

Electrostatics

Object:

This experiment allows you to investigate the production of static charge, conservation of charge and the behavior of charges on conductors which are interacting via Coulomb forces.

Apparatus:

Power supply 30, 500 and 1000 V.D.C., Electrometer, Faraday ice pail, 2 conducting spheres, 1 pair of charge producers, a proof plane, connecting leads, 1 coaxial cable connector, and 1 experimental capacitor.

Introduction:

Electrostatics is the study of stationary charge, but the process of making measurements often disturbs the system being observed. The combination of the Faraday ice pail, which allows the sensing of charge without contacting the charged object, and the electrometer, which behaves like an insulator (preventing large scale flow of charge) allows us to observe charge on an object with minimum disturbance.

Electrometer:

The electrometer can be used to measure the relative size and sign of a charge on an object, though the units displayed on the meter are volts instead of Coulombs. Since charges exert forces on one another there is the possibility of their doing work on one another. This concept is related to energy much like it was in gravitational theory, and you will soon study the potential energy of a charge distribution and the “potential” at a point in space in much the same way gravitational potentials were used. The unit Volt refers to this concept but for our purposes it suffices to realize that the size and sign of the potential (Volts) is proportional to the size and sign of the charge (Coulombs), and hence relative size and sign of charges can be deduced from direct meter measurements.

In the lower right corner of the electrometer is the on-off switch, the lock-open-check toggle switch and a zero adjust. In the lock or check position the meter input is grounded and the meter can be set to zero with the zero adjust. (Anything connected to the meter input will also be grounded and discharged as well). The lock position holds the meter grounded while the check position momentarily grounds it and returns it to the open position when released. Leave the meter in the lock position except when you are ready to make a measurement.

Since the electrometer is so sensitive charges which build up on you, may affect it strongly and give inaccurate measurements, it is advisable to touch a grounded piece of metal (cold water pipe or something connected to an outlet ground) frequently and avoid wearing long sleeve sweaters when making measurements if possible. Also, for each separate measurement start on the 30 volt scale and increase sensitivity as needed.

Faraday Ice Pail:

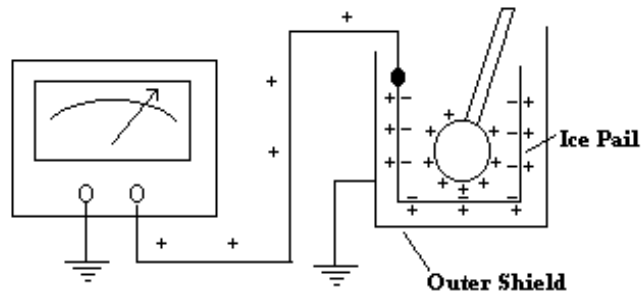
The Faraday ice pail connected to an electrometer uses the fact that charges can move freely in conductors to sense the presence of a charge without actually contacting the charged object. We say that we induce a charge separation on a metal because charges are attracted to opposite charges and tend to move away from those with the same sign (actually though both + and - charges exist in equal numbers in an uncharged metal, the negatively charged electrons do the moving since the positive charges are associated with the massive nuclei which are pretty rigidly locked in place).

Experiment:

Connect your Faraday Ice Pail (the concentric mesh cylinders) to the electrometer using the coaxial cables with the red clip connected to the inner cylinder (ice pail) and the black clip to the outer one (shield). Also connect the outer cylinder to a known ground. (This becomes a convenient ground with which to discharge yourself periodically). With the meter in the 30 volt position and set to "ZERO LOCK" (for older models set the toggle switch to "LOCK"), turn on the meter and zero it. Then turn the bottom dial from "ZERO LOCK" to "PUSH TO ZERO" (set the toggle switch to "OPEN" on older models) and measurements can be made. If the meter fails to return to zero between measurements, pushing the bottom dial in (placing the toggle in "CHECK" on older models) briefly should zero it for you.

The charge producers are aluminum disks with colored (blue and white) material on one side. Initially and between measurements remove residual charge by breathing lightly on each and touching them to the grounded outer mesh. (You may test their neutrality by inserting them about 2/3 of the way into the inner cylinder without touching it and observing a zero reading.)

Figure #1 shows the effect of inserting a net positive charge into the cylinder.



I. Charge Measurement and Conservation

1. Lightly rub the charge producers together and insert one of them into the ice pail being careful not to touch the pail with the charged disk. Note the magnitude and direction of the meter swing. **(Note that the meter should return to zero when the disk is removed).**

2. Again insert a charged disk into the pail but now touch the pail with the disk and remove the disk. Note the reading.

3. Now remove residual charge from each disk and insert both into the pail and then rub them together without touching the pail and note the reading. Then remove one of the disks and note the meter reading due to the remaining disk. Now, remove this disk and insert the other one and note the reading.

Questions:

1. What can you conclude about the charge induced on the ice pail compared to the charge on the object?

2. Have you evidence in your readings to support the law of charge conservation? Explain what you think happens when you rub the charge "producers" together?

3. Is charge actually "produced" or are plus and minus charges only separated?

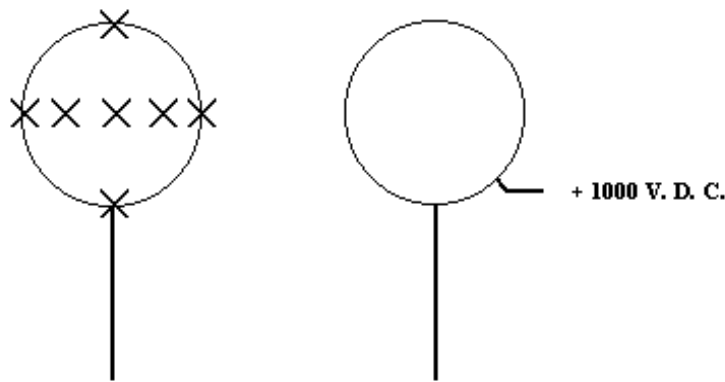
II. Induced Charge on a Sphere

1. With the power supply turned off, connect one of the aluminum spheres to the 1000 Volt D.C. terminal output of the power supply and the GND terminal to the ground of the electrometer.

2. Place the other sphere (isolated) about one cm from the first one - not touching it. Then turn on the power supply (a device which removes negative (-) charges from the sphere giving it a net positive charge), and adjust it to several hundred volts.

3. Using the proof plane (the uncoated aluminum disk on an insulated handle) touch the isolated sphere at various places (not touching the charged sphere) with the flat surface of the proof plane and measure the charge that is transferred to the proof plane from each point of the sphere (which is proportional to the local charge on the sphere). Do not touch the pail or ground with the proof plane between measurements.

4. Sketch the charge distribution on the sphere using (+) and (-) symbols and the electrometer reading to indicate magnitude (for example all points marked "x" on the isolated sphere). See figure #2.



5. Move the isolated sphere well away from the charged sphere and touch the isolated sphere to ground to remove any residual charge. (Check to be sure its net charge is zero using the proof plane and ice pail.)

6. Now move the isolated sphere as close to the charged sphere as possible without touching it. Assuming the charge distribution to be similar to that of 4, choose a point that has the maximum positive charge and touch it with a wire connected to ground for a moment.

7. Turn off the power supply and move the spheres well apart again.

8. Measure the sign and magnitude of any residual charge on the isolated sphere.

Questions:

1. How did you place a charge on the sphere without contacting the charged sphere? If charge is conserved, where did this charge come from?
2. Explain the charge distribution of the isolated sphere in steps 3 and 4.
3. Explain the results obtained for step 8.

III. Experimental Capacitor

The device to be used, called a capacitor, consists of two parallel circular plates, one fixed and one movable, such that the spacing between them may be varied. Spacers fix the minimum separation at 1mm and a vernier allows the spacing to be increased, and measured.

1. Set the plates at 1mm spacing and connect the power supply black post to the fixed plate and also the black wire of the electrometer coax to this plate.
2. Set the electrometer on the 30 volt scale, zero it, and connect the red wire to the movable plate.
3. **Never** connect the power supply to the plates with the electrometer in the "ZERO LOCK" ("LOCK" on older models) position as this will ground the power supply output and "short" circuit it. Set the electrometer in the "PUSH TO ZERO" ("OPEN" on older models) position, adjust the power supply meter to 15 volts and momentarily touch the wire connected to the red 30 volt output post to the movable plate and then remove it. You have now placed a charge on the plates from the power supply and this charge will remain constant.
4. Being careful to avoid touching the plates themselves, slowly move the movable plate increasing the separation between the plates up to about 10mm.
5. Note the changes in electrometer readings.

Never connect the power supply to the plates with the electrometer in the "ZERO LOCK" ("LOCK" on older models) position as this will ground the power supply output and "short" circuit it. The resulting smoke will definitely attract the attention of your lab instructor.

Question:

If the charge remains constant during the separation of the plates why do you see a change in electrometer reading? (Note that the electrometer reads in volts not coulombs).