LABORATORY 2
ELECTRIC FIELD

Objectives

- to be able to describe the concept of electric field both qualitatively and quantitatively
- to be able to represent the electric field at a point in space by a vector
- to be able to represent the electric field by appropriately drawn field lines
- to be able to interpret the field line representation of the electric field
- to be able to discuss the principle of superposition as applied to electric fields

Overview: In this lab, we will explore the concept of electric field, including the vector representation of electric field, the representation of the field by field lines and superposition of fields.

Equipment:

1 rubber rod
1 piece of PVC pipe
1 piece of fur
1 metal-coated pith ball hung from non-conducting threads
1 glass rod
2 stands for rubber and glass rods
1 piece of silk
1 EM Field Program

Exploration 1: Representations of the Electric Field

Exploraton 1.1 Take the pre-test for this lab.

Exploraton 1.2 The Electric Field

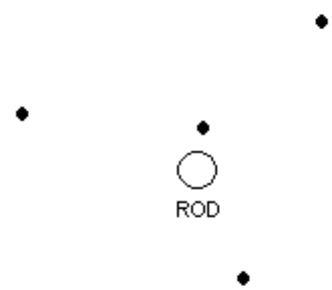
The electric field is a vector quantity defined at a point in space as the force that would be experienced by a small positively charged object placed at that point divided by the charge of the object:

$$\mathbf{E} = \frac{\mathbf{F}}{q}$$

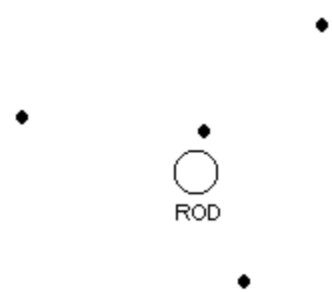
q is a small positive charge. If a small positively charged particle is located at a point in space, the electric field at that point in space is the force on that particle divided by the charge. If there is no charge at a point in space, the electric field at that point can be determined by placing a small positive test charge at that point and finding the force on that charge in order to determine the electric field at that point in space. The units of electric field are N/C.

a. To investigate the vector nature of an electric field, use a *negatively* charged pith ball, suspended from a string, as the test charge. (The ball is charged by touching it with a rubber rod that has been rubbed with rabbit fur.) Charge up the rubber rod by rubbing it with rabbit fur and place it in an insulating stand in a vertical position. Now hold the test charge by its string and move it around the rod. Note the direction and magnitude of the force at various locations around the rod.

Make a qualitative sketch of some of the electric field vectors around the rod at the points in space marked on the following diagram. The length of each vector should roughly indicate the *relative* magnitude of the field (that is, if the E-field is stronger at one point than another, make its vector longer). Of course, the direction of the vector should indicate the direction of the field. Put the tail of the vector at the location of interest.



b. How would the diagram change if the negatively charged rod were replaced with a positively charged rod? Draw the new diagram below.



c. In this part, you will check the diagrams you have drawn by using a program called EM field.

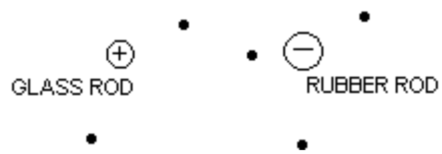
Open the EM field program on the computer. Choose a charge (of either sign and any magnitude) and place it in the center of the screen. Choose *electric field vectors* from the drop down menu. Click on the places indicated in your diagrams above and the program will draw electric field vectors at those points.

Repeat for a charge of the opposite sign.

How do the vectors the program drew compare to the vectors you drew?

Exploration 1.3 Superposition

a. Suppose you had two charged rods, one charged positively and one charged negatively, about 3cm apart. Predict the relative magnitude and the direction of the electric field at each point indicated in the diagram below. Explain your reasoning for your predictions.



b. Check your predictions in part **a** in two ways.

i. Observing the motion of a charged pith ball placed at each location.

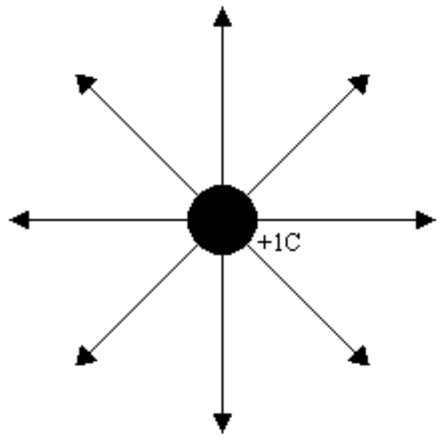
ii. Use the EM field program.

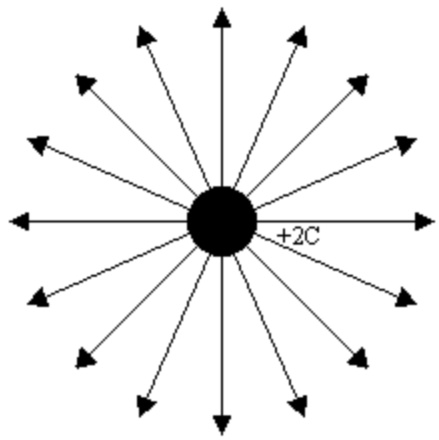
c. The principle of superposition states that the electric field at a point in space can be found by the vector addition of the electric fields at that point in space due to all charged objects. Is this consistent with your answers to part **a** and part **b** above?

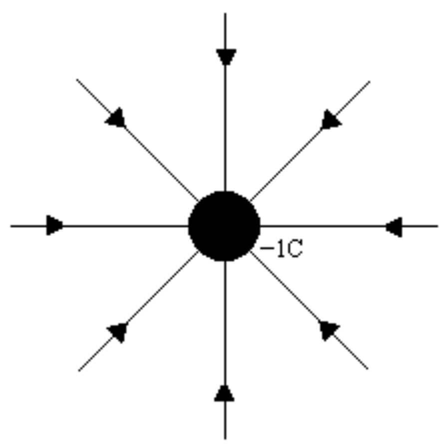
Exploration 1.4 Electric Field Lines

You have been representing the electric field due to a configuration of electric charges by an arrow that indicates magnitude and direction. This is the *conventional representation* of an electric field. An alternative representation of the vector field involves defining *electric field lines*.

Below is a series of diagrams with electric field lines drawn for +1C, +2C, and -1C charges.







a. From looking at the diagrams how do you tell where the field is strongest? Explain. How do you tell where the field is weakest? How do you tell the direction of the field? Explain.

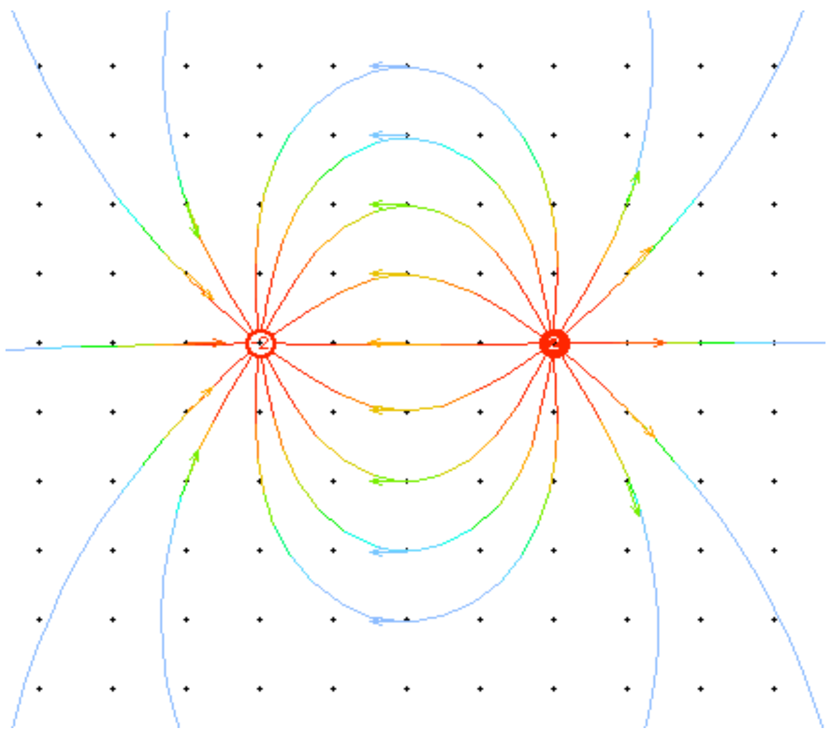
b. Based on the diagrams for electric field lines, draw a diagram with electric field lines for +3C charge.

c. Is there an electric field at points in space where there are no electric field lines drawn? Explain.

d. Use the EM field program to draw electric field lines for different configurations of charges. In the EM field program, how do you tell where the field is strongest? How do you tell where the field is weakest? Explain.

How do you tell the direction of the field? Explain.

f. Below is the electric field line diagram for two charges, +2C and –2C drawn in the electric field program.



(Drawn in *EM Field* by D. Trowbridge and B. Sherwood, Physics Academic Software, 1998)

Use the EM field program to draw the field lines for two charges of the same sign (both positive or both negative) and equal magnitude.

g. Use the EM field program to draw the field lines for two charges with different magnitudes.

h. Use the EM Field program to draw field lines for two different configurations of charges of your choosing.

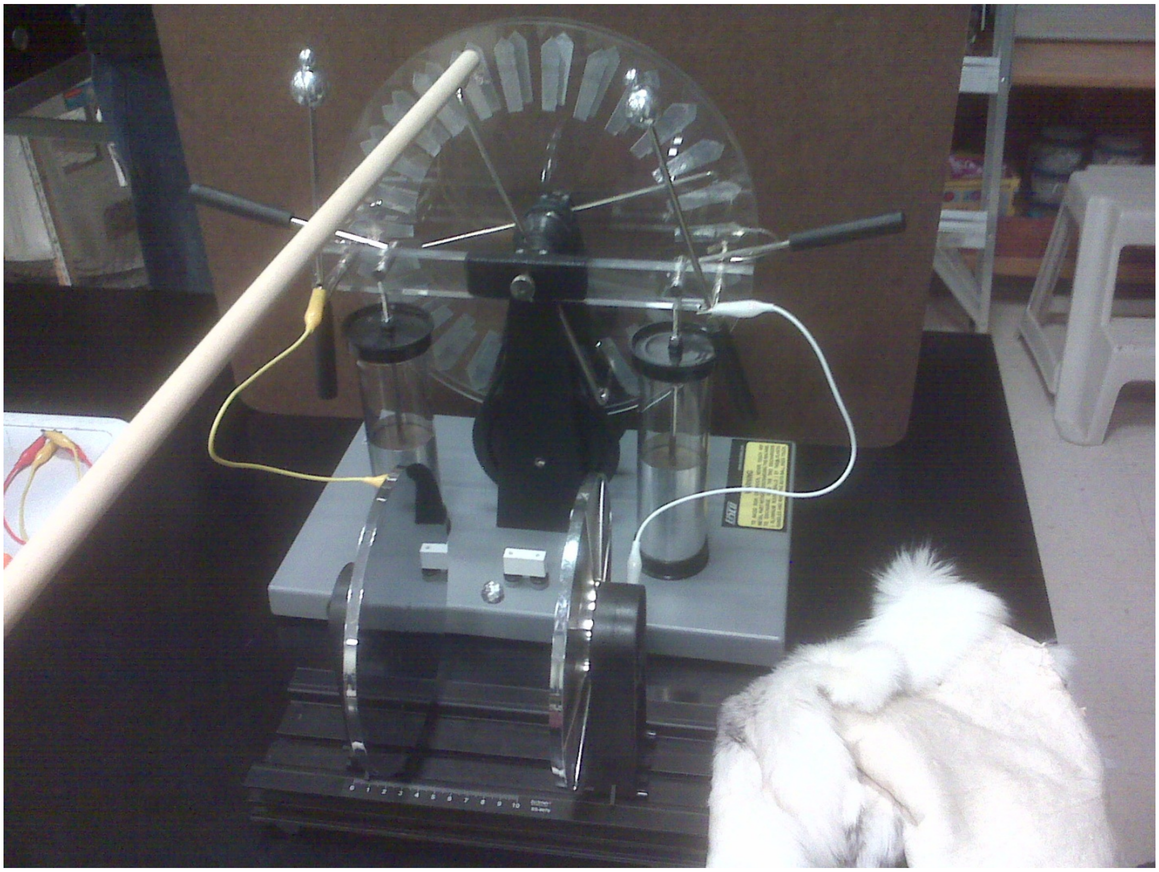
Equipment:

1 Wimshurst machine
2 parallel plates piece of PVC pipe
alligator clips
1 aluminum-coated pith ball hung from non-conducting threads
1 PVC pipe
1 rabbit fur
1 rod stand
1 wooden dowel
1 balance
1 protractor

Investigation 1

a. At your table is a Wimshurst machine, a large parallel plate capacitor with adjustable plates, and alligator clips. Attach the capacitor to the Wimshurst machine using the alligator clips. The setup is shown in the photo below for your reference. Set the plates about a hand's width apart. Humidity can have a strong effect on electrostatic experiments, so this distance will likely have to be adjusted. This is a reasonable estimate to start with. Measure this distance and record it in the space below.

Distance between plates ____________________________________



Measure and record the mass of the aluminum coated pith ball.

Mass of pith ball _________________________

Hang the pith ball from a wooden dowel. Adjust the height of the ball so that it hangs at about the middle of the plates.

Measure the length of the string and record that distance in the space below.

Length of string _________________________

Charge the pith ball by rubbing a piece of PVC pipe with rabbit fur and touching the pipe to the pith ball. The pith ball will probably begin swinging after being touched by the PVC pipe. Allow it to come to rest. After most (or all) of the swinging has stopped, hang the pith ball between the plates in the center of the plates so that it is not attracted strongly to either plate.

Turn the crank on the Wimshurst machine to begin charging the plates. If the plates are too close together, the pith ball will be attracted to one of the plates enough to touch it, and after the pith ball touches the plate, it will bounce back and forth between the plates. While this is fun to watch, it means you will need to increase the separation distance between the plates and start over. If you change the distance between the plates, make sure you record the new distance between the plates.

You want the pith ball to be displaced enough by the electric field between the plates so that it no longer hanging vertically, but at an angle to the vertical. When the pith ball is hanging at an angle, use a protractor measure the angle the string makes with the vertical.

Angle with vertical ___________________________

i) In the space below, draw the free body diagram for the pith ball. Label the forces.

ii) Write the equations for the net force in each direction.

iii) Use the force equations to determine the magnitude and direction of the electric force on the pith ball. Show your work in the space below.

In order to determine the strength of the electric field from the force equations, it is necessary to know the charge on the pith ball. It is not possible to measure the charge on the pith ball accurately with the equipment available in the laboratory. In order to estimate the magnitude of the electric field, we will use the magnitude of the charge you determined for the pith ball last week in lab.

Estimate the strength of the electric field between the plates, using the force equations and the relationship between the field and the force. Show your work in the space below.

b. Change the distance between the plates without touching the plates, so that the amount of charge on each plate remains the same. Do not let the pith ball touch either of the plates while you are changing the distance.

What happens to the angle the pith ball hangs as the distance between the plates changes? Record whether you increased or decreased the distance between the plate and what happened to the angle.

Discuss whether the magnitude of the electric field between the plates increases, decreases or remains the same when you change the distance between the plates, based on your observations.

Discuss your answer with your TA.

d. Repeat the measurements you made in part **a.** to estimate the magnitude of the electric field after you moved the plates. Use the space below to show your work.

e. The potential difference between the plates is determined by the amount of charge on each plate. It is also possible to calculate the potential difference between the plates for this particular situation (two parallel plates) from the magnitude of the electric field and the distance between the plates.

Use the equation $\Delta V = -Ed$ to calculate the potential difference between the plates for both cases above. Show your work in the space below.

Did the value of the potential difference you calculated change after you moved the plates? Is this what you expected? Explain.

Summary. Summarize the measurements you made in order to estimate the magnitude of the electric field between the two capacitor plates.