# Electrostatic Experiment

Equipment Capstone, Charge Sensor, Faraday Ice Pail, Hair dryer, Electrostatic rod kit, Electroscope needle, Electrophorus, Leyden Jar, banana lead, wire plugged into DC wall ground, large hollow cylindrical acrylic rod, soda can

Comments: In this experiment you will observe the transfer of charges on conductors and nonconductors. Before starting the experiment, you should check the hygrometer located by the white board. If the room has a humidity level greater than 65% you might need to use a hair dryer. One will be available on each desk.

## 1 Purpose

To study charges, the forces they exert on each other, and their flow between materials, both conducting and non-conducting. Many of these tests are similar to ones carried out in the eighteenth century. Most of the observations in this experiment will be qualitative.

## 2 Theory

Studies of the nature of charges and the forces between them led to the idea in the eighteenth century that there were two kinds of charges. It was observed that charges could "flow" from one substance to another so they were thought of as some kind of fluid. Benjamin Franklin thought that there was only one kind of charge, and therefore dubbed substances with extra or too few charges positively or negatively charged respectively. We now know that Franklin was wrong on two counts: In our day-to-day interactions with charges, it is just one type of charge that moves around, negatively charged electrons. So an object that is negatively charged has extra negative charges not a paucity of positive charges. And there are actually two types of charge, where the second - positive - charge, is carried by particles like the protons which reside in the atomic nucleus. In electrically neutral material there are an equal number of protons and electrons. When electrons move from one material to another they leave a material which is now positively charged because it has more protons than electrons, and negatively charge their new material because it now has more electrons than protons. As far as we know today, electrons are elementary particles. This means they're not made up of any smaller constituents. Also, it appears that electric charge is conserved.

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That is, when we start with an isolated system with some net amount of charge (adding together plus and minus charges keeping track of the signs) then the net amount of charge will always remain the same no matter what other changes happen to the system.

In the tests done here we will be dealing only with transfer of electrons. For example, when you rub a hard rubber rod with wool, you're displacing the electrons off of the wool and increasing the number of electrons on the hard rubber rod. The wool becomes positively charged due to the lack of electrons and the rubber rod is negatively charged due to the increase of electrons. Like charges - and therefore bodies with the same excess or lack of electrons - repel, while opposite charges attract.

> Magalotti (1665) "It is commonly believed, that Amber attracts the little bodies to itself: but the action is indeed mutual, not more properly belonging to the Amber, than to the Bodies moved, by which it also itself is attracted.."

Conductors are materials in which charges are free to move. Since like charges repel, if a conductor is charged the charges will spread out on it. If we touch a charged conductor with a second conductor, the charges will also spread to the second, charging it by conduction.

If a negatively charged object is brought near a conductor, then negative charges on the conductor will be pushed away and the region of the conductor near the object will be positively charged. A charge imbalance will thus be induced on the conductor. If a much larger conductor is then touched to the first one, most if the extra negative charges will be pushed to the larger conductor, leaving the original one positively charged. The same will be true with all direction of charge motion flipped if the object is positively charged.

An electroscope is a conductor including a fixed part and a well-balanced needle that can easily move. It can be used to detect an excess of charge because the charges in the conducting needle are repelled by those in the rest of the electroscope forcing the needle away.

Non-conductors can also be charged, but the charges are not free to move around. To charge a conductor with a non-conductor it therefore isn't enough to just touch it at one point. Rather, one needs to rub various parts of the non-conductor on the conductor and hope that some of the chargers get rubbed off.

# 3 Charge by conduction and induction of an electroscope needle

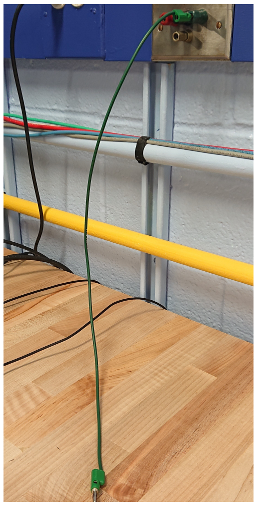
First you will be observing how to apply a charge on an Electroscope needle by conduction. You will rub various rods with different cloth-like materials. This will create a displacement of charge on the rod. Then you will observe how charges are applied to the electroscope needle using the methods of conduction and induction. In both cases you will observe how the behavior requires two different charge polarities.

## 3.1 Setting up the experiment for conduction

1. Before running the experiment check the hygrometer in the front of the class. If the humidity is high and you have damp hands then it's best to use a hair dryer on your

hands and in the vicinity of the experiment.

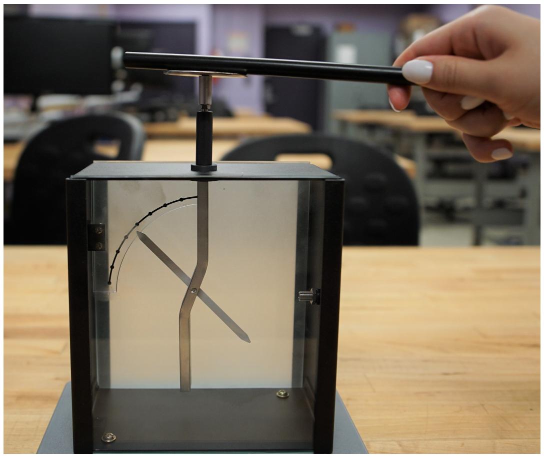
2. To ensure that the electroscope needle has a neutral charge (all excessive charge is removed), open the electroscope needle box by sliding up the front glass window. Then grab the electroscope needle assembly with one hand while touching a ground lead with the other hand. (The ground lead will be connected to the green wall jack.) Below is an image of the ground lead.



Place the glass window back on the electroscope. Below is a picture of the electroscope.

3. Now rub the hard rubber rod vigorously with a sheet of wool. The rubber rod is black and has flat ends.

4. Next, rub the rubber rod along the top of flat disk plate located on the top of the electroscope. Rub the surface of the rod along the metal flat disk plate multiple times.



5. Initially you will see the needle jolt up. Depending on humidity level you might need to repeat the previous step several times to register a reading. (Again you might need to use a hair dryer to reduce the humidity)

6. Keep in mind that on the electroscope a higher needle displacement correlates to a stronger charge build up.

#### 3.1.1 Questions and analysis

**How does the electroscope needle work? What is occurring to the electroscope needle as you continue to add charge? Why does the needle continue to move further away as you transfer more charge?**

### 3.2 Charging with another material

Discharge the electroscope by touching the ground plug to the top electroscope plate. Now do the exact same steps again, but this time use the perspex (acrylic) rod - it's the clear rod with flat tops- and rub it with silk.

#### 3.2.1 Questions and analysis

**Is the behavior observed of charging with the perspex rod any different qualitatively from that seen for the rubber rod?**

### 3.3 Observing the other charge

Discharge the electroscope and charge it again with the rubber rod.

1. Now rub the perspex rod with silk and bring it close to the metal disk on top of the electroscope, but do not touch the disk! Observe the reaction.

2. Go back and forth with the perspex rod several times without touching the metal disk. (Pretend you have a magic wand and you're casting a spell on the electroscope) **When observing the oscillations of the needle, what direction does the electroscope needle go as you bring the rod closer to the metal disk? What causes the electroscope needle to deflect in that manner? Does the perspex rod have the same or opposite charge as the needle?**

3. Return to the rubber rod. Rub the hard rubber rod with a sheet of wool vigorously.

4. You will repeat the previous steps of 3 and 4 from section 3.1. This entails displacing a charge on electroscope using a rubber rod.

5. After you're done charging the electroscope with the rubber rod, touch the metal disk with the wool cloth. **What is occuring to the electroscope needle? Explain in regards of the charges. Does the wool cloth have the same charge as the acrylic rod?**

### 3.4 Setting up the experiment for induction

In this section you will observe how to apply a charge on an electroscope needle by induction. Again you will rub various rods with different materials. This will charge the rod either positively or negatively. Then you will induce a charge by moving the rod towards the disk **but you will not touch the disk with the rod**. At the same time you will need to ground out the electroscope needle. Below are two methods of running the experiment.

**Method 1**

Removing the ground from disk and keeping the rod in place.

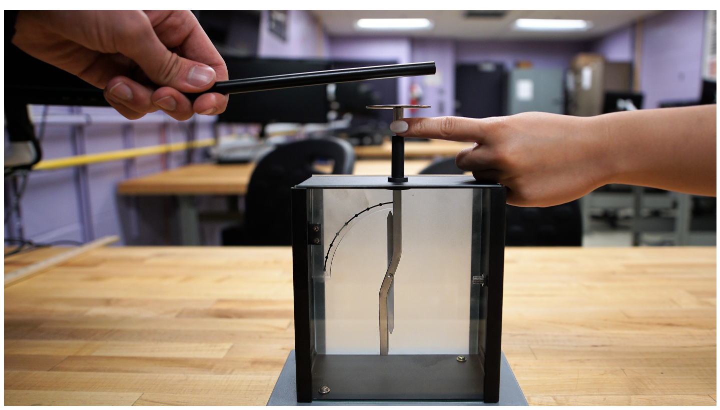
1. Open up the glass case and grab the electroscope needle with one hand. Then with the other hand grab the ground wire. Hold both items for a couple of seconds.

2. Let go of the electroscope and ground wire; the electroscope needle should go back to zero.

3. Close the glass case and vigorously rub the hard rubber rod with the sheet of wool. **What charge does the rubber rod have? Does the wool have an opposing charge?**

4. Bring the rubber rod close to the metal disk on top of the electroscope, but do not touch the disk! You should start seeing a displacement.

5. When you have the rubber rod close to the disk, have your lab partner touch the bottom side of the disk with one hand and at the same time touch ground wire with the other hand.

   Once your partner makes contact, continue to induce a charge by waving the rod back and forth above the disk. **Make sure you don't touch the disk.** If you touch the disk with your rod then you have to start from the beginning and ground out the electroscope needle.

6. **First** let your partner let go of the bottom side of the disk. Then move the rubber rod away from the disk. **What occurs to the electroscope needle? What is the physics phenomenon of this occurrence?**

7. Repeat steps 3 to 6. **What is occurring to the electroscope needle?**

**Method 2**

Removing the rod from the metal disk and then releasing the ground from the disk.

1. Repeat the first three steps from method 1.
2. Before bringing the rod close to the disk, **first have your lab partner use their finger to ground the side of the disk!**
3. Now bring the rubber rod close to the disk. At the same time, your lab partner should still be touching the bottom side of the disk and the ground wire.
4. Wave the rubber rod several times near the metal disk and then move the rod away.
5. Next remove your ground finger off the bottom of the metal disk. **Is there a deflection of the electroscope needle? Why or why not? Why is there a difference between the two methods?**

# 4 Attracting and opposing effect on pith balls

In this section you will observe the induced polarization of two hanging pith ball insulators.

1. Neutralize the pith balls by grabbing both of the pith balls while at the same time touching the ground wire.
2. Rub the acrylic rod thoroughly with silk. **What type of polarity will the acrylic rod be charged to?**
3. Bring the acrylic rod towards the pith balls and observe the reaction of the pith balls. **Explain what is occurring to the charges across the pith balls as the acrylic rod comes towards them.**
4. Again, neutralize the pith balls by grabbing both of them thoroughly and touching the ground wire at the same time.
5. Rub the acrylic rod thoroughly with silk. Then rub the acrylic rod across both pith balls. **What happens to the pith balls? What occurs to the charges of both pith balls?**

# 5 Leyden jar and electrophorus

In this part you will use the method of electrophorus to distribute charge onto an electrostatic needle. Then, you will transfer the charges onto a Leyden jar. You will be observing the effects of transferring charges from a non-conductor to a conductor, then transferring the charges to different conductors. Initially, you will build up a charge by induction on a metal disk. Then, you will transfer the charge to an electrostatic needle and then to another conductor, which is the Leyden jar.

## 5.1 Setting up the Leyden jar with a charge sensor

Before going straight into electrophorus; it's best to setup the Leyden jar with a charge sensor, so you can easily flow from one step to another.

1. Start the Capstone software.
2. Make sure your charge sensor has been connected to one of the blue Passport ports located on the bottom of the interface. Next, connect the positive alligator clip to the center rod of the Leyden jar. Then, connect the second alligator clip lead to the bottom lip of the Leyden jar. Look at the illustration below for guidance.

3. Go to the displays section and select and drag a display meter to the experimental window.
4. Under "Select Measurements" pick "Charge($\mu$C.)"
5. Run the program by clicking **Record**.
6. Initially there might be some charge on the Leyden jar. You need to ground out the jar by grabbing the center rod and outer conductor at the same time. Also, at the same time press the zero button that is located on the charge sensor.

Stop the software. At this point the Leyden jar is queued to accept charge.

## 5.2 Electrophorus

1. Neutralize the electroscope needle as you have done in the earlier section.
2. Rub the thick plastic base that has four rubber feet with the white cotton cloth.
3. Place the 18cm diameter aluminum plate that has a long black insulating handle on top of the thick plastic plate that you have just rubbed.

4. Touch and leave your finger on the backside of the aluminum plate disk for a couple of seconds.

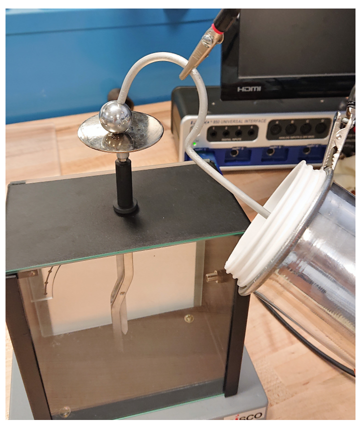
5. Transfer the aluminum plate to the electrostatic needle. You will see a jump from the electrostatic needle. Repeat steps 4 and 5 several times to build up enough charge on the electroscope needle. **How does the electrophours method continue to build up charge without rubbing the base plate over and over again? Does the base plate ever run out of charge?**

## 5.3 Transfer of charge from Electroscope to Leyden Jar

At this point of the lab, you should have charged the Electroscope to at least the sixth point scale. Now you will transfer the charge off the electroscope needle onto the Leyden jar. You should already have queued the Leyden jar with the charge sensor from section 5.1.

1. Click record on Capstone.

2. Grab the Leyden jar by the bottom and bring the Leyden jar to the Electroscope needle. **Make sure that the clips don't come off the Leyden Jar**. Touch the center ball of the Leyden jar onto center of the metal disk of the Electroscope needle.



3. You should see the display meter of the charge sensor go up. **What happens to the charges from the Electroscope needle?**

4. Repeat steps 3, 4, and 5 of section 5.2.

5. Once the Electroscope has been charged repeat step 2. Continue this process until the Leyden jar is fully charged. **How are the charges distributed across the Leyden jar? Where are they being stored?**

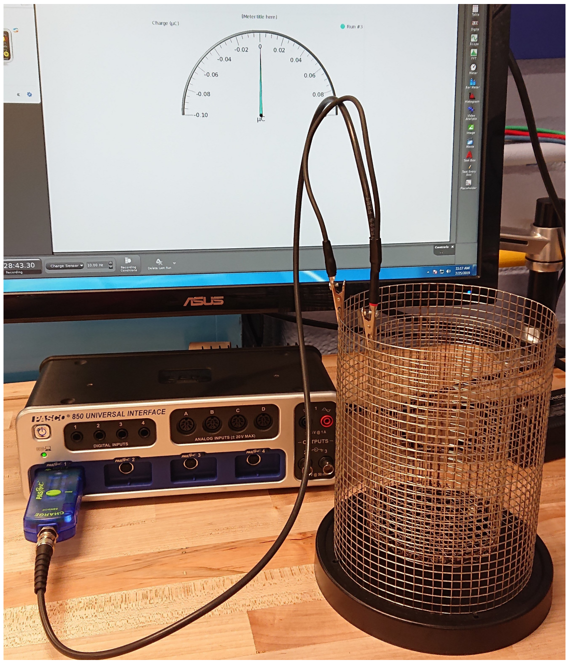
6. Now that you have a fully charged Leyden jar it's time to discharge it. Take a banana lead and touch the center rod with one end. Then touch the outer side of the metal jar with the other end. **What happens to the display meter of the charge sensor? What happens to the charges on the Leyden jar?**

# 6 Faraday Ice bucket

You will be using the Faraday Ice bucket device. It's a metal wire mesh device that has a shielding wrapped around it. Also, you will connect the charge sensor across the Faraday bucket. Initially, you will observe how charges become distributed across a metal bucket as you insert a charged particle. Next, charge the inner bucket by induction. Lastly, you will see the effects of placing a charge on the outside of the bucket.

## 6.1 Setup

You will connect the charge sensor to the Faraday bucket as illustrated below. The positive (red) alligator clip is clipped onto the center bucket and the ground (black) alligator clip is connected to the outer shield.




Keep in mind before running each part in this section you will need to ground out the inner coil. To do this, you need to grab the inner and outer buckets together with the same hand.

## 6.2 Observing the effects of inserting differently charged rods.

1. Check that the charge sensor is still active in Capstone software.
2. You should still have the meter display set up from section 5.1. If not, go configure Capstone software for the charge sensor meter.
3. In Capstone click the **Record** button on the bottom.

4. Now vigorously rub the perspex rod (acrylic) with silk and insert the rod into the center bucket slowly. Do not touch the inner part of the bucket with your rod. **What happens as you insert the rod? As you slowly insert the rod what is occurring to the charges in and on the outside of the bucket? Can you tell if the rod is positive or negatively charged?**

5. Now rub the hard rubber rod with a sheet of wool vigorously. Repeat the previous step. **What are differences between these rods?**

6. Go back and vigorously rub the perspex rod (acrylic) with silk. Now have your lab partner rub the hard rubber rod with a sheet of wool vigorously.

7. Slowly insert the perspex rod into the center bucket. At the same time have your lab partner insert the hard rubber rod. Observe the reaction of the meter. **What occurs to the charges on the inner part of the bucket?**

## 6.3 Charging the bucket by induction

1. Ground the bucket and press the zero button on the sensor.

2. In Capstone, click the **Record** button on the bottom.

3. Now vigorously rub the perspex rod (acrylic) with silk and insert the rod into the center bucket slowly.

4. With the rod being held still in the center, have your lab partner ground the Faraday bucket. **What is occurring to the meter display?**

5. Once you have grounded the bucket, remove your hand from both coils. Then remove the charged rod. **What is the meter reading now and why? What happens to the charges when you ground out the bucket?**

## 6.4 Placing a charged object outside the bucket

1. Ground the bucket and press the zero button on the sensor.

2. In Capstone click the **Record** button on the bottom.

3. Rub the hard rubber rod with a sheet of wool vigorously.

4. Place the rubber rod on the outside of the wire shield. Move the rod just around the outer shield. Do not make contact with the rod or shield. **What is occurring to the meter display? Will there be any movement of charges on the inner bucket?**

# 7 Moving a soda can by electrostatic charge. Also known as magic.

Charges can easily be redistributed along the surface of a conductor. In this case you will observe the rotation of a conductor (metal can) by simply placing a charged non-conductor (acrylic rod) near it.

1. You need to ensure that the metal can has a neutral charge. Grab the metal can and touch the ground wire at the same time.
2. Place the metal can on the table and lay it flat on its side.
3. Charge the large acrylic cylinder by rubbing it hard with the wool cloth.
4. Place the charged acrylic rod parallel to the metal can. Now at this point you should see the can rotate. Don't let the can touch the rod. **Does the can move away or toward the rod? Does the metal can have a similar, opposite, or neutral charge when compared to the nonconductor?**
5. Move the rod away from the can in a parallel motion. **As you move the rod away what is occurring to the charges on the surface of the can?**

# 8 That is it for the lab. Put everything back as it was and enjoy your day