Electrostatics

Introduction

This lab will give you experience with, and allow you to experimentally verify, some of the basic principles of electrostatics that have been introduced in lecture. You will learn to detect the presence of electric charges and, at least semi-quantitatively, measure them. You will learn what it means to “charge” an object, and gain some insight into what factors influence the distribution of charges on real physical objects.

Equipment

You will detect the presence of charge on an object by using an instrument called an electrometer, which will be connected to a device consisting of double wire mesh cylinders mounted on a set of insulators. The inner cylinder, called a Faraday Ice Pail, is surrounded by a larger mesh cylinder, called a Faraday Cage, which can be “grounded”, that is, connected in such a way that there is no charge on it. The Faraday Cage shields the Ice Pail from the effects of extraneous charges which may be present in the laboratory (for example, on your clothing or your books) and allows the electrometer to measure only those charges which are placed inside, or physically on, the Ice Pail itself.

You will be working with two “sources” of charge in the course of this experiment. One source will be a pair of disc-shaped objects, one white and one blue, which are mounted on insulated handles. When these discs are rubbed together, they become “charged”, and you can then investigate the characteristics of these charged objects using the Ice Pail and electrometer.

The other source of charge is a high-voltage device called an “Electrostatics Voltage Source”. Using the Electrostatics Voltage Source, you will be able to charge large objects so that you can investigate the manner in which charge is distributed over their surfaces.

Caution: Never allow the Electrostatics Voltage Source, or anything connected to it, to come in direct contact with the electrometer or the Ice Pail to which the electrometer will be connected. The electrometer is a very delicate instrument, and any direct contact with high voltage devices will destroy it.

Caution: Never allow the Electrostatics Voltage Source, or anything connected to it, to come near or touch the computer monitors. Damage to the monitor can occur.

Throughout this experiment, the Ice Pail should be connected to the electrometer as shown in Figure 1. The electrometer has two connections on the right side. The connector labeled “ground” should be connected to the “com” connector on the Electrostatics Voltage Source. The “signal input” connector should have a special cable, called a coaxial cable, connected to it. The other side of this cable should end in two alligator clips, one color-coded red, the other black. The black clip should be connected to the outer Faraday Cage which surrounds the Ice Pail; the red clip should be connected to the inner Ice Pail. This arrangement of connections will allow the electrometer to detect and measure any charge placed within, or on, the Ice Pail. (Note: The electrometer reading is a voltage, not a charge. The voltage is proportional to, not equal to, the amount of charge placed in the Ice Pail.)
1. Measuring charge

Introduction

In this experiment you will use the electrometer to investigate how two materials become charged when they are rubbed together.

Preparation

At your lab station, you should have three disc-shaped objects mounted on long, insulating handles. One of these is silver. It is referred to as a “proof plane”. This can be put aside for now, it will be used later in the experiment.

Of the other two, one should be white and one blue. These will “produce” the charges you will be experimenting with. But in order to clearly understand what is going on with these charges, it is important that the results not be “muddled” by the presence of unwanted stray charges. Therefore, you must first ensure that there is no stray charge already on the Ice Pail or on either of the colored discs.

To ensure that there is no stray charge on the Ice Pail, first turn on the electrometer. Then simultaneously touch both the Ice Pail and the Faraday Cage with your hand. While doing this, depress the zero button on the face of the electrometer. If it wasn’t before, the electrometer should now read zero. Release the zero button and remove your hands from the Ice Pail and Faraday cage. The electrometer should still read zero. If you are unable to get the electrometer to zero, consult your instructor.

You can now use the electrometer to verify that the two colored discs are uncharged. To do this, take each disc separately and insert it into the Ice Pail. Be careful not to actually touch the disc to the Ice Pail, just placing it within the Ice Pail, somewhere near the bottom, is sufficient. The disc is uncharged if the electrometer continues to read zero.

If the needle of the electrometer moves, indicating that either or both of the colored discs are charged, you will need to discharge them before proceeding. To do this, lightly breathe on them so that they become slightly moist from the moisture in your breath, then touch the colored surface to your hand. This should discharge the disc. Check it with the electrometer to make sure that it is indeed discharged. If not, repeat the process until the electrometer indicates that there is no excess charge on the disc.

Now that you are sure that the discs are discharged, and the electrometer is reading zero, you are ready to investigate what happens when an object becomes charged.

Figure 1: Apparatus
**Electrostatics**

**Procedure**

- Rub the white and blue discs together to charge them.
- Insert the white disc into the Ice Pail, being careful not to actually touch either the Ice Pail or the Faraday Cage surrounding it. Adjust the range setting on the electrometer to obtain the maximum needle deflection possible without going off scale. Record the electrometer reading, both magnitude and polarity, in Table 1 below. Withdraw the white disc from the Ice Pail, again making sure the disc does not touch anything.
- As with the white disc, insert the blue disc in the Ice Pail. Record the electrometer reading in Table 1. Withdraw the blue disc, making sure it does not touch anything.
- Now hold both discs near, but not in contact with, each other and insert both of them into the Ice Pail simultaneously. Record the electrometer reading.
- Repeat the measurement for the white and blue discs individually to ensure they are still charged. Record your results.

<table>
<thead>
<tr>
<th>Object Inserted in Ice Pail</th>
<th>Electrometer Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>White disc (first trial)</td>
<td></td>
</tr>
<tr>
<td>Blue disc (first trial)</td>
<td></td>
</tr>
<tr>
<td>White and blue disc together</td>
<td></td>
</tr>
<tr>
<td>White disc (second trial)</td>
<td></td>
</tr>
<tr>
<td>Blue disc (second trial)</td>
<td></td>
</tr>
</tbody>
</table>

*Table 1*

**Conclusions**

Based on your observations and measurements, describe the process by which the two discs became charged.
Which disc became positive and which negative?

Did one disc become significantly more highly charged than the other (which would indicate that the charge somehow came from some external source) or were the two discs charged to nearly the same magnitude (which would indicate that charge was simply transferred from one disc to the other)? Be sure to state explicitly what experimental evidence you have that “charge” was transferred.

2. Charge distribution on a charged conducting object

Introduction

In part 1 you used the electrometer to investigate the charge on a small charged object. But how is charge distributed on an object? Is it spread out evenly, like a coat of paint on a surface, or is there more charge some places than others? And if so, what determines how the charge is distributed? In this part of the lab you will investigate these questions using large objects so that any variations in the charge distribution can be detected.

a. Charged conducting sphere

Procedure

- At your lab station there should be two insulated metal spheres, approximately 12 cm in diameter. One of them should have a red wire connected to it. Connect this wire to the +1000 V connection on the Electrostatics Voltage Source and turn the Source on.
- Set the electrometer to the 10 volt range and make sure that it is zeroed.
- Now take the proof plane (the silver colored disc), touch it to the sphere, then insert it into the Ice Pail (as usual, do not actually touch the Ice Pail). Note the polarity and magnitude of the electrometer reading. On the circle in Figure 2 draw an arrow that points to the spot on the sphere where you touched the proof plane. Then record the electrometer reading next to the arrow.
• Withdraw the proof plane from the Ice Pail, touch it to a different place on the sphere, and again insert it into the Ice Pail, measuring and recording the electrometer reading.

• Repeat for several different places on the sphere.

Figure 2: Measurements on the charged conducting sphere

Conclusion

Referring to your results, in writing draw a conclusion about the way in which charge is distributed over the surface of the sphere. Is it evenly distributed or are there places that have a significantly greater amount of charge? Also illustrate your conclusion by filling the circle in Figure 3 with + and/or – signs so that their density conveys the nature of the actual charge distribution.

Figure 3: Illustration of charge distribution on sphere
b. Charged conducting cylinder

Procedure

- At your lab station there should be an insulated metal plate with a metal cylinder sitting on it, and a red wire with an alligator clip attached to it. Disconnect the sphere from the +1000 V terminal and connect one corner of the metal plate to the same terminal using the wire and alligator clip.
- Repeat the procedure in part a above. Investigate the entire surface of the cylinder and plate including the edges of the plate and the edges of the cylinder. As with the sphere record your electrometer measurements in Figure 4 below using the side view or top view as appropriate.

![Side View](image1.png)  ![Top View](image2.png)

*Figure 4: Measurements on the charged cylinder*

Conclusion

Referring to your results, in writing draw a conclusion about the way in which charge is distributed over the surface of this object. Is it evenly distributed or are there places that have a significantly greater amount of charge? How is the cylinder different from the sphere? Also illustrate your conclusion by filling both the top and side views in Figure 5 with + and/or – signs so that their density conveys the nature of the actual charge distribution.
c. **Charge distribution on an isolated object**

**Procedure**

- Disconnect the metal plate from the Electrostatics Voltage Source and reconnect the metal sphere.
- Take the second metal sphere, ground it by touching it briefly with your hand, and use the proof plane to verify that it is uncharged. While you are doing this, make sure you do not bring the second sphere anywhere near the one connected to the Electrostatics Voltage Source.
- Now bring the second sphere near, but not in contact with, the one connected to the Electrostatics Voltage Source. A distance of about 5 cm should work nicely.
- Use the proof plane to investigate how (or if) charge is distributed over the surface of the second (isolated) sphere. Be careful as you make your investigation that you do not touch the proof plane to the high voltage sphere. As before, record the electrometer readings on the circle representing the isolated sphere in Figure 6 below.
Conclusion

Referring to your results, in writing draw a conclusion about the way in which charge is distributed over the surface of this object. Is it evenly distributed or are there places that have a significantly greater amount of charge? How is the isolated sphere different from the charged sphere in part a? Also illustrate your conclusion by filling the circle that represents the isolated sphere in Figure 7 with + and/or – signs so that their density conveys the nature of the actual charge distribution.

Figure 7: Illustration of charge distribution on isolated sphere

3. Charging by induction

Introduction

In this experiment you will add another step to the procedure you carried out in the last section with the high voltage and isolated spheres to investigate a process called charging by induction.

Procedure

- Move the isolated sphere at least 50 cm away from the high voltage sphere and verify that the isolated sphere is still uncharged.
- Move the isolated sphere back to a position about 5 cm away from the high voltage sphere and briefly touch the back side of the isolated sphere with your hand. (Be careful not to touch the high voltage sphere while you are doing this).
- Now carefully move the isolated sphere away from the high voltage sphere and turn off the Electrostatics Voltage Source. Make sure when you do this that you do not touch the isolated sphere. Handle it only by its base.
Now use the proof plane to investigate whether there is any charge on the isolated sphere. As before, record the electrometer readings on the circle in Figure 8 below.

Figure 8: Measurements on the sphere

Conclusion

Referring to your results, in writing draw a conclusion about the way in which charge is distributed over the surface of this object. Is it evenly distributed or are there places that have a significantly greater amount of charge? How is this sphere different from the charged sphere in part 2a and the isolated sphere in part 2c? Also illustrate your conclusion by filling the circle in Figure 9 with + and/or – signs so that their density conveys the nature of the actual charge distribution.

Figure 9: Illustration of charge distribution on the sphere

Write a detailed description, including diagrams if necessary, of how the charging by induction process, just observed, occurred. Then write an explanation of what you would have to do differently, perhaps using different equipment, in order to produce an isolated sphere charged with the opposite sign by the same technique; that is, by touching the isolated sphere while it is near, but not in contact with, a high voltage object. (Use the back of this page if necessary.)