Electrostatics

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**Objective**: The objective of this experiment is to observe the process of inductance and the nature of induced charges. This will be done by measuring induced charges with an electrometer in three ways: first by inducing charge in a Faraday’s Ice Pail by rubbing charge producing objects together, using a conducting sphere hooked to a power supply to induce a charge in another unpowered sphere at close proximity, and finally using a pair of plates and a power supply to create an experimental capacitor and measuring the charge at varied separation distances. It should be noted that we will actually be measuring electric potential with the electrometer instead of directly measuring charge because it is easier to measure potential than charge. This is acceptable because the potential will be of similar magnitude and sign as the charge, so the measurements will be indicative of the actual results.

**Theory**

Electric charges produce fields that exert forces on other charges, much the same way mass produces a gravitational field that acts on other masses. Electric charge is measured in Coulombs (C).

The force exerted by an electric field from a point charge can be determined by solving the following equation:

[1]

while the magnitude of the electric field can be found by:

[2]

where k is Coulomb’s constant 8.99 E 9 N \* m2 / C2, q represents the charge of the source point charge and the object falling in the electric field of the source point in Coulombs, r is the radial distance in meters between the two, and r hat is the direction vector between the point source and the object.

In general, electric charges are restricted to protons and electrons, but can be observed in even smaller particles. Most of the time only protons and electrons are considered, especially for rudimentary science, such as is performed by undergraduate students. Because of this, electric charge is considered to be quantized, meaning charge can be measured by counts of the protons and electrons involved. The charge of these particles (also known as the fundamental or elementary charge) is -1.6 E -19 Coulombs for electrons, and -1.6 E -19 for protons, usuall represented in writing as an electron charge, e-. Often, though, due to the small size and large quantities these particles are present in, we measure charge as though it were a continuous quantity.

Because electrons and protons are often present in such close proximity, their oppositely charged fields often cancel one another for most purposes. However, when the two are distributed unevenly (known as a charge separation), then a consequential field will present itself. Because protons are more tightly held in the structure of an atom than are electrons, charge distributions are usually the product of displaced electrons, rather than displaced protons. This is readily apparent in materials like metals, where electrons are allowed to freely flow throughout the object, while the protons remain relatively stationary.

Electrostatics is the study of these charge distributions, which remain static until acted upon. In this lab we will attempt to measure the characteristics of objects with non-neutral charge distributions, which can be difficult because measuring uneven charge distributions often disturbs them. This will be done using a Faraday Ice Pail and an Electrometer.

A Faraday Ice Pail, does not actually hold ice, but rather is a tool that aids in measuring the charge on an object without touching it and disturbing the charge distribution (it is called an ice pail for historic reasons, because the actual implement used by Faraday was an ice pail). The Faraday pail is simply a conductive container with an open end. If a charged object is inserted into the inner space of the pail, then a charge is induced in the pail by the attractive or repulsive electric field coming from the charged object. The electric field emanating from the object causes a charge separation in the material (protons, electrons) of the pail, or induces a charge, without making contact. This method allows the charge in the object to exert a force on the electrons of the pail to move them, and the induced charge is equivalent to the charge on the object. Because this is done without the object and pail touching, a conductive path is never formed for electrons to flow between pail and object, disallowing a charge redistribution back to normal. The result is that the charge on the object is relatively undisturbed, while the pail is equivalently charged. This allows us to indirectly measure the charge on the object by proxy by using the electrometer to measure the charge on the pail.

The electrometer actually collects potential readings, which are measured in volts, as opposed to collecting charge readings in Coulombs. However, since the relative size and sign of the voltage reading will correspond to the relative size and the same sign as the charges we are measuring, it will be acceptable to measure the potential in volts rather than the charge in Coulombs. The following equation relates electric potential an charge to demonstrate this fact:

[3]

where V is the electric potential (voltage) measured in Volts (1 V = 1 J/C), k is Coulomb’s constant, q is the charge in Coulombs, and r is the distance to the field origin point from the point we are measuring from in meters. This potential indicates the change in energy incurred by moving a charged object through an electric field.

**Procedure**

The materials for the experiment include a 30, 500 and 1000 V.D.C. power supply, an Electrometer, a Faraday ice pail, 2 conducting spheres, 1 pair of charge producers, a proof plane, connecting leads, 1 coaxial cable connector, and 1 experimental capacitor.

The experiment will be performed in three parts:

Part I

The two charge producers will be rubbed together to create a charge on each of them. One of the charge producers will be inserted into the Faraday’s pail and withdrawn. The induced charge on the pail will be measured with the electrometer while the object is in the pail, and the reading will be recorded. Then the object will be inserted again, but this time so that it touches the pail, and the reading is recorded. Then the charge will be removed from both charge producers, and both will be inserted into the pail and rubbed together, carefully to not touch the sides of the pail. A reading is collected. Then one object will be withdrawn and this reading will be collected. Each of these steps will be repeated, but using the charge producer that was not used the first time.

Part II

With the power supply turned off, a conducting sphere will be connected to the power supply. The second sphere is place roughly 1 cm away, but not touching the first. The power supply is then turned on to about 100V. The proof plane is then touched to various points on the unpowered sphere, then removed, and the charge on the proof plane is measured. This is done repeatedly to “map” the size and magnitude of the charges on the sphere. This map is sketched.

The power supply is turned off and the unpowered sphere is then moved away and discharged through a ground. The unpowered sphere is then moved as close as possible to the powered sphere without touching, the power is turned back on, and the mapping procedure is repeated.

Part III

The two experimental capacitor plates are placed parallel to each other, such that one is fixed and the other moveable so that their spacing may be varied. The starting spacing should be about 1 mm. The black wires of the power supply and electrometer are connected to the fixed plate. Before connecting the red wire of the power supply to the moveable plate, connect the electrometer and zero it. It is very important to take care that the power supply is not connected while zeroing the electrometer, otherwise it can be damaged. After zeroing the electrometer, then the power supply can be fully connected.

The power supply is then turned on, and the plates are slowly moved apart, taking care not to let them touch one another. The plates are slowly moved to a separation of about 10 mm and readings are taken at 1mm, 2mm, 5mm, and 10 mm of separation.