Electric Charge and the Electrostatic Force

Goals and Introduction

When two electrically-charged objects are brought near each other, they can either attract or repel, depending on the sign of each of the electric charges. In nature, we find two types of electric charge: *positive* and *negative*. This was known early on even though we had no way of knowing which was which. It was through experiments, similar to the investigations you will perform in this activity, that allow us to know there must be two types of electric charge.

When we bring an electrically-charged object near another, they will exert equal and opposite forces on one another based on Coulomb's Law (Eq. 1). Coulomb's Law expresses that the magnitude of the electric force between two charged objects with electric charges q_1 and q_2, depends on the distance between the centers of the objects, r, and a constant, k, called Coulomb's constant $k = 8.99\times10^{9}\ \mathrm{N\cdot m^2/C^2}$.

$$F_e = \frac{k|q_1||q_2|}{r^2} \qquad \text{(Eq. 1)}$$

Objects can become electrically charged through friction. When two objects experiencing a friction force between each other, some of the electrons on one of the surfaces can be transferred to the other. In this sense, one of the objects can become positively charged (loses electrons) and the other can become negatively charged (gains electrons). It wasn't until we better understood the existence of the atom that we could determine that it is really the negative charges (electrons that are transferred, because in the end, all we would be able to discern is that each object would have an opposite effect on another charged object. This was evidence of their being two kinds of electric charge.

The story, and these investigations is only made more interesting when we observe that some materials "appear" to always be charged, and yet so not possesses any excess charge – these materials are conductors. Conductors have an atomic structure that allows electrons to redistribute themselves anywhere on the conductor. This means that if we were to have an uncharged conductor hanging motionless, and bring a positively-charged object nearby, the electrons on the conductor would rearrange themselves to be nearer the rod, leaving behind some nuclei with fewer electrons on the far-side of the conductor. The resulting difference in distance between the rod and the two regions of electric charge on the conductor means that the net electric force on the conductor would be attractive, and toward, the positively-charged rod! To understand this, we must think about Coulomb's Law applied between the rod and each region of charge on the conductor separately. The electrons are closer to the rod than the nuclei they left behind, and thus the electric force between they and the rod will be greater, and attractive, than the repulsive electric force between the rod and the positive nuclei.

In today's lab, you will go through a series of experiments to observe that there are two types of electric charge and attempt to determine the amount of electric charge that had been transferred during an act of charging a set of originally neutral objects.

Goals: (1) Observe the effect of a charged object on a charged and on an uncharged conductor
(2) Observe that there are two types of electric charge
(3) Measure the electric force between two charged objects and determine an estimate for the amount of charge transferred during the charging process.

Procedure

Equipment – base with hanger, two hanging metallic spheres, a glass rod, a rubber rod, an acrylic rod, silk fabric, wool fabric, ruler

NOTE: At several junctures during this experiment, you will need to make sure that the metal spheres are discharged before performing the next step of the experiment. This can usually be accomplished by touching a charged sphere with your hand and holding it for a second.

1) **Measure and record** the mass of each of the metal spheres. Yes, the mass is not large. Be sure to keep track of which is which so you don't have to measure them again!

2) **Measure and record** the length of the string attached to each sphere. Again, be sure to keep track of which is which!

3) Hang one of the metal spheres from the hanger. You may need to rotate the hanger so that the sphere hangs freely and possibly have it hang over the edge of the table. Discharge the sphere.

4) Using friction, transfer electric charge between the acrylic rod and the silk. Then, bring the rod near the sphere without touching it. **Record** your observations.

Question 1: What happened when you brought the acrylic rod near the sphere? Explain what you observed. Why did it happen?

5) Using friction, transfer electric charge between the acrylic rod and the silk. Then, allow the rod to touch the sphere before removing it. Transfer charge between the acrylic rod and the silk again and bring it near the sphere without touching it. **Record** your observations.

Question 2: What happened when you brought the acrylic rod near the sphere? Explain what you observed. Why did it happen? What must have happened when you touched the rod to the sphere earlier?

6) Now, using friction, transfer electric charge between the rubber rod and the wool. Then, bring the rod near the sphere without touching it. **Record** your observations.

Question 3: What happened when you brought the rubber rod near the sphere? Explain what you observed. Why did it happen?

Question 4: Do the observations, thus far, confirm that there are two types of electric charge, if we assume friction is able to move charges from one object to another? Explain.

7) Now, using friction, transfer electric charge between the glass rod and the silk. Then, bring the rod near the sphere without touching it. **Record** your observations.

Question 5: Based on your observations, what can we say about the electric charge on the glass rod? Explain.

8) Discharge the sphere. One of the rods should have caused different behavior than the other two. Use friction to charge this rod and allow it to touch the sphere. Then, **predict** what one of the other rods will do when it is charged and brought near the sphere. Charge it and brin it near the sphere without touching it. **Record** your observations.

Question 6: Was your prediction verified? State your prediction and explain the outcome.

9) Hang both of the spheres from the hanger and discharge them. **Make note** of the location of the where the spheres touch. You might consider having one person hold a ruler underneath the spheres, or lay one along the table that you can use as a reference. Be sure that the spheres touch each other in some way as they hang freely.

10) Using friction, transfer electric charge between the rubber rod and the wool. Then, allow the rod to touch the spheres before removing it. **Record** your observations of the spheres once they settle down and return to equilibrium.

Question 7: Why are the spheres no longer touching? Explain.

11) **Measure and record** the distance each of the spheres has moved from the original location they shared before they were touched. Call this distance, *x*, in each case, but keep track of which value goes with which sphere. Then, discharge the spheres so they hang, touching again.

12) Repeat steps 9 through 11 two more times.

As always, be sure to organize your data records for presentation in your lab report, using tables and labels where appropriate.

Data Analysis

Calculate the gravitational force on each of the spheres, separately.

Consider one of your spheres, the length of its string, and the distance *x* you recorded in each case. Calculate the angle that the string makes with the vertical direction in each case.

Repeat this for each case of the other sphere.

Use the angle and the gravitational force, for each sphere in each case, to calculate the tension that must be in the string in each case. You should consider the free-body diagram for each sphere to help you do this.

Note that in those free-body diagrams, the horizontal component of the tension must equal the electric force in each case. Also, note that the electric force on each sphere should be equal and opposite in each case. Use the tension in each case to calculate a value for the electric force that each sphere is experiencing.

Calculate the distance, *r*, between the spheres by adding the values of *x* in each trail.

Then, assuming each sphere acquired an equal amount of electric charge, calculate the amount of electric charge on each sphere for each of the three trials (steps 9-11).

Questions 8: How well did the values of the electric force on each sphere match up in each individual trial? Explain.

Question 9: Do the values of the electric charges you found seem reasonable? How many electrons must have been transferred, in each trial, to account for the total charge on the spheres?

Error Analysis

There is no Error Analysis for this lab.

Questions and Conclusions

Be sure to address Questions 1 through 9 and describe what has been verified and tested by this experiment. What are the likely sources of error? Where might the physics principles investigated in this lab manifest in everyday life, or in a job setting?

Pre-Lab Questions

Please read through all the instructions for this experiment to acquaint yourself with the experimental setup and procedures, and develop any questions you may want to discuss with your lab partner or TA before you begin. Then answer the following questions and type your answers into the Canvas quiz tool for "Electric Charge and the Electrostatic Force" and submit it before the start of your lab section on the day this experiment is to be run.

PL-1) As a charged object is brought near an uncharged conductor, it will

A) attract the conductor.

B) repel the conductor.

C) do nothing.

D) hurt.

PL-2) A positively-charged object touches a conductor and the conductor acquires a net positive charge after the object is removed. This occurs because

A) electrons move from the object to the conductor.

B) electrons are pulled into the air off of the conductor.

C) there is magic everywhere you look.

D) electrons will move from the conductor to the object.

PL-3) Suppose that an object repels a second object as it is brought near to it. If a third object is brought near the second object and attracts it, which of the following statements is FALSE?

A) The third object attracts the second because they have opposite signs of excess charge.

B) The first object repels the second object because they have like types of excess charge.

C) The third object would attract the first object.

D) The third object would repel the first object.

PL-4) Prakesh calculates that there is an electric force of 0.0035 N between the spheres in this experiment. If the spheres are separated by 0.054 m, what is the magnitude of the excess charge on each sphere? Express your answer in nanocoulombs, nC.

PL-5) Prakesh calculates that there is an electric force of 0.0035 N between the spheres in this experiment. The spheres are separated by 0.054 m. As in the previous question, he determines, q, the excess charge on each sphere. What is the total excess charge on the spheres, combined, that originally came from the rod? Express your answer in nanocoulombs, nC.