Electrostatic Charging

Equipment List

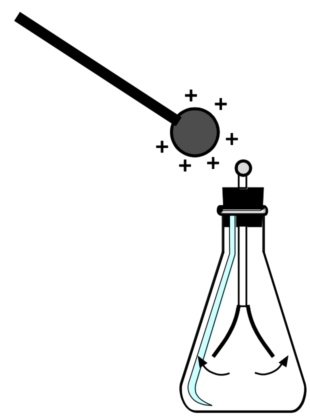
Qty	Items	Part Numbers
1	Charge Sensor	CI-6555
1	Charge Producers and Proof Planes	ES-9057A
1	Faraday Ice Pail	ES-9024A

Introduction

The purpose of this activity is to investigate the nature of charging an object by contact as compared to charging an object by induction. You will also determine the polarity of two charge 'producers' and measure the amount of charge on each.

Background

Electric charge is one of the fundamental properties of matter. Electrostatics is the study of electric charges and their characteristics. For example, like charges repel and unlike charges attract. An object is electrically neutral most of the time; that is, it has a balance of positive and negative electric charges. The positive charges (+) come from the proton, while the negative charges (-) are a result from the electrons. Rubbing different materials together, contact with a charged object, and charging by induction are three ways to create an imbalance of electric charge – sometimes called static electricity. Static electricity is a charge and the unit of charge is the coulomb with its SI symbol, *q*. Any positive or negative charge, q, that can be detected can be written as $q = ne$ where $n = \pm 1, \pm 2, \pm 3, \ldots$ in which *e*, the **elementary charge**, has the value of 1.602×10^{-19}C. Frequently in experiments milliCoulombs (mC), microCoulombs (μC), nanoCoulombs (nC) and even picoCoulombs (pC) are used.



When a positively charged object like a glass rod is placed near a conductor, like a plastic rod, electric fields inside the conductor exert forces on the free charge carriers in the conductor, which cause them to move. Some of those negative charges redistribute themselves near the glass rod leaving parts of the conductor furthest from the glass rod positively charged. This process occurs rapidly and stops when there is no longer any electric field inside of the conductor. The surface of the conductor ends up with regions where there are excess of one type of the charge over the other. This charge distribution is called an induced charge distribution. And the process of separating positive from negative charges on a conductor by the presence of a charged object is called electrostatic induction.

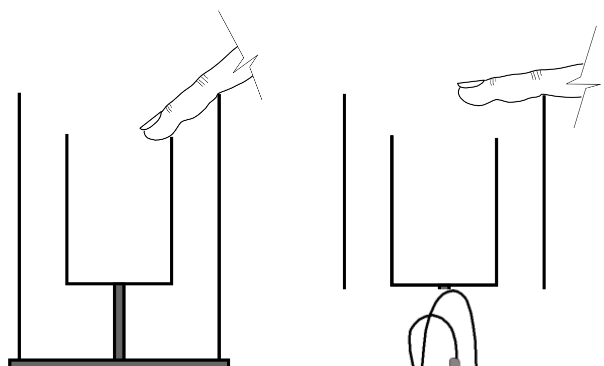
Michael Faraday used a metal ice pail as a conducting object to study how charges distributed themselves with a charged object was brought inside the pail. The 'ice pail' had a lid with a small opening through which he lowered a positively-charged metal ball into the pail without touching it to the pail. Negative charges in the pail moved to the inner surface of the pail leaving positive charges on the outside.

If the charged ball touches the inside of the ice pail, electrons would flow into the ball exactly neutralizing the ball. This would leave the pail with a net positive charge residing on the outer surface of the pail.

To experimentally investigate electrostatics, some charge-detecting or measuring device is needed. A common instrument for this purpose is the electroscope, a device with two thin gold leaves vertically suspended from a common point. When a charged object is brought near the electroscope, the gold leaves separate, roughly indicating the magnitude of the charge.

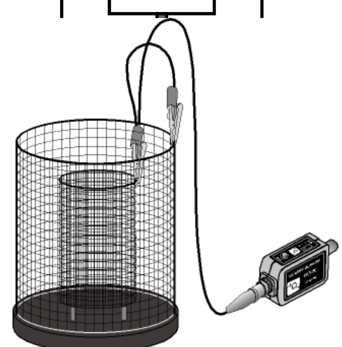
Although there are many different versions of the electroscope, all such instruments depend upon the repulsion of like charges to produce an output or reading. Unfortunately, such devices are relatively insensitive (large amounts of charge are needed to make the gold leaves separate), and the device does not have a quantitative reading.

The Charge Sensor is an ‘electronic electroscope’. In addition to providing a quantitative measurement, the Charge Sensor is more sensitive and indicates polarity directly.



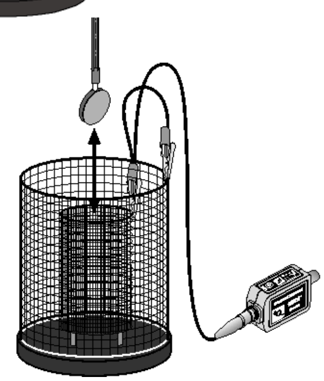
Setup

1. Connect the Charge Sensor to the interface & start *DataStudio*.
2. Set the “Gain Select Switch” of the Charge Sensor to 5X and the sample rate to 10 Hz.
3. Open a graph displaying the voltage from the Charge Sensor (Charge vs. Time Graph) and a Meter display.
4. Connect the alligator clips of the sensor’s cable assembly to the inner (**longer wire inside**) and outer baskets (**shorter wire outside**) of the Faraday Ice Pail.



Preparing to Record Data

Before starting any experiment using the ‘Faraday Ice Pail’, the pail must be momentarily grounded. To ground the pail, touch the inner pail and the shield at the same time with the finger of one hand.



Procedure

Determine the Polarity of the Charge Producers

1. Ground the ‘Ice Pail’ and press the ‘ZERO’ button on the Charge Sensor to discharge the sensor.
2. Briskly rub the blue and white surfaces of the Charge Producers together several times.

3. Click 'Start' in *DataStudio* to start recording data.

- Without touching the 'Ice Pail', lower the white Charge Producer into the 'Ice Pail'. Watch the Meter and Graph displays.
- Remove the white Charge Producer and then lower the blue Charge Producer into the 'Ice Pail'. Watch the results.

4. After a few moments, stop recording data.

Measure the Charge on the White Charge Producer.

5. Ground the 'Ice Pail' and press the 'ZERO' button on the Charge Sensor to discharge the sensor.
6. Briskly rub the blue and white surfaces of the Charge Producers together several times.
7. Start recording data.

- Lower the white Charge Producer into the 'Ice Pail'. Rub the surface of the white Charge Producer against the inner pail and then remove the Charge Producer. Watch the Meter and Graph displays.

8. After a few moments, stop recording data and save graph.

Measure the Charge on the Blue Charge Producer

9. Ground the 'Ice Pail' and press the 'ZERO' button on the Charge Sensor to discharge the sensor.
10. Briskly rub the blue and white surfaces of the Charge Producers together several times.
11. Start recording data.

- Lower the blue Charge Producer into the 'Ice Pail'. Rub the surface of the blue Charge Producer against the inner pail and then remove the Charge Producer. Watch the Meter and Graph displays.

12. After a few moments, stop recording data and save graph..

Charge the 'Ice Pail' by Induction

13. Ground the 'Ice Pail' and press the 'ZERO' button on the Charge Sensor to discharge the sensor.
14. Briskly rub the blue and white surfaces of the Charge Producers together several times.
15. Start recording data.

- <u>Without touching the 'Ice Pail' with the Charge Producer</u>, lower the white Charge Producer into the 'Ice Pail'.
- While the Charge Producer is still inside the inner pail, use the finger of one hand to momentarily ground the 'Ice Pail'. Watch the results.
- After you ground the 'Ice Pail', remove your hand and then remove the Charge Producer.

16. After a few moments, stop recording data.

17. Ground the ‘Ice Pail’ and zero the sensor and repeat the procedure using the blue Charge Producer and save graph..

Record your results in the Lab Report section.

Lab Report: Electrostatic Charging

Name: ____

Prediction

When two charge producers with different surface materials are rubbed together to create a charge imbalance, how will the electric charge on one of the producers compare to the electric charge on the other?

Graphs:

Indicate on the graphs each step of the experiment, i.e. charge producers ‘far’ away from experiment; charge producer inducing current, pail grounded, charge producer in contact with pail, etc.

Analysis

Questions

1. What charge (with sign) and polarity is the white Charge Producer? What charge (with sign) polarity is the blue Charge Producer?

2. What happens to the charge on the ‘Ice Pail’ when you rub the inner pail with the white Charge Producer and then remove the Charge Producer?

3. What happens to the charge on the ‘Ice Pail’ when you rub the inner pail with the blue Charge Producer and then remove the Charge Producer?

4. What happens to the charge on the ‘Ice Pail’ when the white Charge Producer is lowered into the inner pail without touching the inner pail?

5. What happens to the charge on the ‘Ice Pail’ when the ‘Ice Pail’ is momentarily grounded while the Charge Producer is still inside the inner pail?

6. What happens to the charge on the 'Ice Pail' after the white Charge Producer is removed from the inner pail?

7. How does the process of charging by contact differ from the process of charging by induction?

8. How many electrons are inside of the pail if the pail has a charge of 50 μC?

9. Assuming you have 6.24×10^{14} electrons and the surface area of the pail is 0.2 m^2, what is the charge density (C/m^2)?

