Electrostatics

Goal: To make observations of electrostatic phenomena and interpret the phenomena in terms of the behavior of electric charges.

Lab Preparation

Most of what you will see in this lab can be explained simply by the following:

Like charges repel and unlike charges attract.

These repelling and attracting forces that occur can be found using Coulomb's law, which is stated as

$$F = k\frac{|q_1||q_2|}{r^2}$$

where F is the electrostatic force, k is the Coulomb constant (8.99×10^9 Nm^2/C^2), q_1 and q_2 are the charges the objects carry, and r is how far apart the objects are.

A neutral atom of a substance contains equal amounts of positive and negative charge. The positive charge resides in the nucleus, where each proton carries a charge of $+1.602 \times 10^{-19}$ C. The negative charge is provided by an equal number of electrons associated with and surrounding the nucleus, each carrying a charge of -1.602×10^{-19} C. Macroscopically sized samples of everyday materials usually contain very nearly equal numbers of positive and negative charges. When some dissimilar materials are rubbed together, some charges are transferred from one material to the other leaving each object with a small net charge. For example, when a glass rod is rubbed with silk, the rod usually ends up with a positive charge and the silk ends up with a negative charge.

Materials can be cast into two electrical categories: insulators and conductors. The atomic or molecular structure of the material determines whether some charges are free to move (a conductor, such as metallic materials) or largely fixed in place (an insulator). Even in insulators, the charges in the material can respond to electric forces in a way that causes small displacement of opposite charges in opposite directions, leading to electric polarization.

Equipment

Electroscope. An electroscope (Figure 1) is used to detect the presence and magnitude of electric charge on a body. It consists of a metal disk that is attached to metal stem with an attached pivoting needle (note – the metal circle is insulated from the disk and stem). When charge is transferred to or altered on the metal plate charges spread down to the stem and needle causing the needle to deflect from the stem due to like charges being located on both and thus repelling one another.

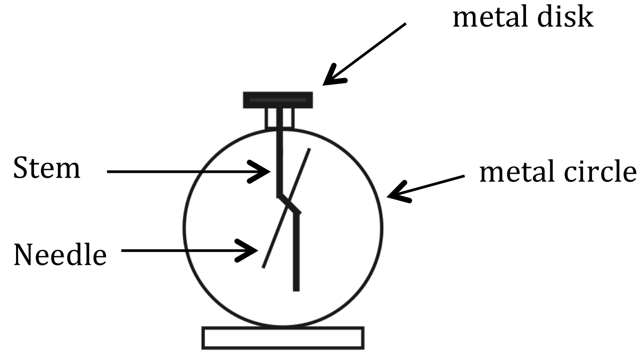

Figure 1

Van de Graaff generator. The Van de Graaff generator is a common laboratory device used for producing high voltages and creating static electricity. Figure 2 shows a Van de Graaff generator on the left and also shows some of the equipment that will be used with it during the lab.

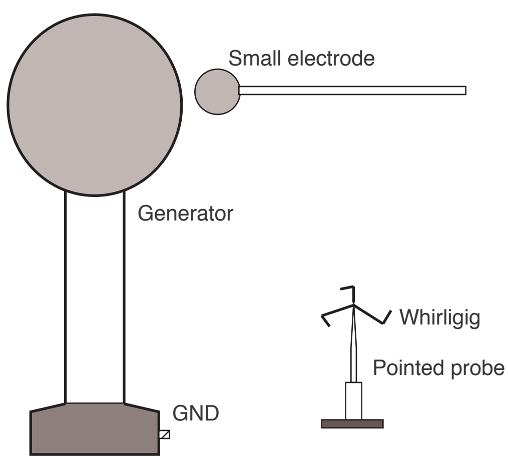

Figure 2

On the Van de Graaff, a hollow metal sphere is supported by a cylindrical insulating support stand. A motor-driven belt inside the support stand passes by a comblike set of metal tips in the base. Discharge by the tips deposits a continuous supply of electrons on the belt, which are carried up into the hollow conducting sphere, where the electrons repel one another to the outer surface of the sphere.

Procedure

The success of electrostatics experiments depends on weather and the condition of the materials. Many of the following observations can be difficult to see in humid conditions. Once action that can help you obtain reliable results is to clean the various rods used with rubbing alcohol to make sure they are free of excess moisture or grease from frequent handling. Allowing the materials or fabric samples to dry by laying them flat between uses can also help.

***When drawing sketches of the electroscope always show how the charges are arranged on the metal disk, stem, and needle.**

I. Frictional charging and the electroscope

A. Several different rods and patches of materials or fabrics are provided. Rub various combinations of rod and fabric together. Bring each rod close to the metal disk on the electroscope without making contact (if you hear a spark then you brought it too close). Make a table with fabrics on the top and rods on the left side and record the responses of the electroscope in the table. Indicate the strongest response with a "++++" and the weakest response with a "+." Rank the other combinations accordingly.

B. Assume for the moment the rod ends up with a positive charge when rubbed. Sketch how charges are arranged on the electroscope and rod when the rod is near the electroscope. Does the electroscope carry a net charge when the rod is near? After the rod is moved away?

C. With the combination of rod and fabric that provided the strongest response in part A, charge the rod by rubbing it again and allow it to touch the electroscope's disk and then remove the rod. What happens to the electroscope? Make a sketch of how the electric charge is now distributed on the electroscope.

D. Charge up the electroscope with the strongest combination again, as done in part C. Now, try other combinations of rods and fabrics (excluding the aluminum rod) and bring this rod close to the charged electroscope disk (without touching again), and then remove the rod. Which combination of rod and material had the strongest *opposite* charge? Explain how you know the rod brought close to the charged electroscope carries the opposite charge.

E. Taking the charge on a glass rod rubbed with silk to be positive, which combination of rod and fabric produced the strongest positively charged rod? Which combination produced the strongest negatively charged rod?

II. Charging by induction

A. While touching the edge of the electroscope metal disk with your finger, bring a strongly charged rod near the disk without touching. Then remove your finger from the disk, and then remove the nearby charged rod. Determine the sign of the charge left on the electroscope. Explain how you determined this sign. Use a series of diagrams to help explain how the electroscope became charged.

B. Connect a metal wire to the disk with an alligator clip, and connect the other end of the wire to "ground" (there is a ground plug in on the wall). Again bring a strongly charged rod near the disk (without touching it), and carefully disconnect the ground wire from the disk. Remove the rod. Once again determine the sign of the charge left on the electroscope and use a series of diagrams to help explain how the electroscope became charged.

III. Polarization

A. Suspend a metal rod horizontally in a metal stirrup hanging on a string and allow it to come to rest. Strongly charge up another rod and bring it close to the suspended rod without touching. Describe what happens. Use a series of diagrams to help explain the results.

B. Repeat A with a plastic rod suspended. Once again describe what happens and draw a series of diagrams to help explain the results. Note that you suspended an insulator for part B whereas in part A you suspended a conductor so your explanations for part A and part B should be different.

C. Bring a positively charged rod near a steady narrow gentle stream of water from a faucet (keep all fabric materials dry and well away from the water). Repeat the process with a negatively charged rod. Describe what happens to the water in each case (draw a diagram to help describe).

Due to the large electric fields present in this part of the experiment and potential for large electrostatic discharges, sensitive electronic equipment, including calculators and computers, should be kept away from the Van de Graaff generator.

IV. Van de Graaff generator experiments

A. Start the Van de Graaff generator at a low speed. Holding the smaller spherical electrode by (refer to Figure 2) the plastic handle and no wire connecting it to ground, bring it into contact with the generator dome. Remove the spherical electrode from the generator, turn off the generator, and then bring the spherical electrode into contact with an electroscope. Determine the sign of the charge taken from the Van de Graaff generator. Explain how you determined this sign.

B. Ground the smaller spherical electrode and mount horizontally, level with center of the Van de Graaff dome about 30 cm away. Turn the generator on high and make sure you don't get any closer to the Van de Graaff dome than the small spherical electrode (unless you want to get shocked). Carefully slide the small spherical electrode towards the generator and determine how close the spheres must be before a discharge arc occurs periodically between the two. Explain what is happening to produce this phenomenon.

C. Ground the metal shaft of the sharply pointed probe and hold well away from the generator. Re-start the generator and re-establish the discharge between generator dome and the small spherical electrode. Then gradually bring the pointed probe toward the generator dome. Describe what happens to the arc. How far away is the pointed probe from the generator when you notice a change?

D. Put the pointed probe on the table near the generator and place the three-armed whirligig on top. With the probe shaft grounded turn on the generator. What happens? Repeat with the ground wire removed from the shaft. What happens now? Try to explain the behavior you observe.

***When finished with your lab clean up your lab station.**

Homework

1. Consider the result from Polarization part C. Does the water have a net electrical charge? Draw a diagram to explain why the water deflects.

2. Suppose an electroscope is charged positively and you bring a neutral metal rod close to the metal disk without touching. What happens? Use a series of diagrams to help explain.

3. What might be a practical application for the pointed probe used with the Van de Graaff generator in part C?