LAB 18. POLARIZATION

Problem

- How can an object become electrically charged?
- How do electric charges behave?
- How do charges behave differently in conductors and insulators?

Equipment

Electrophorus: Tape, foam cup, foam plate, foam slab, aluminum plate, fur or wool.

Elecgtroscope: Electroscope, plastic rods, balloon, fur or cloth pieces.

Acknowledgements

The “Electrophorus” section of this lab is adapted from a Harvard University Physics 1b laboratory. The “Electroscope” section is adapted from a University of Colorado at Boulder Physics 2020 laboratory.

Activities

This lab consists of two apparatus. Your task will be to explain why the two systems behave as they do.

1. Electrophorus

Alessandro Count Volta is credited with inventing the electrophorus perpetuum in 1775. This practical machine allowed the (apparent) perpetual generation of charge. The principle behind it is simple. Like charge repels like charge. When a neutral conductor is brought near a negatively charged dielectric, the free electrons in the conductor flow as far from the charged dielectric as they can get. If the opposite end of the conductor is then touched with a conductive object connected to ground, those electrons will actually flee the neutral object, leaving it positively charged. If the conductor touches the charged dielectric, some electrons from the dielectric will flow onto conductor, making it negatively charged.

In this part of the lab, you will create your own electrophorus perpetuum in a manner similar to that used by Volta. A plastic foam slab or foam plate becomes a charged dielectric when it is rubbed against your hair or a wool sweater. Combine this with an aluminum pie plate with Polystyrene foam-cup handle, and you're ready to “create” charge!

1. Tape an upside-down polystyrene foam plate to a table or counter top. The tape should only touch the edges of the plate. (If you use a foam slab, you won’t need to tape it.) This is your dielectric.
2. Tape a polystyrene foam cup to the inside of an aluminum pie plate. The cup will serve as an insulating handle for holding the charged pie plate.

3. Charge the polystyrene foam plate by rubbing it with fur or wool.
4. Charge a balloon by rubbing it with fur or wool. Bring it close to the polystyrene foam plate. Observe the interaction and record in your lab notebook.
5. Make sure the aluminum pie plate is neutral (uncharged). Touching it with one hand while touching a water faucet with the other hand should work.
6. Holding on to its polystyrene foam handle, move the neutral aluminum plate as close as possible to the dielectric without letting them touch. While keeping the plates as close together as possible, momentarily touch a finger to the top surface of the aluminum pie plate, and then raise the aluminum plate away from the dielectric.
7. Now while touching only the handle bring the aluminum pie plate near the charged balloon. Observe the interaction and record in your lab notebook.
8. Remove the balloon. Ground the pie plate by touching it. Record your observations.
9. You can recharge the aluminum plate as many times as you want, as long as you don't allow the two plates to touch. Verify that this is true. The process of charging the plate requires energy, which is introduced by the work done when the aluminum plate is separated from the charged polystyrene foam.
10. Now use a light foam plate that is not taped to the table as your dielectric. Charge it, ground your aluminum pie plate, and bring the pie plate close to the charged dielectric. While they are adjacent, ground the pie plate. Observe and record the interaction.
11. Ground the pie plate. This time, while holding it by its insulated handle, touch it to the charged dielectric. Strive for good contact between the plate and dielectric. Remove the pie plate from the dielectric, and bring a charged balloon near it. How do the pie plate and balloon interact? Record your observations.
12. Remove the balloon. Ground the pie plate by touching it. Record your observations.

2. Electroscope

The electroscope consists of a metal plate connected by a metal rod (the stem) to two leaves of aluminum foil. The fragile part of the instrument is enclosed in the glass. Electrons can flow freely within the plate, stem, and foil. The foil leaves are very lightweight and floppy, so that an electrical repulsive force acting to lift them up can more easily overcome the downward force of gravity.

Notes

• Never tilt the electroscope or turn it upside down. This can tear the foil. Just leave it on the table.

• When you bring a charged object near the electroscope, do so from the top. Do not bring any charged object near the glass sides, as this can twist the foil and rip it off.

• In order to ground the electroscope (that is, remove all the net charge from it so it’s neutral), touch your hand to the top of the electroscope. First be sure that you do not have any charge on your hands. (You can ground yourself by touching a water faucet.)

• Before charging and testing the plastic rods, make sure that they are neutral first. You can ground the plastic rods by covering a water faucet with a damp towel and wipe the rods across the towel. Always test the rod with the electroscope to make sure it is neutral first.

• If you rub two objects together to test the charge on each, make sure you hold the side that was rubbed near to the disk on the electroscope.

Procedure

1. Charge a plastic rod or balloon by rubbing it with fur.
2. Make sure there is no charge on the electroscope so that its leaves hang straight down. Now bring the rod close to (but not touching) the plate of the electroscope. Record your observations.
3. Take the rod or balloon away, and bring the fur close to the plate. (Because the charge is spread over the fur, it is harder to see an effect this way.) Record your observations.
4. Take a charged rod or balloon and touch it to the metal plate on the electroscope, then take the rod away. Record your observations.
5. Find out and explain how you can increase the amount of charge left on the electroscope. How can you tell that more charge has been left?
6. Now (with the electroscope charged negatively) bring the negative rod or balloon close to, but not touching, the plate. Do the same with the positive fur. In each case record what happens.
7. Neutralize the electroscope. Then, holding the rod or balloon in one hand, bring it close to (but not touching) the plate. Now, keeping the rod in place, touch the opposite edge of the plate with a finger of your other hand. Then remove first your finger and then the rod.
8. What happens now when you bring a negative charge close to the electroscope's plate? What if you bring up a positive charge? Observe and record.

Check

Before you leave the lab, describe your observations to the instructor.

Explain

Review all of your observations with your group members. Try to explain, using the principles of electrostatics that we have learned in class, all of the observations.

If you aren't sure how to explain any of your observations, think of an experiment you could do to help you figure it out. At a bare minimum, make sure that any discrepant event you observed is genuine, and not a mistaken observation.

Test

Do the experiments. Record what you did and what you observed. Are you able to answer your questions given the new information? If not, think of and carry out more experiments until you are satisfied.

Lab Report

Submit one lab report per group. The report should bear the names of all group members who worked on it.

Abstract: Identify the apparatus you used, the phenomena you observed, and name the principles you used to explain your observations.

Purpose: Identify what you are trying to understand or explain.

Theory: Here, explain the fundamentals: how charges interact and affect nearby objects, and how conductors behave.

Experimental: Don't explain each individual thing you tried. Here, describe how you charged your dielectric objects, how you grounded your conductors, and what sorts of observations you made.

Observations, Analysis, and Discussion: Tell me what you observed for each of the steps given in these instructions. Explain each observation from fundamental physical principles. If you performed additional experiments to test and confirm your hypotheses, explain what you did, what you were trying to figure out, what you observed, and what you learned from it.

Structure this section to report on each step in turn, including questions, experiments, and conclusions.

Conclusions: Briefly cite the physics principles that explain the phenomena that you observed, giving select evidence from your investigations. If any of the phenomena you observed defy explanation, explain the problem.