Name	________________________________	Date	__________	Time to Complete	____h ____m
Partner	________________________________	Course/ Section	______/_______	Grade	__________

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*. 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.)**

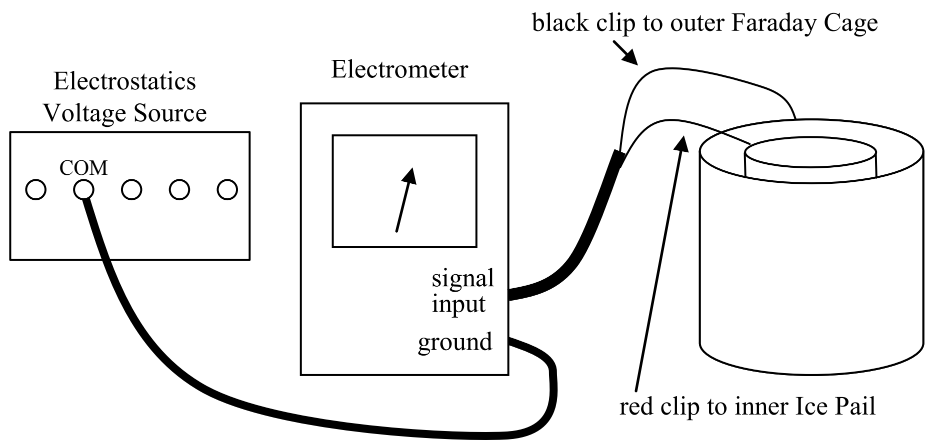


Figure 1: Apparatus

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. (Touch, don't rub.) This should discharge the disc. Check it with the electrometer to make sure that it is indeed discharged. If not, repeat the process, or perform other feats of black magic, until the electrometer indicates there is no excess charge on the disc.

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

Prediction

You have learned in lecture that two neutral objects can become charged if they rub against each other. Based on your understanding of this phenomenon predict the outcome of electrometer measurements of the charge state of the blue and white disks after rubbing them together. Include a prediction of the *sign* of each disk's charge and the *relative magnitude* of disk's charge.

Prediction:

Experiment

Use the electrometer to explore the outcome of rubbing the two disks together. Your prediction might be confirmed on your first try, or you might observe a variety of phenomena that are difficult to interpret. Electrostatics experiments are notorious for being difficult to control.

In words describe the phenomena you observe, but also record the results of the electrometer readings in an organized fashion.

Here are some things to watch for. Of course, first and foremost, what electrometer reading do you observe for each disk after rubbing them together? Is the result consistent upon repeated trials? What do you (what should you) observe when both disks are put in the Ice Pail together before *and after* rubbing them? If you hold a charged disk in the Ice Pail for a long time can you observe it discharging? Does one disk consistently discharge faster than the other, and how does this cloud or clarify your interpretation of earlier results? Does the electrometer respond to objects other than the disks, like the plastic sticks the disks are attached to, or your arm, or the motion of a person nearby?

Try to make sense of your observations in light of what you have learned about charging by rubbing.

Observations and results:

Conclusions

Can you conclude that one disk has a tendency to become positively charged and one negatively charged? If so which one?

Point to the evidence, if you found any, which was consistent with your prediction. If none, explain how your results are inconsistent with your prediction, and discuss any conclusion they suggest.

Although you don't observe anything at the microscopic level in this experiment, describe in words a microscopic model of this phenomenon that is consistent with your main results.

2. Charge distribution on a charged conducting object

Introduction

In Part 1 you used the electrometer to investigate the *net* 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. Spherical conductor

Procedure

- At your lab station there should be two isolated metal spheres, approximately 12 cm in diameter. One of them should have a red wire connected to it. Connect this wire to the +3000 V connection on the Electrostatics Voltage Source and turn the Source on.
- Set the electrometer to the 10 volt range to start, and make sure it is zeroed, but switch to a higher or lower range if appropriate.
- 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 sphere 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.

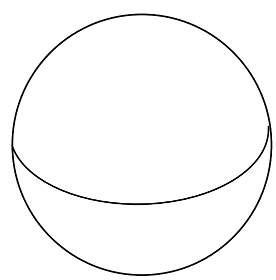


Figure 2: Measurements on the charged conducting sphere

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 surface of the sphere in *Figure 3* on the next page with + and/or – signs so that their density conveys the nature of the actual charge distribution.

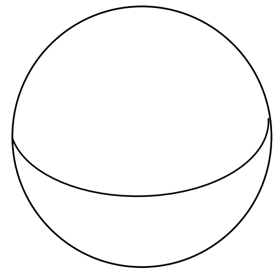


Figure 3: Illustration of charge distribution on sphere's surface

(Note: The + and/or – symbols that you added in *Figure 3* should *not* be placed *only* at the points where the proof plane touched the surface. This is not simply a symbolic picture of your results. It is rather a *conclusion*, in the sense that it is an interpolation of your measurements to a conclusion as to how charge is spread over the *entire* surface. In more technical phrasing, you are attempting to illustrate the object's *surface charge density* as a function of location on the surface. Therefore, the + and/or – symbols should fill the surface in a way that reflects your conclusion.)

b. Irregularly shaped conductor

Introduction

Next you will use the proof plane to investigate the charge distribution on the surface of a charged, but irregularly shaped, conductor. The idea behind the proof plane technique is to make the relatively small proof plane a part of the local surface where it makes contact. To the extent that its shape matches the local shape of the surface it, in a sense, becomes the surface, and takes on the properties of the surface, namely, the local surface charge density. Therefore, it can be used to map a surface's charge density.

The one caveat to this technique is that quantitative comparisons are only reliable to the extent that the proof plane's shape matches the local shape of the surface at the point where it makes contact. Our proof plane is flat. Therefore, we can expect quantitatively reliable results when investigating flat surfaces or curved surfaces having a large radius of curvature. That said, in this activity you will investigate regions of a surface that are not flat at all, sharp edges and corners. This might certainly color our interpretation of the results.

Nonetheless, the technique will be effective at giving at least a qualitative look at local surface charge density, in that it should give a correct ranking of charge density as you explore different locations on the surface.

Procedure

- At your lab station there should be an insulated metal platform with a metal cylinder sitting on it, and a red wire with an alligator clip attached to it. Disconnect the sphere from the +3000 V terminal and connect one corner of the metal platform to the same terminal using the wire and alligator clip.
- Investigate the charge distribution on the cylinder-and-platform. *Alternating back-and-forth with your partner*, conduct a proof-plane measurement as in Part 2a at least three times at each of the six marked locations in *Figure 4*. Record your measurements on the blank lines.

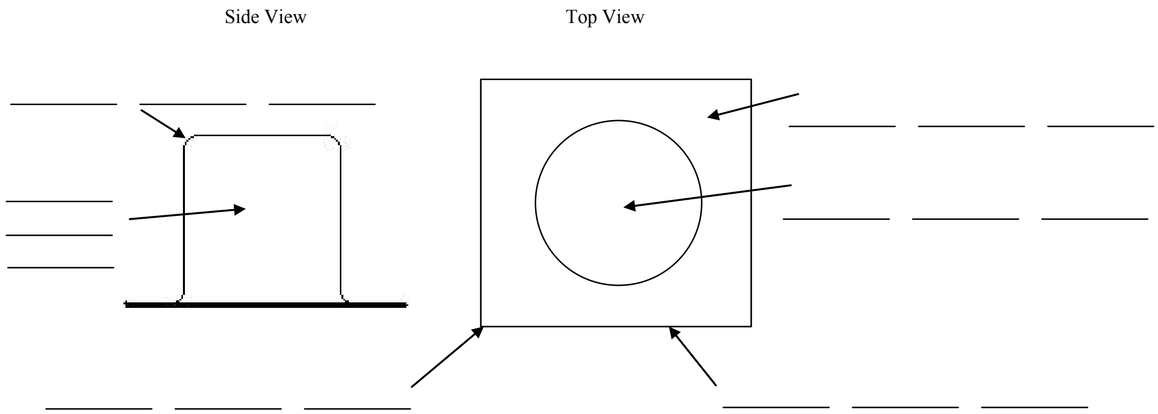


Figure 4: Measurements on the charged cylinder-and-platform

Conclusion

Based on trends in your results, in writing draw a conclusion about the way in which charge is distributed over the surface of this object, cylinder-and-platform. Is it evenly distributed or are there locations that have a significantly greater charge density? How is the cylinder different from the sphere?

If you didn't include the answer to the following question in your conclusion, answer it here. *What kinds* of locations on the cylinder-and-platform have a greater surface charge density?

Illustrate your conclusion by filling the surfaces of the plate and cylinder in 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.

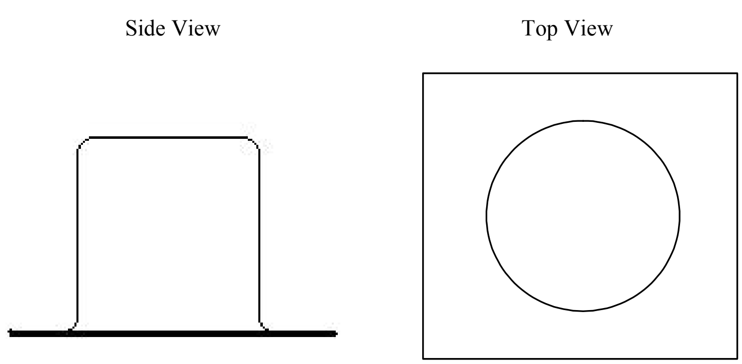
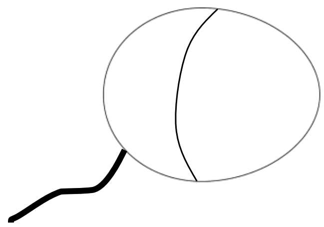


Figure 5: Charge distribution on cylinder's and platform's surface

Questions

1. Imagine a conducting object as shown in the picture below, shaped like an egg, which is connected to the high voltage power supply. Based on the conclusion you just wrote, where will the charge density be highest and where will it be lowest on the surface of the egg? *Draw* your prediction for the egg's surface charge distribution and *explain* your prediction.



2. You have learned that a spherical conductor connected to a high voltage supply has a uniform charge distribution over its surface. Now consider two spherical conductors, one having twice the radius of the other. Both are connected to identical high voltage supplies. (The spheres are far enough apart that they do not interact with each other; consider them separately.)

   Although each sphere will have a uniform surface charge density, which one will have a greater surface charge density? Or will they both have the same surface charge density? Explain your prediction. *It should be based on the conclusion you just wrote.*

   In answering the last question, at any point did you find yourself saying, "On the larger sphere the same amount of charge is spread over a larger area, therefore…." You shouldn't have. This statement is incorrect; they do not have the same amount of charge, even though the voltage is identical. We will come back to this issue in a few chapters. *Restrict yourself to a prediction based on your conclusion about trends in the charge distribution on the cylinder and platform.*

c. Charge distribution on an isolated sphere near a high voltage sphere

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 1-2 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 sphere representing the isolated sphere in *Figure 6* below. Choose a judicious set of points on the surface at which to conduct your measurements.

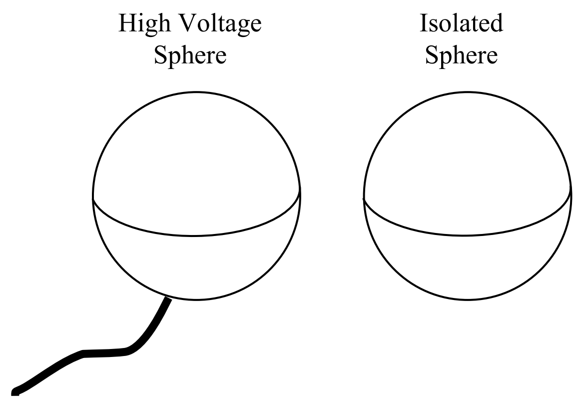


Figure 6: Measurements on the isolated sphere

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 the isolated sphere different from the charged sphere in Part 2a?

Also illustrate your conclusion by filling the surface of the sphere that represents the isolated sphere in *Figure 7* with + and/or – signs so that their density conveys the nature of the actual charge distribution.

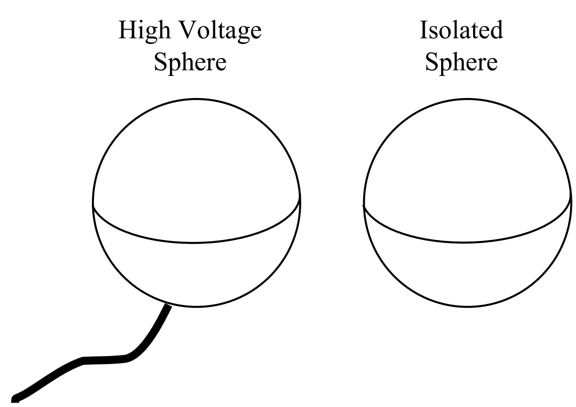


Figure 7: Illustration of charge distribution on isolated sphere's surface

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 far away from the high voltage sphere and verify that the isolated sphere is still uncharged.
- Move the isolated sphere back to a position about 1-2 cm away from the high voltage sphere and briefly touch the back side of the isolated sphere with your finger. (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 sphere in *Figure 8* below.

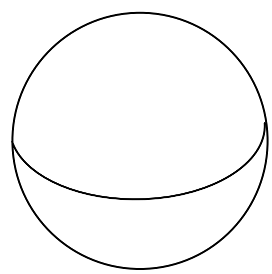


Figure 8: Measurements on the sphere

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 surface of the sphere in *Figure 9* with + and/or – signs so that their density conveys the nature of the actual charge distribution.

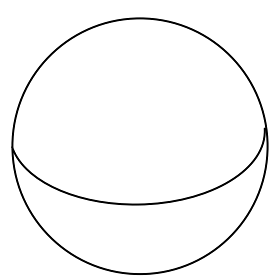


Figure 9: Illustration of charge distribution on the sphere's surface

Write a detailed *written explanation* of how the charging by induction process, just observed, occurred. (No pictures please, just words.)

In this process, how much charge transferred from the high voltage sphere to the isolated sphere?

Imagine conducting the same procedure with one difference. Instead of using an Electrostatics Voltage Source with high *positive* voltages, use one with high *negative* voltages. Incorporating this one change *draw* a step by step description/explanation of charging by induction. (Pictures only please, no words.)