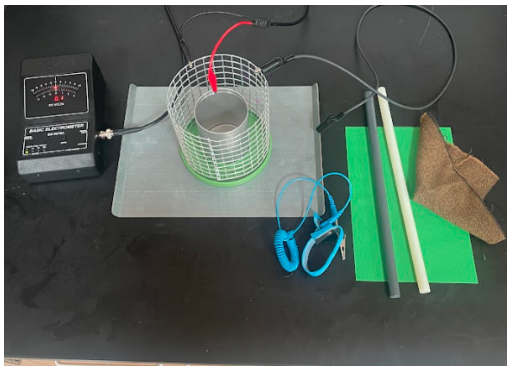
Physics 196 Lab 1: Static Electric Charge

Equipment:

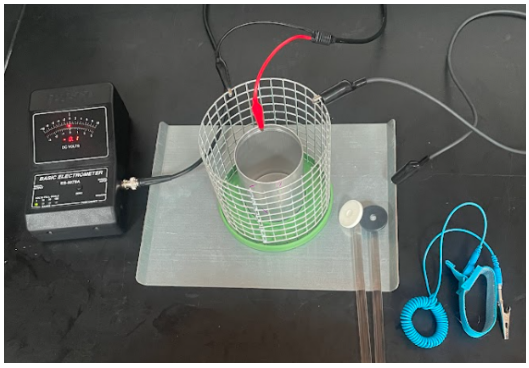
Scotch tape, Meter Stick, Damp Paper Towel, Faraday Pail, Cage, and Ground Plane, Pasco Electrometer (ES-9078A), Grounding Wire, PVC Rod, Nylon Rod, Vinyl, Cloth, Black and White Charge Separators, Grounding Wrist Strap, High Voltage Power Source (HVEK-CRG), Conducting Spheres, Voltage Transfer Terminal, Charge Transfer Proof Plane

Layouts:

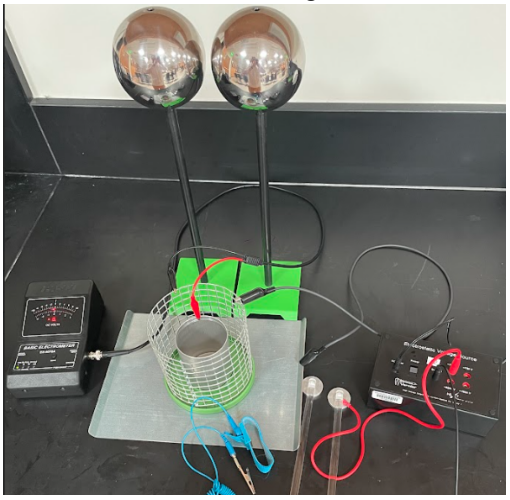
Experiment 1: Scotch Tape Electricity



Experiment 2: Electrostatic Charge measurement



Experiment 3: Electrostatic Charge balance



Experiment 4: Charge distribution and transfer

Summary: Students will investigate static charge using scotch tape, their bodies, and rubbing together appropriate materials. Relative charge magnitudes will be measured using a Faraday Pail. Charge transfer and distribution will be investigated using a high voltage electrostatic source and conducting spheres.

Prelab:

Purchase your laboratory notebook and prepare it with the Table of Contents on page 1. Tape the "Laboratory Notebook Guidelines" on page 2. Tape the first page of this write-up (including the equipment list, experiment photographs and summary) on page 3 of the notebook. Have the rest of the lab write-up available to follow, either in printed or electronic form.

Lab:

Experiment 1, Scotch Tape Electricity: It is possible to separate charge using transparent tape.

1. Cut a 10 cm long piece of tape, fold over a few mm at one end, and stick the tape to the table. Then pull it up. Bring various objects such as a pen, pencil, or finger close to the tape, and describe what happens. Then rub the tape off with a damp towel. Now describe what happens when various objects are brought near. (It should be possible to remove any residual charge from the tape with the damp towel). What do you think is going on?
2. Take a new piece of tape, pull it up off the table, and attach it to the end of a meter stick with most of the tape hanging off the edge. Take another piece of tape, pull it off the table, and bring it near the piece of tape on the meter stick. What do you observe? Should both pieces of tape have the same sign of charge on them? Does what you observe make sense? You can attach this piece of tape on the other side of the meter stick from the first one.
3. Now prepare two pieces of tape (ends folded over) with one stuck to the table, and then the second one stuck on top of the first one. Pull the double piece of tape off of the table. Now pull the two pieces of tape apart. Alternately bring one piece of tape or the other close to the tape hanging from the meter stick. What do you observe? Do you get a different effect from the top and bottom piece of tape from the pair pulled off the table? (You should). Does what you observe make sense? Discuss with your lab partners, and describe what you observed to the instructor before going on to the next part of the experiment.

Experiment 2, Electrostatic Charge Measurement:

Insert the Faraday Pail in the Faraday Cage, place it on the Ground Plane, and connect the Faraday Cage to the Ground Plane with an alligator-alligator lead. Attach the Electrometer to the connecting wire, and connect the red lead to the Faraday Pail and the black lead to the surrounding Faraday Cage. Charge accumulated on an object which is inserted into the Faraday Pail (without touching it) will lead to a reading from the electrometer which is proportional to the amount of charge. (The charge on the inserted object attracts the opposite charge to the inner pail, which then balances with the same charge on the outer cage. This charge difference between the Faraday pail and cage leads to a voltage which is measured by the electrometer.) Remember that for each reading the electrometer needs to be zeroed using the button on its front side.

Describe the equipment and what you are doing in your lab notebook, including a diagram of how the equipment is connected. Use the electrometer on the 2V setting to start.

1. Rub your shoes on the floor and see how much charge you can measure when you stick your finger into the Faraday Pail (without touching). I was able to accumulate more charge by using my socks on the floor rather than shoes, so go ahead and try this (if you are wearing socks). Compare the amount of charge that different team members can accumulate. When you find the method that allows for the most charge to be measured, compare the amount of charge you see with the finger inserted and then removed (should go back to zero). Then touch your finger to the ground plane and reinsert it into the Faraday Pail (should stay at zero). Explain what you think is going on in your notebook.
2. At the end of the experiment, put on the wrist strap, connect the wrist strap to the ground plane, and verify that now your body carries no charge. Use the wrist strap for all subsequent experiments.
3. See if you can measure the charge on the scotch tape when you pull it directly off of the table, and when you pull it off of another piece of tape. Is the charge opposite in these two cases? Do the results agree with what you would expect?
4. See how large of a charge you can measure with the white nylon rod rubbed on the green vinyl and the grey PVC rod rubbed with the cloth. Do the nylon and PVC give opposite signs for the charge? See if the amount of charge you can measure changes depending on how long or how hard you rub the materials together. Make sure you are not saturating the detector – if you are you may have to change the scale. Note that if you achieve a voltage of 100 volts, that is the maximum the sensor can read.

Experiment 3, Electrostatic Charge Balance:

In these experiments charge is not created. Instead, it is transferred from one object to another. In particular, since electrons are much more easily moved around than atomic nuclei, it is really electrons, with their negative charge, which are transferred from one object to another. This process is technically known as charge separation. If one object ends up with a positive charge, it donated electrons to the second object it was rubbed against. If one object ends up with a negative charge, it accepts extra electrons from the second object. In this experiment we will explore the idea that charge is not created, but rather redistributed, by trying to work quantitatively with the black and white charge separators and the Faraday Pail and Cage.

1. Rub off the two charge separators with the damp cloth. Wear the wrist strap, and zero the electrometer. Insert the two charge separators together into the Faraday Pail, and verify that there is no net charge.
2. Now carefully rub the two charge separators together while they are in the pail. You must be very careful not to touch the pail with either your body or the charge separators while you do this. Does the net charge stay at zero? (It should). (Please note, that there is a slow drift on the electrometer, so "zero" really means relatively small.)
3. Now pull out one of the separators from the pail, leaving the other one inside. What charge do you measure? (Note which separator is in and which is out). Now reinsert the charge separator (so both are in the pail). What charge do you measure? (It should go back to zero).
4. Repeat step 3 switching which charge separator you pull out.
5. Have all team members do this same experiment. Working with static electric charges can be tricky, depending on the humidity and other factors. However, this experiment, if done carefully, demonstrates the most important concept from today's laboratory. Namely, charge is not created, but only transferred between different objects. Were you able to convince yourself that this is really true? Please discuss this concept in your notebook and with the professor before moving on.

Experiment 4, Charge Distribution and Transfer:

Add the High Voltage Electrostatic source, the two conducting spheres, and the Voltage Transfer Terminal (with red lead) and the charge transfer proof plane (aluminum paddle) to your set-up. You still need the Faraday Pail, Cage and electrometer. A black banana-alligator lead connects the High Voltage Source to the Faraday Cage Ground. The red banana lead on the voltage transfer terminal plugs into one of the different voltage terminals.

1. Using a single sphere, charge the sphere by touching it with the voltage transfer terminal connected to the 750 V source. Remove the voltage transfer terminal, and then touch the charge transfer proof plane to the sphere. Now insert the proof plane into the Faraday Cage and record the amount of charge. Repeat this measurement with the 1500V, 3000V and 6000V sources. (Don't forget to zero the electrometer each time, and also rub off the charge transfer proof plane between measurements using the damp cloth). Graph the measured charge vs. the Charging voltage in your notebook. Remember that the horizontal voltage scale has 4 measurements which are not varying by equal amounts. Is the relationship between charge and voltage linear?

2. Using the 6000V source, charge up the single sphere and remove the source. Measure the charge on different parts of the sphere by touching the proof plane to different parts and inserting into the Faraday Pail. If you don't wipe the proof plane between measurements, you should be able to keep all of the charge on the sphere about constant. Did the amount of charge you measured depend on the position of the sphere you transferred it from?

3. (Charging by conduction). Charge up one of the spheres using the 6000V source, and measure the charge. Now temporarily ground the second sphere to remove any charge, and then after removing it from ground briefly touch it to the first sphere. Measure the charge on the first and second sphere. It should be about half of the original charge. What is going on here?

4. (Charging by Induction). Now put the two spheres close together, but not touching. Charge up one of the spheres using the 6000V source. Measure the distribution of charge at various locations on the two spheres, especially at the far ends and near the gap between the spheres. Was the charge the same or different in the different locations? Try to explain what you saw. No briefly ground the far end of the second sphere (the one you didn't charge.) Remove the ground, move the second sphere away from the first sphere, and measure its charge. What do you observe? (The instructor should ask you about this when grading the notebooks).

Conclusion:

At the end of the lab write-up, include a short conclusion paragraph which summarizes the main theme on what you did and learned in the lab today.