Electrostatics

Introduction

In the first semester of this two-part course, we learned about Newton's three laws and the gravitation force. These are the backbone of what is called Classical Mechanics. In the second part of this course we begin the discussion of electric forces.

Electric forces were studied scientifically for the first time by Benjamin Franklin (1706-1790). He observed that rubbing different materials on other materials caused attractive and repulsive forces to develop. It was later shown by Robert Millikan (1868-1953) that charge always changes by multiples of a fundamental charge, *e*. This charge is the same magnitude as that of the charge of an electron and a proton. By definition the proton is given a positive sign and the electron a negative.

In this lab we will observe the same attractive and repulsive forces observed by Franklin. These forces will be due to the electric force generated by conductively charging objects. In the last part of this lab we will build a Van de Graaff generator. This will use conduction to generate large voltages.

Theory

Some materials allow electrons to be loosely bound to them. These electrons can act as 'free' charges on the surface of the material. Such material is called a conductor. Other materials have all the electrons tightly bound to them. This prevents electrons from freely moving along them. Such materials are called insulators.

When a material is rubbed against another material or placed in a close proximity of the other material, if the force by which the electrons are bound to the materials are different, it is possible for electrons to move from one material to the other. When that happens, the material that gains electrons becomes negatively charged. The material that looses the electrons becomes positively charged. Thus the two objects become *charged* carrying opposite but equal charges.

Procedure

The construction and pictures of this Van de Graaff generator were taken from http://scitoys.com/scitoys/scitoys/electro/electro6.htm a copy is provided at http://physci.kennesaw.edu/labs/vdg.htm

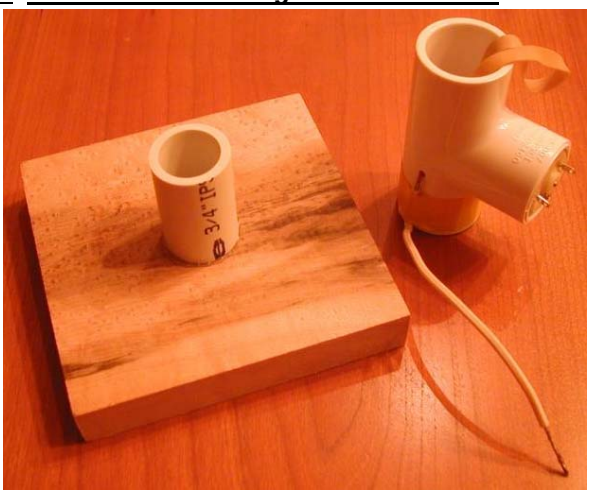
Items needed:

- An empty soda can
- A small nail
- A rubber band, ¼ inch by 3 or 4 inches
- A 5x20 millimeter glass tube
- A small DC motor (such as Radio Shack #273-223)
- A battery clip (Radio Shack #270-324) and a battery holder (Radio Shack #270-382)
- A Styrofoam cup (a paper cup will also work)
- Two 6 inch long stranded electrical wires (such as from an extension cord)
- One piece of 3/4 inch PVC plumbing pipe, about 2 or 3 inches long
- One piece of 3/4 inch PVC plumbing pipe, about 1 to 1.5 inches long
- One ¾ inch PVC coupler
- One ¾ inch PVC T connector
- Some electrical tape
- A block of wood

Step 1: Mounting the motor

1. The first thing to do is to cut a 2 to 3 inch long piece of 3/4 inch PVC pipe, and hot-glue that to the wooden base. This piece will hold the generator up, and allow us to remove it to more easily replace the rubber band, or make adjustments.
2. The PVC "T" connector will hold the small motor. The motor fits too loosely by itself, so we wrap paper or tape around it to make a snug fit. The shaft of the motor can be left bare, but the generator will work a

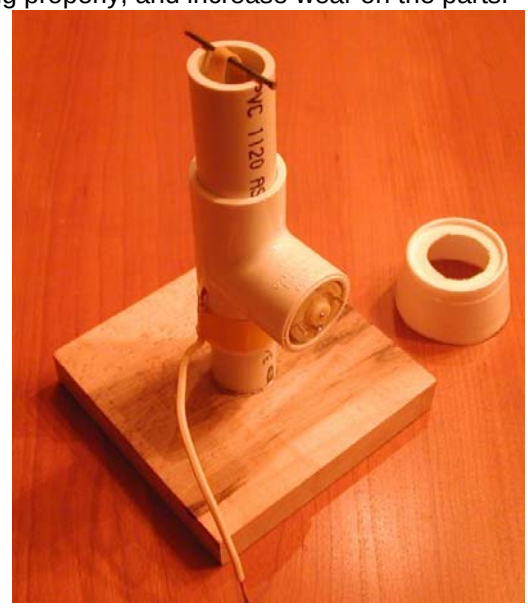
little better if it is made fatter by wrapping tape around it, or (better) putting a plastic rod with a hole in the center onto the shaft to act as a pulley for the rubber band. **We have used with good success the plastic wrapping of the stranded electrical wires. You can get the plastic off by using the wire stripper.**



3. A small hole in the side of the PVC "T" connector, just under the makeshift pulley on the motor will be used to hold the lower "brush", a bit of stranded wire frayed at the end that is ***almost*** touching the rubber band on the pulley.
4. As the photo shows, the stranded wire is held in place with some electrical tape, or some other kind of tape or glue.
5. The rubber band is now placed on the pulley, and allowed to hang out the top of the "T" connector.

Step 2: Belt Rollers and PVC Columns

1. Next, get a 1 or 1.5 inch piece of 3/4 inch PVC plumbing pipe. This will go into the top of the "T" connector, with the rubber band going up through it. Use the small nail to hold the rubber band in place, as in the photo below. The length of the PVC pipe should be just enough to fit the rubber band. The rubber band should not be stretched too tightly, since the resulting friction would prevent the motor from turning properly, and increase wear on the parts.



2. Cut the Styrofoam cup about 1/2 inch from the bottom, and carefully cut a ¾ inch diameter hole in the center of the bottom of the cup. This hole should fit snugly onto the 3/4 inch PVC pipe.
3. Now drill three holes near the top of the PVC union coupling. Two of these holes need to be diametrically opposite one another, since they will hold the small nail, which will act as an axle for the rubber band. The third hole is between the other two, and it will hold the top "brush", which, like the bottom brush, will almost touch the rubber band.
4. The top brush is taped to the PVC union coupler, and the coupler is placed on the ¾ inch pipe, above the Styrofoam cup collar. The rubber band is threaded through the coupler, and held in place with the small nail, as before.
5. Bare the top brush (so it has no insulation) and twist it to keep the individual wires from coming apart.
6. The free end of the top brush will be curled up inside the empty soda can when we are done, and thus electrically connect the soda can to the top brush.

Step 3: Upper Terminal

1. The next step is a little tricky. The small nail is placed through one of the two holes in the PVC union coupler, and the small glass tube is placed on the nail. The rubber band is then placed on the glass tube and the nail is placed in the second hole. The rubber band is on the glass tube, which is free to rotate around the nail.
2. Now we glue the Styrofoam collar in place on the PVC pipe. We will use a hot glue gun for this since the glue can be laid on thickly to stabilize the collar, it sets quickly and it does not dissolve the Styrofoam.
3. At this point we are ready for the empty soda can. Aluminum pop-top cans are good for high voltage because they have nice rounded edges, which minimize "corona discharge". With a sharp knife, carefully cut out the top of the soda can. Leave the nice crimped edge, and cut close to the side of the can so as to leave very little in the way of sharp edges. You can smooth the cut edge by "stirring" the can with a metal tool like a screwdriver, pressing outward as you stir, to flatten the sharp edge.
4. Tuck the free end of the top brush wire into the can, and invert the can over the top of the device, until it rests snugly on the Styrofoam collar.
5. The last step is to attach the batteries. We will use the alligator clip wires to connect the ends of the motor to the holder for two AA size batteries

Put it all together:

Activity Sheet

In this lab we will experiment with the qualitative behavior of the Van de Graaff generator we have just built. First we will try to understand charge by conduction.

Sticky Tape:

Cut two pieces of tape of about 20.0 cm length and tape them about 19.0 cm to the top of your bench. After making sure that taped portions are making good contact with the bench, pull them off quickly. Holding each of the pieces from one end, approach them to each other. What do you observe?

Try to explain why they behave that way:

Now tape the two pieces of tape to each other, **sticky side over non-sticky side**. Pull both pieces apart. Holding each of the pieces from one end, approach them to each other. What do you observe?

Try to explain why they behave that way:

Get two fresh pieces of tape. Tape the two pieces of tape to each other, **sticky side over sticky side**. Pull both pieces apart. Holding each of the pieces from one end, approach them to each other. What do you observe?

Try to explain why they behave that way:

Where did the charges come from in the three experiments you have just performed?

Straws and Paper:

You'll need a straw covered with paper. Tear a few tiny pieces of paper from the top of the straw wrapper (while keeping the straw in the wrapper) and lay them on the bench. With the straw still in the wrapper, carefully rub it against the wrapper five to ten times using an in and out motion. Pull the straw out of the paper and hold one end with your fingertips. Like a wand, lower the straw and hold it next to the pieces of paper, then raise the straw again. What happens?

Now take the straw and "wipe" it through your bare palm a couple of times. Once again hold the straw to the paper. What happens?

When you rub the straw against the paper there is a static electric charge present. Where did this charge originate?

Why won't the straw pick up the paper after you wipe the straw through your bare hand a few times?

Did the paper that you were able to lift we the straw carry a net charge?

Using the Van de Graaff generator:

Now lets use the device we built. First tape some tissue paper to the soda can in strips. What happens to the tissue paper when you attach the battery?

Can you explain why this is happening? Why is it important we had the glass and the rubber band in contact?

Since energy cannot come from nothing, where does the energy come from to allow the tissue paper to move? How is it provided?

Now lets blow some bubbles around the generator when it is on. What do you observe? Why does this happen?

Lastly, stand on an insulating surface and touch the generator when it is on. Does anything happen? What about when you are standing on the ground? Explain.