LABORATORY 1
ELECTROSTATIC FORCES AND COULOMB'S LAW

Objectives

- to be able to explain charging by contact
- to be able to explain grounding
- to be able to explain the concept of charging by induction
- to be able to use Coulomb's Law for qualitative explanations, estimations and quantitative calculations

Overview: In this lab, you will explore concepts in electrostatics and then apply these concepts in an investigation in order to determine the amount of charge on different size spheres using Coulomb's Law.

Equipment:

1 piece of PVC pipe
1 glass or acrylic rod
1 piece of fur
1 piece of silk
1 electroscope
1 large piece of metal

Exploration 1: Electrostatics

Exploration 1.1 Take Pre-test 1 Electrostatics.

Exploration 1.2 Charging by contact

a. Obtain an electroscope. Touch a charged piece of PVC pipe to the ball on the top of the electroscope and then remove it. What happens to the leaves of the electroscope?

Draw a picture of the charge distribution on the electroscope that could be used to explain why the leaves of the electroscope moved apart.

Was charge transferred from the rod to the electroscope? How do you know? Are your observations -- that the leaves moved apart – and your model (your picture of the charge distribution) consistent with charge being transferred to the electroscope?

b. While the leaves on the electroscope are still apart, touch the top of the electroscope with a large piece of metal (large conductor) and then remove it. Draw a series of pictures of how the charge distribution changes on the electroscope and on the large piece of metal that explain why the leaves of the electroscope go down. Start with a picture of the charge distribution before the metal comes in contact with the electroscope. Draw at least one picture of a possible charge distribution while the metal and electroscope are in contact and draw a picture of the charge distribution after the metal and electroscope are no longer in contact.

Do either the electroscope or the metal have a net charge after this process? Explain.

c. Charge the electroscope again. While the leaves on the electroscope are still apart, touch the top of the electroscope with your finger and then remove it. Are you an insulator or a conductor? Explain. Do you have a net charge after your finger is removed?

When we touch the electroscope with a large conductor, we are said to have *discharged* the electroscope. This is also called *grounding* the electroscope.

Exploration 1.3 Charging by Induction

a. One person should touch the ball on top of the electroscope with their finger and hold their finger there, while another person brings a charged PVC pipe near, but not touching the leaves of the electroscope. While the PVC pipe is near the electroscope, the first person should remove their finger from the top of the electroscope. Then remove the PVC pipe from near the electroscope.

Draw a series of pictures of how the charge distribution changes on the electroscope and on the large piece of metal throughout this process. You should draw at least four pictures.

Use your pictures to predict the sign of the charge that is now on the electroscope. Record your prediction here.

Use a charged PVC pipe or glass rod brought near, <u>but not touching</u>, the electroscope to test your prediction.

Discuss the charge on the electroscope with your TA.

This is called *charging by induction*.

Exploration 2: Coulomb's Law

Exploration 2.1

This exploration is a thought experiment.

a. Consider two identical conducting spheres. One conductor is touched with a piece of PVC pipe that has been rubbed with fur. The sphere that has been touched with the rod is now charged. Let's say that it has a negative charge q.

Draw a picture of how the excess charge q is distributed on the sphere. Remember that a sphere with charge q has both positive and negative charges, but more negative than positive charges. The symbol q represents the additional negative charges, the excess negative charge. It is common to draw only the excess charge in a picture, with the understanding that the object contains both positive and negative charges, but more negative charges than positive ones. Explain how the charges would be distributed on the sphere.

If the two spheres were put in contact with each other, how would the charge be distributed? How much charge would be on each sphere? Explain your reasoning.

Discuss your answer with a TA.

Equipment:

- 1 Wimshurst machine
- 1 Coulomb's Law experimental setup
- 1 pith ball
- 2 foil coated Styrofoam balls of different sizes
- 1 electronic scale to measure the mass of the balls
- 1 lamp
- 1 rod stand
- 2 rods
- 2 clamps

Investigation 1: The amount of charge on a pith ball

Coulomb's Law describes the interaction force between two point charges. By Newton's Third Law, each charge exerts a force of equal magnitude and opposite direction on the other charge. Coulomb's Law states that the magnitude of the force is directly proportional to the product of the charges and inversely proportional to the square of the distance between them. The direction of the force is along a line between the two charges. Mathematically, the magnitude of the force is given by

$$F = k\frac{Q_1 Q_2}{r^2},$$

where Q_1 and Q_2 are the charges, r is the distance between the charges and k is a constant equal to 9.0×10^9 Nm^2 /C^2.

A Wimshurst machine is a machine that can be used to charge objects positively or negatively. When you turn the crank on the Wimshurst machine, one of the balls on the arms of the machine is charged positively and one is charged negatively. You can attach other objects to each of the balls by a conducting wire, in order to charge them up.

At your lab table is a Wimshurst machine connected to two pith balls hanging from threads from a wooden rod, as in the picture below. When you turn the crank, the pith balls will be charged. Since the pith balls are identical, they will have approximately the same amount of charge.

Investigation 1.1 When the balls are charged up, how much charge do you think will be on each pith ball? Predict for each size ball in the table below, how much charge would be on each ball, for the same distance between the centers of the balls. This is a prediction. (It is not right or wrong.) Each person in your group may make a different prediction and the predictions may be very different. We are going to do an experiment to test your prediction. We are going to do an experiment to estimate the amount of charge on each ball.

Estimate the magnitude of the charge on one sphere from each set of spheres.

Type of Sphere	Estimated Charge on One Sphere (C)
Pith ball	
Foil covered Styrofoam 1	
Foil covered Styrofoam 2	

In the space below describe why you chose the magnitude of charge you did for each sphere. Discuss why your predictions of the magnitudes are either the same or different.

Investigation 1.2 The pith balls are suspended inside a box. There is a grid on the bottom of the box. A light is shone down from above so that the shadows of the balls can be seen on the grid. You can then measure the distance between the pith balls when they are charged up. Using the distance measurement, a measurement of the mass of the ball and a measurement of the length of the string, you will be able to calculate the electrical force on each ball and use that to find the amount of charge on each ball.

a. You should have three sets of spheres: pith balls and two sizes of foil covered Styrofoam balls, and foil covered ping pong balls. If the balls are not covered with foil, cover them at this time. Measure the masses of the balls and record them in the table below.

Type of Sphere	Mass (kg)
Pith ball	
Foil covered Styrofoam 1	
Foil covered Styrofoam 2	

The balls will be suspended from the hook and charged using the Wimshurst machine. The charges on each sphere should be the same magnitude and sign. In the space below, explain why this is so.

b. Tie one set of spheres to the hook. Make sure the strings have the same length and are not twisted about each other. Measure the length of the string and record it in the table following these instructions. Place the light guard around the spheres. Slowly crank the Wimshurst machine. The spheres should begin to repel each other. By slowly cranking the Wimshurst machine the spheres should move apart slowly. Make sure the arms of the Wimshurst machine are far enough apart that no arcing occurs between them. If you charge the spheres quickly, they may begin to swing in such a way that determining the distance between their shadows is difficult. You want the spheres to move apart and stay about the same distance from each other. This is best achieved by slowing charging them rather than quickly charging them. Do not let spheres get too close to the side of the light guard or they could discharge. Once the spheres are separated, record the distance between the centers of their shadows in the table below. Do this for each set of spheres. Before changing the spheres, be sure to touch the arms of the Wimshurst machine to each other to discharge them.

Type of Sphere	Length of String (m)	Distance (m)
Pith ball		
Foil covered Styrofoam 1		
Foil covered Styrofoam 2		

c. In the space below draw the free body diagram for one of the spheres and derive the equation for the electric force on the sphere in terms of separation distance, charge, and mass.

Discuss your equation with your TA.

d. Calculate the charge on each of the spheres and record it in the table below. Show your calculations clearly.

Type of Sphere	Calculated Charge on One Sphere (C)
Pith balls	
Foil covered Styrofoam 1	
Foil covered Styrofoam 2	

e. How does the amount of the charge you calculated from each measurement compare to your prediction? Discuss why they were similar or different.

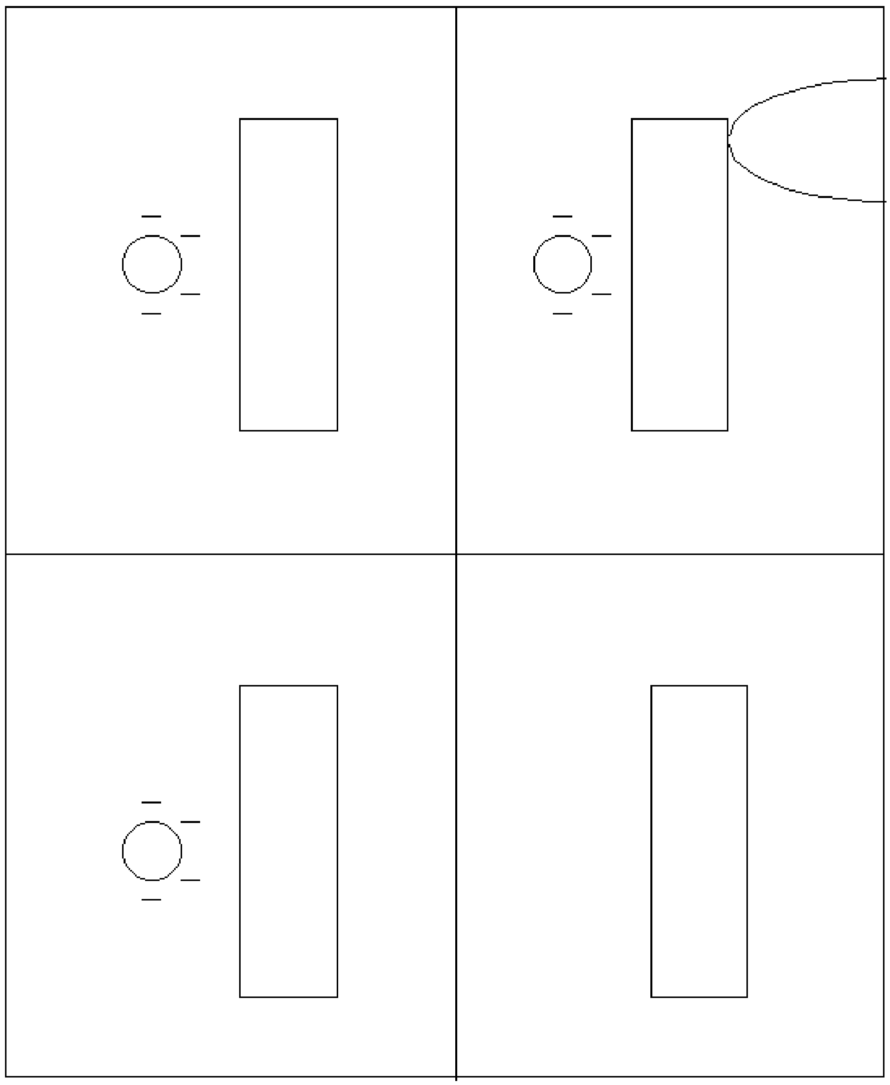
f. Summarize your results below.

Summary. In the space below, summarize what you have learned about the magnitude of charge on a pith ball and the measurements you made in order to determine the magnitude of the charge. Describe, briefly, what you did, show any relevant equations, and discuss how the equations were used.

Laboratory 1 Homework
Exploring the Nature of Electrostatic Forces

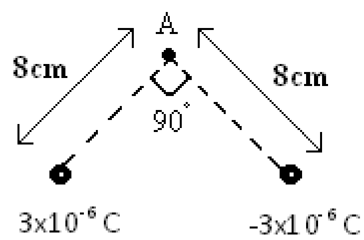
1) Consider a piece of aluminum foil near a negatively charged pen, as in the picture below. While the pen is near the foil, you touch the foil, then remove your finger. Then remove the pen.

The "comic strip" below illustrates the process. Draw other relevant charges, and explain the motion of charges in each frame.



(from Ruth Chabay and Bruce Sherwood, *Electric and Magnetic Interactions*, John, Wiley, and Sons Inc., NY, 1995)

2) Two point charges, each of magnitude $3x10^{-6}$ C, but opposite sign, are placed 8cm from point A, as in the diagram below. A point charge of magnitude $1x10^{-6}$ C is placed at point A.



Determine the magnitude and direction of the net electric force on the charge at point A. Show your work and explain your reasoning.