Lab #2: Mapping the Electric Field

OBJECTIVES

- To map the equipotential lines and electric field for:
    1. two fixed charges (i.e. a dipole)
    2. a parallel plate capacitor
- To determine the magnitude of the electric field inside a hollow conducting circle.

MATERIALS

- 2-4 sheets of conducting paper
- Ruler with centimeter scale
- Digital multimeter with wire probes
- Silver Ink Pen
- Field Mapping Kit with the following items:
    1. Corkboard
    2. push pins
    3. connecting wires
- 6V Battery or DC power supply

PRELIMINARY QUESTIONS

1. For a "point" charge, how does the electric field (magnitude and direction) vary as the distance from the charge is increased? Sketch the electric field lines for: a) a "+" charge b) a "-" charge. *Be sure to include the direction of the electric field!*

2. If the 2 charges described in question 1 are located close together, they would form a dipole. Sketch the field lines for the dipole. Be sure to include the direction of the electric field lines.

3. For a "charged" parallel plate capacitor, how does the electric field (magnitude and direction) vary as you move between the plates from one plate to the other? Sketch the electric field lines.

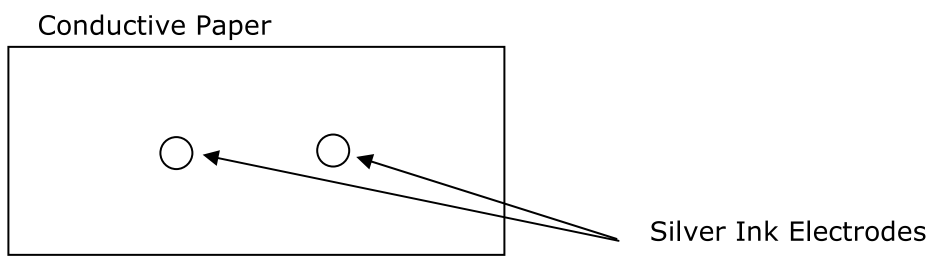
PROCEDURE

A. Drawing the Point Charge and Parallel Plate Capacitor:

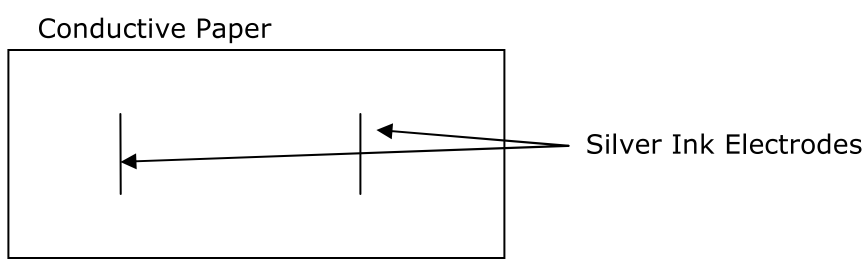
1. Before drawing, shake the silver ink pen vigorously for about a minute. Keep the pen perpendicular to the paper and apply slight pressure to the barrel of the pen while drawing.

2. Place a sheet of the special black paper directly on the table to ensure a firm drawing surface. Using the provided template, draw a small circular point. You can choose any size circle you wish.

3. Draw a second circular charge (same size) located at least 5-10 cm away from the first one. Be careful not to touch the ink until it is completely dry. Drying should take about 15 - 20 minutes depending on the thickness of the circle/line you have drawn.



4. On a second sheet of conducting paper, draw 2 parallel lines of thickness 2 to 4 millimeters wide. You may choose how far apart to draw the lines and how long to make them, but remember that there must be enough room between them so that you can obtain several potential readings inside and around them using the given probes.



Note: These silver ink lines/shapes will be referred to as electrodes in the remainder of this exercise.

B. Mapping the Electric Fields:

1. When the conductive fluid has dried, mount the sheet (with the two fixed charges drawn on it) on the corkboard by pushing a metal pushpin through each corner of the paper.

2. Connect one of-the electrodes (i.e. one of the two silver points) to the negative terminal of the power source. To do this, use a pushpin to connect the "eye" connector end of the black, plastic-coated terminal wire to the electrode: push the pin through the metal loop (the "eye" connector), through the dry conductive fluid, and firmly into the corkboard.

3. Insert the other end of the wire (it should be a banana plug) into the negative terminal of the power source.

4. Connect the negative terminal of the power supply to ground with another black wire with banana plugs on either end.

5. Connect the other electrode to the positive terminal of the power source using the procedure outlined in (2) above, except with a red lead. When you turn on the power source in step (7), it will produce charge on the electrodes. *Note: If you are using a battery as the power source, do not attach the red lead to the positive (or "+" terminal) until Step 7.*

6. Turn on the multimeter by setting the control dial to the 20V mode of the Voltmeter Selection. Insert the banana plug of the red probe wire into the "VΩ" INPUT terminal of the multimeter. This will be your probe throughout this experiment.

7. Turn on the power supply (or attach the red lead to the "+" terminal of the battery) and place the probe tip on the black paper. The multimeter serves as a voltmeter to record the difference in potential between the electrode connected to the negative terminal of the power supply and the probe.

Question: Is the potential affected by touching the paper with your hand? Why or why not?

8. Use the probe to find points of equal potential and mark points having the same potential in pencil on the paper. Connect these points with a pencil line to form lines of equipotential. What is the value of the potential along each electrode? If it is not constant, see your instructor. Label each equipotential line with the potential along that line. Draw at least 6 equipotential lines.

9. Disconnect the black lead connecting the common terminal of the voltmeter to the negative terminal of the power supply. Insert the banana plug at the end of the black probe wire into the common terminal of the voltmeter. You should now have a red and a black probe connected to the voltmeter.

10. Hold the probes firmly together and measure the potential difference between the two probes. The distance (Δs) between the probes should be kept 1.0 cm during these measurements. It may help to use tape to secure the probes together at a fixed distance.

11. Slowly rotate the probes while keeping them firmly together and in contact with the paper. Observe the voltmeter. How does the potential change? Note, the direction of the' electric field at a given point is the direction the probes are pointing (positive to negative).

12. Calculate the maximum electric field present. The electric field magnitude is given by:

$$\left|\vec{E}\right| = -\frac{\Delta V}{\Delta s}$$

where:

ΔV is the maximum measured potential difference (in volts) at a given point

Δs is the separation distance of the two probes (in meters).

What are the units of electric field?

13. In what direction does this maximum field point? Draw a vector on the black paper showing the direction and magnitude of the electric field.

14. Repeat this process until you have found the electric field at enough points so that you can map the electric field lines.

15. Repeat the steps 1-14 for sheet with the parallel plate capacitor.

Question: What is the angle between the equipotentials and electric field lines in general?

Question: For two fixed charges of opposite charge, what can you say about the direction of the field lines? Where do they originate? Where do they terminate?

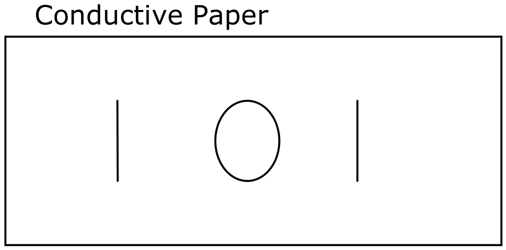
Question: For two fixed charges of the same charge, what might you predict the direction of the electric field lines to be for: Two positive charges? Two negative charges? Sketch your predictions.

Question: What can you say about the magnitude of the electric field between two parallel plates?

EXTENSION

1. On a new piece of black conductive paper, draw a parallel plate capacitor (two lines similar to your second experiment). Draw a hollow circular electrode in-between the plates/lines. The circle should be large enough to fit the probes inside it for measurement.

Conductive Paper



2. When the sheet has dried for 15-20 minutes, set-up the power supply and multimeter as described above for the parallel plate capacitor. Do not connect the circular electrode to the power supply.

3. Map the equipotential and electric field lines inside the plates.

Question: How does the potential and electric field between the plates differ inside versus outside the circular electrode?