touching it with charged rods. You will suspend a polystyrene "ball" instead of a rod for this experiment.

Procedures:

Repulsion Pairs (SAFETY NOTE: Do <u>not</u> mount rods at eye level or sticking out beyond desktop.)

1. Insert the long rod vertically into the desk rod holder and attach a short rod (horizontally) using a clamp. Attach a string to the center of the brass rod holder and suspend it from the end of the horizontal rod.

2. Rub the (unlabeled) end of an acrylic (clear plastic) rod **<u>firmly</u>** and **<u>vigorously</u>** for <u>at least 15 s</u> with a wool cloth and suspend that rod horizontally in the friction rod holder. (<u>In all cases below, be sure to rub the rods firmly and vigorously for at least 15 s.)</u> Ensure that the rod is balanced and nearly stationary. <u>NOTE</u>: Don't delay between steps, as some objects may not hold their charge for very long.
3. Rub the other acrylic rod with wool and bring it near (alongside) the charged end of the suspended rod.

4. Observe the change in (rotational) motion of the suspended rod when the other rod is brought near.

5. Record results in Table 1 (below).

6. Neutralize the entire surface of the handheld rod using your hands. Repeat Steps 2-5 using silk cloth.

7. Neutralize the entire surface of the handheld rod using your hands. Repeat Steps 2-5 using fur.

8. Repeat Steps 2-7 now using the two black nylon rods instead of the two acrylic rods. (Charge the <u>pointed</u> ends of the nylon rods for best results.)

9. Answer questions 1-3 on the last page.

Table 1. Observations from Repulsion Pairs Experiment

	Rod Material	**Fabric Material**	**Did Repulsion Occur? (Record 'Yes' or 'No')**
1	acrylic	wool	
2	acrylic	silk	
3	acrylic	fur	
4	nylon	wool	
5	nylon	silk	
6	nylon	fur	

Note: If any of your results in Table1 don't make sense to you, try repeating them, but this time neutralize (ie. ground) the cloth/fur before rubbing each rod by pressing your hands all over its rubbing surface. (Sometimes it may be necessary to use a metal water pipe (i.e. faucet) for a good grounding surface.)

Attraction or Repulsion?

1. Charge the unlabeled end of an acrylic rod ("Rod 1") using the silk fabric and suspend that rod, ensuring that it is balanced, stable and not rotating.

2. One-by-one, charge the nylon, glass, and PVC rods using wool, silk, and fur and bring them near (without touching) the charged end of the suspended acrylic rod. (Note: Hold the "frosted" end of the glass rod and rub the clear end.) Observe whether the change in motion of the plastic rod indicates attraction or repulsion. Note the rate of change of motion of the suspended rod as a qualitative way to estimate the magnitude of the force as per 3 & 4 below. Record your observations in Table 2.

3. Asterisk next to the observed pair(s) which showed very low magnitude attractive or repulsive force.

4. Double asterisk next to the observed pair(s) which showed a very high magnitude attractive or repulsive force.

5. Neutralize the acrylic rod and the silk cloth. Recharge the acrylic rod and suspend it. See if the cloth attracts or repels the charged end of the suspended acrylic rod (without touching it). Record your result.

6. Answer questions 4 and 5. On the last page.

NOTE: Do not forget that the suspended rod will "bleed off" its charge to humid air fairly quickly. The higher the humidity, the faster the charge will "bleed off". YOU MAY NEED TO RECHARGE ROD 1 FREQUENTLY TO GET GOOD RESULTS.

CAUTION: BE CAREFUL NOT TO DROP THE GLASS ROD. IT WILL BREAK!

Table 2. Observations for Attraction/Repulsion Pairs Using Acrylic Rubbed with Silk as Rod 1

	Rod 2 Material	**Fabric Material**	**Attraction, Repulsion or Neither (Record here)**
1	nylon	wool	
2	nylon	silk	
3	nylon	fur	
4	glass	wool	
5	glass	silk	
6	glass	fur	
7	PVC	wool	
8	PVC	silk	
9	PVC	fur	
10	acrylic	wool	
11	acrylic	silk	
12	acrylic	fur	

"Sticky" Styrofoam® Balls

1. Given that glass, when rubbed with silk, adopts a positive charge, and that nylon when rubbed with fur, adopts a negative charge, deduce from Table 2 whether the charge on the rod is (+) or (–), and fill in column 3 of Table 3. From those two "known" charges, and your observations in Table 2, you should be able to deduce the charge on each of these rods when rubbed with each type of fabric.

2. Using a piece of string, suspend one of your Styrofoam® (i.e. polystyrene) "balls" from the short rod (instead of the rod holder).

3. Make sure the polystyrene ball is electrically neutral by touching all parts of its surface with your hands. Your body should be very nearly neutral, and can serve as a source or a sink for electrons to make the polystyrene neutral

4. Charge the clear end of the glass rod using wool and bring it near, but not touching, the polystyrene ball. Is the ball attracted toward or repelled from it? Record your observation in col. 4 of Table 3.

5. Now touch the polystyrene ball with the glass rod and try to transfer as much charge as you can from the surface of the rod to the surface of the polystyrene ball. Record your observation in col. 5 of Table 3.

6. Repeat steps 3, 4 and 5 using silk and fur respectively.

7. Repeat steps 3, 4, 5 and 6 using nylon, acrylic and PVC.

8. Answer questions 6 and 7 on the last page.

Table 3. Observations from "Sticky" Styrofoam Balls Experiment

	Rod Material	**Fabric Material**	**Charge on Rod (Record here)**	**Attraction or Repulsion (without touching)**	**Attraction or Repulsion (after touching)**
1	glass	wool			
2	glass	silk	positive (+)*		
3	glass	fur			
4	nylon	wool			
5	nylon	silk			
6	nylon	fur			
7	acrylic	wool			
8	acrylic	silk			
9	acrylic	fur			
10	PVC	wool	negative (-)*		
11	PVC	silk			
12	PVC	fur			

* from textbook NOTE: Nylon discharges quickly. Confirm the charge on nylon with the electrometer

Questions:

From **Repulsion Pairs**:

1. Were all of the observations recorded in column 3 of Table 1 the same?

   Did your observations confirm your expectations? Explain.

2. Did the rate of change of motion of the suspended rods depend on how close you held the other charged rod?

   What does this imply about the dependence of the force between charged objects on distance?

3. From this experiment alone, were you able to determine whether the fabric added electrons to the acrylic rod or removed electrons from the rod?

   Why or Why not? Explain.

From **Attraction or Repulsion**:

4. Which observed pairs showed a very high magnitude attractive force? _____

   Very low? _____

5. **Conservation of Charge:** Do you think any net charge was created or destroyed in the process of rubbing the acrylic rod with the silk cloth? YES/NO (Circle one). Explain

   Are the results of step 5 consistent with your answer? YES/NO (Circle one). Explain.

From **Sticky Styrofoam Balls:**

6. Do the results in the next to last column of Table 3 seem consistent with the observed list of attractions/repulsions recorded in Table 2? YES/NO (Circle one).

   Try to explain these results (assuming no net change of the charge on the ball).

7. Do the results in the last column of Table 3 seem consistent with the observed list of attractions/repulsions recorded in Table 2? YES/NO (Circle one).

   Try to explain these results.

OPTIONAL (BONUS?) QUESTION:
Rub the "frosted" end of the glass rod (or a separate frosted glass rod) with silk. Does it becomes positively charged, negatively charged or neither? How does this compare to your result when you rubbed the clear end with silk?

How would you explain these results?