1. Electrostatics

I. INTRODUCTION

Bodies are charged when they have either an excess or deficiency of electrons. For example, when a nylon rod is rubbed with a piece of wool, it acquires electrons and becomes negatively charged. A glass rod, on the other hand, loses its electrons and becomes positively charged when it is rubbed with a piece of silk. The positive charges are always fixed, while the negative charges can move about to balance the electrostatic forces.

A conductor is a material in which electrons can flow. In a conductor, all excess charge resides on its surface. There is no net charge at any point inside a conductor. In addition the electric field inside of a conductor vanishes, while it is perpendicular to the outer surface of the conductor. This explains why it is safe to be in an airplane in a lightning storm. If lightning were to hit the airplane, the charge would travel on the outside of the plane while the passengers remain safe inside, since there is no field inside a conductor like the metal body of an airplane.

In this experiment you will investigate how conductors are charged and discharged. You will learn how to charge by conduction and induction, and how they can be discharged by grounding. And finally, you will observe the nature of the charge on a conductor.

II. APPARATUS

You will need the following items for this experiment:

- Leaf Electroscope with metal cage and ground wires
- Acrylic and Nylon rods
- Wool and Cellophane
- Electrometer with leads
- Faraday Ice Pail
III. PROCEDURE

A. The Electroscope

Do the following procedures and answer each question on the attached answer sheet. The leaf electroscope should be placed in the metal cage (see Figure 1), and the black grounding wire should be clipped to the grounding prong of the outlet on the lab table. The free wire is used for grounding and only needs to be touched momentarily to whatever is to be grounded. This experiment is greatly affected by moisture and results may be hard to obtain if it is very humid. Wipe off rods with a cloth and dry your hands if you are unable to produce good results. When rubbing rods it is best to rub only in one direction.

Ground the electroscope after completing each step.

1. Rub the acrylic rod with wool. This will give the rod a net negative charge. Then rub the rod lightly against the metal sphere on top of the electroscope. Remove the rod. The leaves should be standing out indicating that the electroscope is charged. You have charged it by conduction.
   A. What is the sign of the charge on the electroscope?
   B. What was the direction of electron flow?

Figure 1: The electroscope.
2. Again negatively charge the acrylic rod by rubbing it with wool. Hold the acrylic rod close to but not touching the top sphere of the electroscope. The leaves should separate.
   C. What is the sign of the charge on the top sphere of the electroscope?
   D. What is the sign of the charge on the leaves of the electroscope?
   E. What happens if you take the rod away from the electroscope? Explain.

3. Bring the negatively charged acrylic rod about one-half centimeter above the top of the electroscope without touching it. Ground the electroscope by briefly touching the top sphere with the ground wire. Remove the acrylic rod and the leaves will stand out. You have charged by induction.
   F. What is the sign of the charge on the electroscope?
   G. Why do the leaves collapse upon grounding and stand out when the rod is removed? Explain in terms of the whole charging process.

4. Give the electroscope a negative charge by conduction as in part 1. Next, charge the nylon rod by rubbing it with cellophane. Bring the rod near the electroscope.
   H. What happens to the leaves?
   I. What does this tell you about the movement of charge?
   J. What can you conclude about the sign of the charge on the nylon rod?

5. Again give the electroscope a negative charge by conduction as in part 1. Charge the nylon rod by rubbing it with wool. Bring the rod near the electroscope.
   K. What happens to the leaves?
   L. What does this tell you about the movement of charge?
   M. Comment on the sign of the charge on the nylon rod here and in part 4.

B. The Faraday Ice Pail

The electrometer is an improvement to the electroscope because it gives an indication of the magnitude and polarity of the charge. The electrometer should be connected as shown (see Figure 2). Use a banana lead with alligator clip to connect the electrometer to earth ground, the same as you did for the metal cage from part A. Make sure to attach another grounding lead to ground yourself with. When performing the experiment, adjust the sensitivity of the electrometer so that most readings are in the upper 2/3 of the scale. To set the meter to zero, make sure the earth ground is connected.
and press the “ZERO” button. This button can also be used to ground the ice pail when the test leads are connected to both pails. Upon completion of the experiment, be sure to turn the electrometer off.

The charge producers from the first portion of the experiment (various rods and other materials) will again be used as the charged objects. These charged objects must be inserted into at least the lower half of the ice pail. You should attempt to rub the end of the rod with the various materials (rather than simple the middle section of the rod). This will ensure that the portion of the rod that is inside the pail actually has a static charge.

![Figure 2: The experimental setup for the Faraday Ice Pail with Electrometer usage.](image)

The electrometer works by measuring the amount (and sign) of the charge on a metallic object inside of the device (see Figure 3). Effectively, this metallic object is connected to the inner pail via the cable & red alligator connector. The inner pail, metallic object inside the electrometer and cable may all be treated as ideal conductors that are in contact with each other. The outer pail is essentially neutral and not connected to either the inner pail or the inner workings of the electrometer. (How the device measures the amount of charge on the metallic object is a bit beyond us right now. Eventually we will learn that the metallic object is simply a capacitor and the
Electrometer is able to accurately measure the voltage across the capacitor, which is directly proportional to the amount of charge).

![Diagram](https://via.placeholder.com/150)

**Figure 3**: Simplified schematic of the electrometer and inner pail.

*The electrometer should be zeroed before beginning each part of the experiment.*

1. Rub the acrylic rod with wool and insert the rod into the inner pail. Do not let the rod touch the either pail. Note the electrometer reading. Remove the rod completely from the pail and again note the electrometer reading.
   N. What was the polarity shown on the electrometer while the rod was inserted?
   O. What can be concluded about the polarity of the charge on the rod? To help you determine the answer to this question, draw a picture showing the distribution of charges which should answer the following questions: What is the sign of the net charge on the metallic object? Inner pail? And, rod? Does your net charge on the rod agree with your earlier experiments?

2. Rub the nylon rod with cellophane and insert the rod into the inner pail. Do not let the rod touch the either pail. Note the electrometer reading. Remove the rod completely from the pail and again note the electrometer reading.
   P. What was the polarity shown on the electrometer while the rod was inserted?
   Q. What can be concluded about the polarity of the charge on the rod? To help you determine the answer to this question, draw a picture showing the distribution of charges which should answer the following questions: What is the sign of the net charge on the metallic object? Inner pail? The rod? Does your net charge on the rod agree with your earlier experiments?
3. Again rub the acrylic rod with wool and insert the rod into the inner pail. This time you do want to make contact with the inner pail. Rub the rod on the inner pail. To get a greater deflection on the electrometer, you may have to repeat this procedure (being sure not to touch the inner pail with your body between rubbings). After you have rubbed the inner pail, you should remove the rod from the pail. Note the electrometer reading after you have touched the rod to the inner pail.

R. What was the polarity shown on the electrometer after the rod contacted the inner pail?

S. What can be concluded about the polarity of the charge on the rod? To help you determine the answer to this question, draw a picture showing the distribution of charges which should answer the following questions: What is the sign of the net charge on the metallic object? Inner pail? And, rod? Does your net charge on the rod agree with your earlier experiments?
IV. DATA - Electrostatics

Date: _____________________

Date: _____________________

A. ______________________________________________________________________

B. ______________________________________________________________________

C. ______________________________________________________________________

D. ______________________________________________________________________

E. ______________________________________________________________________

F. ______________________________________________________________________

G. ______________________________________________________________________

H. ______________________________________________________________________

I. ______________________________________________________________________

J. ______________________________________________________________________

K. ______________________________________________________________________

L. ______________________________________________________________________

M. ______________________________________________________________________

N. ______________________________________________________________________
V. ADDITIONAL QUESTIONS

1. In the first experiment what would happen to the leaves of the electroscope if instead of touching the rod to the upper plate/ball, you touched it to a copper wire? This wire is firmly connected to the upper plate/ball of the electroscope and not touching any other objects. In your explanation be sure to comment on any movement of charges.
2. Consider another hypothetical experiment where like the previous one you don’t touch the rod directly to the electroscope. Instead you touch it to a nylon (acrylic) thread that is in turn connected to the electroscope. Again, comment on the electroscope’s leaves as well as the movement of any charges.

![Diagram of charged rod and nylon thread connected to electroscope]

3. Consider a much larger Faraday Ice Pail, one where you could comfortably stand inside the inner pail. Assume that there is a platform on which you can stand that is not in electrical contact with the pail or any other objects. What would the electrometer show if you were to now rub the acrylic rod with the wool? Carefully, explain how the charge may or may not move in each of the relevant objects. You might want to also draw a picture.