Experiment 1

Electric Charges

Annika Moffitt, Nikole Scillitani, Michael Gonzales

OBJECTIVE

- To investigate the behavior of electric charges
- To investigate charging an object by contact as compared to charging an object by induction
- To investigate the distribution of charge on a conducting object

APPARATUS

- Glass and plastic rods, wool, silk, fur
- Scotch tape
- Electroscope
- Charge Sensor connected to a computer
- Spherical conducting shell
- Proof plane (rod with metal disk at one end)
- Electrostatic Generator (Van de Graaf)

THEORY

All matter is made up of atoms in various combinations called molecules. In turn, each atom consists of a central nucleus surrounded by a cloud of electrons. The nucleus consists of particles called protons and neutrons. The neutron is electrically neutral, the proton is electrically positive, and the electron is the smallest possible negative charge occurring in nature. In ordinary matter the total negative charge equals the total positive charge and the substance is said to be electrically neutral. If by some means electrons are removed from an atom, the remaining part of the atom, called an ion, will be left with one positive charge for each electron removed.

Substances may be classified as conductors, insulators and semi-conductors. If the electrons are relatively free to move about, the substance is a conductor; on the other hand, if the electrons are tightly bound to their nuclei, the substance is an insulator. Other substances, lying between these extremes, are called semi-conductors. Note that in dealing with solid bodies it is the electrons which move rather than the positively charged ions.

When two different substances are rubbed together, one sometimes picks up an excess of electrons from the other. The one with an excess of electrons is then said to be negatively charged and the other with fewer electrons is said to be positively charged.

A substance may be given a charge by direct contact with another charged body, or by a process called induction that does not involve direct contact with a charged body.

In performing the following experiments remember that electrical charge cannot be created or destroyed. Electrical effects are produced only when the equal amounts of positive and negative charge in neutral matter are somehow separated. This separation requires an external force, since positive and negative charges attract each other. On the other hand like charges repel each other, and the deflection of the electroscope leaf is due to this repulsion.

PROCEDURE AND REPORT (*Answer all the questions indicated with ♦*)

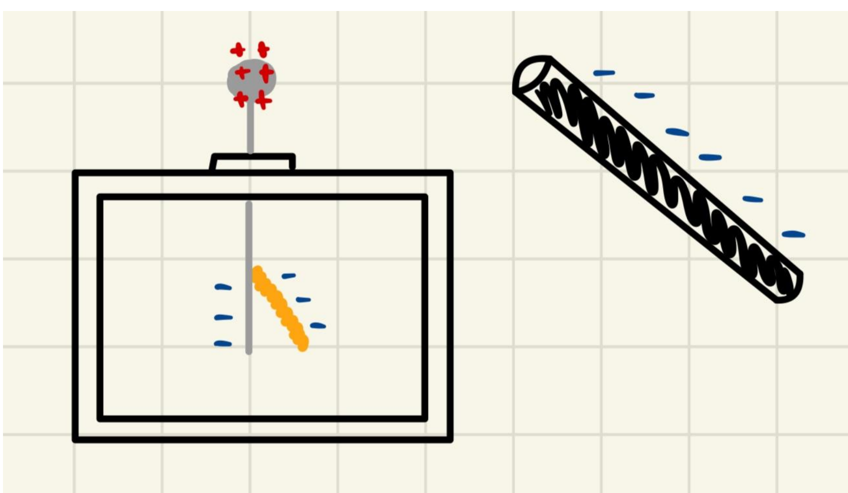
Report
For your report this week, fill out all questions in this manual and turn it in with your name, all of partners' names, and circle the group reporter's name.

Procedure
To experimentally investigate electrostatics, some charge detecting or measuring device is needed. A common instrument used for this purpose is the electroscope, a device with a thin gold foil (called a leaf) suspended from a metal bar. When a charged object is brought near the electroscope, the gold leaf separates due to repulsion of like charges. The degree of separation of the gold leaf roughly indicates the magnitude of the charge. However, a quantitative reading and direct determination of the sign of the charge is not possible.

You also have available a Charge Sensor which is an 'electronic electroscope' capable of giving a measurement of both the sign and the size of the charge. The Charge Sensor should already set-up and is connected to the computer for you to use in this experiment. With the Charge Sensor plugged into the green Vernier LabPro box, start the LoggerPro program. (If not on the desktop, open "Macintosh" → "Applications" → "LoggerPro 3".)

1. Behavior of Charges and Charging by Contact
a) Rub the plastic rod with the fur, this should leave a negative charge on the rod.
Bring the charged rod near the electroscope without touching it and then move it away.

- ♦ Make a neat, detailed sketch of the object and the electroscope to visually explain what is happening to the charges including the electrostatic locations.

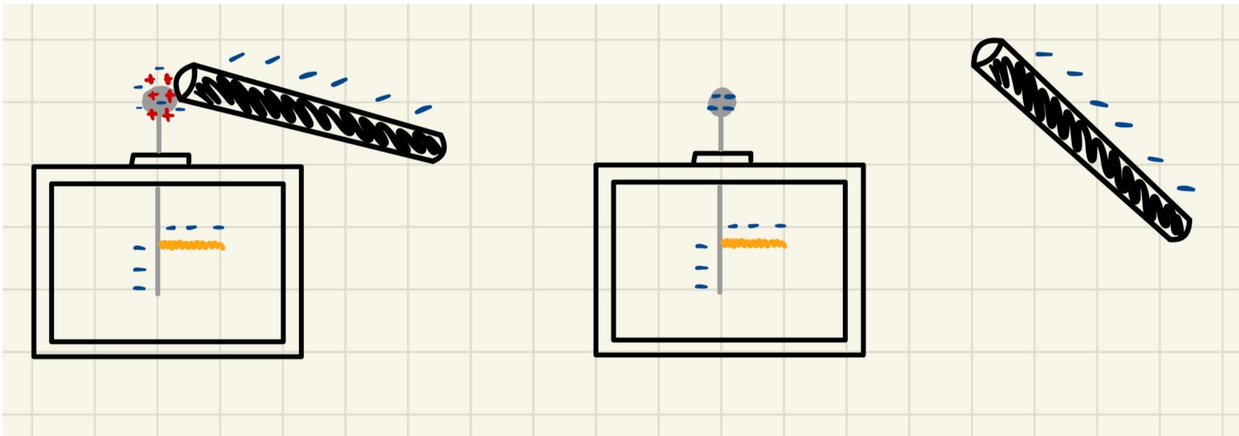


- ♦ What happens? What is the reason for this behavior?

As the negatively charged plastic rod moves towards the electroscope, the electrons from the electroscope move downwards and repel each other, causing the gold leaf to move away from the metal.

Touch the plastic rod to the electroscope and rub it on the top of the electroscope and then move the rod away.

♦ Make a neat, detailed sketch of what is happening to the charges, and include their locations.



♦ What happens? What is the reason for this behavior?

After rubbing the plastic rod onto the electroscope, the gold leaf lifted away from the metal and remained in that position. This happened because the negative charge was transferred from the plastic rod to the electroscope after contact. Thus, the electroscope became negatively charged and the electrons in the metal and the gold leaf repelled each other.

♦ Start measuring with LoggerPro and bring the rod near the Charge Sensor and determine the sign of the charge. Record the sign indicated by the Charge Sensor.

- 2.08 nC

b) Rub the glass rod with the silk, this should leave a positive charge on the rod.
Make sure the electroscope is uncharged by touching it. Bring the charged glass rod near the electroscope and then move it away.

♦ What happens? What is the reason for this behavior?

As the glass rod got closer to the electroscope, the positive charge on the glass rod caused the electrons on the electroscope to move upwards and caused the positive charges to move towards the bottom. At the bottom, positive charges repelled against each other, causing the gold leaf to lift up from the metal.

Touch the glass rod to the electroscope and rub it to try and "scrape off" the charges and then move it away.

♦ What happens? What is the reason for this behavior?

After scraping off the positive charges from the glass rod onto the electroscope, the gold leaf remained perpendicular to the electroscope. This is because scraping the positively charged glass rod onto the electroscope made the electroscope positively charged, which caused the gold leaf to remain repelled because both the electroscope and the gold leaf were positively charged.

♦ Now bring the rod near the Charge Sensor and determine the sign of the charge. Record the sign indicated by the Charge Sensor.

+ 2.91 nC

c) Pull a couple of strips of Scotch tape from a roll. Each one should be about 15-20 cm long. Hold them up by their ends then slowly bring the <u>non-sticky</u> sides close together but not touching.

What happens as they come closer?

As the pieces of tape came closer, they repelled each other.

♦ What is the reason for their behavior?

The pieces of tape repelled each other because they had the same charge. Like charges repel.

♦ Do they carry opposite or like charges? Verify using the Charge Sensor.

They carry like charges (both are positive).

♦ Bring one of the strips near the electroscope, what happens? Remove the first strip and touch the electroscope with your finger to discharge. Then bring the other strip near the electroscope, what happens?

The gold leaf lifts from the metal when the tape gets closer to the electroscope. Bringing the other strip of tape after it was discharged did the same thing.

d) One at a time, pass each strip of tape completely between your fingers to neutralize them. Check with the Charge Sensor and if they still have charge repeat the process. If you are unable to neutralize this way, you can drag the non-sticky side of the tape across a *very slightly* moistened sponge. Be careful not to get the tape wet.

Fold over the end of each strip to give you a non-sticky handle to work with. Carefully stick the two strips to each other so the <u>sticky side of one strip adheres to the non-sticky side</u> of the other. Ideally, the tapes should be the same length so that the entire lengths of both pieces are in contact with each other. Discharge the now “2-layered” tape again by sliding it through your fingers. Verify using the charge sensor that the 2-layered tape pair is neutral. Now grasp the handles and rapidly peel the strips apart. Keep them separated and slowly bring the <u>non-sticky sides</u> close together but not touching.

- ♦ What happens?

The two pieces of tape were attracted to each other.

- ♦ Do the two strips of tape carry opposite or like charges? Verify using the Charge Sensor, and record the sign of the charge for each strip of tape.

The strips of tape carry opposite charges. One had a charge of roughly 0.34 nC and the other had a charge of roughly -0.76 nC.

- ♦ According to theory, total net electric charge of the system is conserved. Does your Charge Sensor reading confirm this? Explain.

Our Charge Sensor reading did not precisely confirm this, but in theory the net electric charge of the system should have been conserved. There may have been errors due to the slight positive charge of the sensor before the tapes were near or experimental errors in neutralizing the tapes.

- ♦ From the observations and measurements you have made so far, which side of the tape gives up electrons? Which side tends to steal them?

The negative piece of tape (non-sticky side) stole electrons from the other piece of tape, causing it to become positive (sticky side). The sticky side tends to steal electrons from the non-sticky side.

e) You are now going to repeat part d) again, but this time <u>stick the strips together with their sticky sides facing each other. (Don't forget to discharge the 2-layered pair.)</u>

- ♦ Do the tapes become charged? Explain why or why not.

The tapes did not appear charged after. When held near each other and near the Charge Sensor, both tapes appeared neutral.

2. Charging by Induction

You will charge the proof plane by induction. First, by using the Charge Sensor verify that the proof plane is neutral. Then hold the proof plane so that it is touching a properly grounded object. Ask your instructor if you are unsure of where a ground is located. After charging the plastic rod negatively by rubbing with the fur, bring it near to (but not touching) the proof plane and keep it there for a second. Then, while keeping the plastic rod near (but not touching) the proof plane, move the proof plane away from the grounded object. Once contact between the proof plane and the grounded object is broken, you can move the rod away.

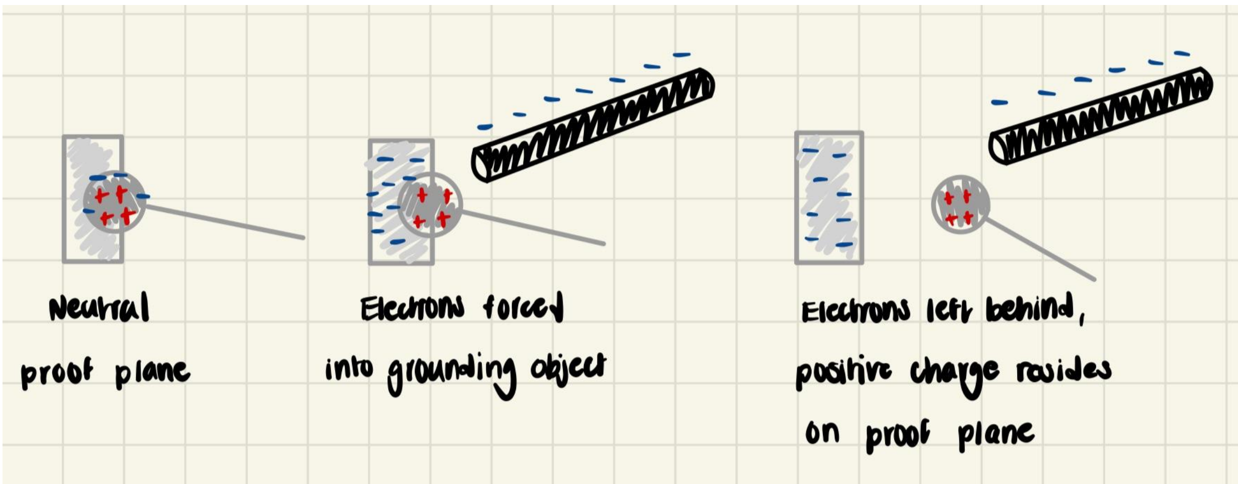
- ♦ Use the Charge Sensor to verify that there is charge on the proof plane, record the sign of the charge.

+ 0.41nC

♦ Check to verify that the plastic rod had negative charge using the Charge Sensor.

- 4.27 nC was recorded when the plastic rod touched the Charge Sensor.

♦ Make a neat sketch of the charge movement during this process of charging by induction.



♦ Explain how the proof plane acquired this charge without making contact with the charged rod.

By negatively charging the plastic rod (with the fur) and then holding it near the proof plane and grounding object, the electrons were forced out of the proof plane and into the grounding object. The electrons were repelled by the negatively charged plastic rod. When the rod and the proof plane were pulled away from the grounding object at the same time, the proof plane became positively charged due to its loss of electrons.

3. Electrostatic Charge Distribution on a Conductor

Charge the conducting spherical shell using the Electrostatic Generator. Your instructor will show you how to do this safely. The spherical shell can hold a fairly large amount of charge so keep it at a distance from the Charge Sensor otherwise it may affect your reading. Touch the metal part of the proof plane to neutralize it first and verify its neutrality using the Charge Sensor. Touch the proof plane to the outer surface of the spherical shell to pick up charge and then bring it near the Charge Sensor.

♦ Were you able to pick up any charge with the proof plane from the outer surface of the shell?

A slightly negative charge was picked up from the outer surface of the shell via the proof plane. A reading of -0.20 nC was observed using the Charge Sensor.

Neutralize the proof plane by touching it and verify using the Charge Sensor. Now gently insert the proof plane into the spherical shell without touching the outer surface or the edges of the hole. Rub the proof plane on the inside surface of the shell and take it out without touching the outer surface or the edges of the hole.

♦ Were you able to pick up any charge with the proof plane from the inner surface of the shell?

When the proof plane was placed into the inner surface of the shell and held close to the Charge Sensor, there was a slight negative charge that was picked up in the reading. The readings didn't show a significant negative charge that was present, but in theory, we would expect the proof plane to remain neutral because the electrons in the negatively charged shell would repel and reside on the outside of the sphere, not the inside.

♦ On a conducting object where does the excess charge reside?

The excess charge should only be on the outside. Upon observation, there was a slight negative charge on the inner shell, but theoretically, the charge on the inner shell should be neutral.