**EXPERIMENT: EQUIPOTENTIAL PLOTTING AND THE ELECTRIC FIELD**

[Equipment list: Field Mapping Board, Variously Shaped Electrode Configuration Boards, DC Power Supply, Digital Multimeter]

**Overview:**

A solitary positive point charge situated in empty space generates an Electric Field, which radiates outwardly, in all directions. The following equation describes how the Electric Field changes strength as a function of how far away you are from the point charge.

A test charge, qo, placed into an Electric Field will experience a force upon it. The Potential Difference is a measure of the amount of work done in moving this test charge per the charge of the test charge.

The amount of work done in moving a test charge from position A to position B is as follows:

The Electric Force on the charge is equal to -qoE, the product of the charge and the Electric Field.

If the test charge is moved perpendicularly to the Electric Field then no work is done and the change in Potential is equal to zero. This means that the Potential at point B is the same value as that at point A as you move the test charge perpendicularly to the Electric Field. Thus, these Equipotential surfaces (or lines in 2-dimensional space) are always situated perpendicular to the Electric Field.

This experiment uses this relationship between Equipotential surfaces (lines) and the Electric Field to map the Electric Field for various configurations of two electrodes that are charged up equally in magnitude, but oppositely in sign.

A single positively charged point charge will have an

Electric Field (solid-line arrows) radiating outward

from the charge as shown in the figure to the right.

The Equipotential lines (dashed-line circles) are

circular in shape due to the geometry.

The equation, , represents how the Potential

changes as a function of the radial distance. Going out

the same distance r in all directions will map out a circle figure 1

(a sphere in 3 dimensions) representing points of the same potential.

A larger distance r will map out another Equipotential surface. Note that the Electric Field lines cross the Equipotential lines perpendicularly.

The Field Mapping Device is used to map out several Equipotentials of various voltages.

DC Power Supply

Volt Meter

Field Mapping Board

Fig. 2

Fig. 2 shows the basic setup for drawing 7 different Equipotential lines. Start by flipping over the Field Mapping Board. You should see two plastic-knobbed screws each screwed into a metal bar. Unscrew these and center an Electrode Configuration board such that the painted graphite and silver electrode configuration is oriented up, and the two holes in the board coincide with two holes in the two metal bars. Replace the screws and secure the board. Flip the Field Mapping Board back over. Attach a sheet of graph paper to the top side of the Field Mapping Board (as shown in fig. 2) by pressing down on the Field Mapping Board (the legs are spring loaded). The black rubber bumpers will rise up. Slip the corners of the graph paper under the rubber bumpers and release the board thus trapping the corners of the graph paper. Locate the clear plastic template that matches the Electrode Configuration you have attached to the underneath of the Field Mapping Board ( it is actually a composite of a couple of configurations) and place it over the graph paper. There are two small holes in the template that will fit over two metal projections on the Field Mapping Board. This is to align the template properly. Trace the shapes that correspond to the Electrode Configuration that you have chosen and remove the template.

Before you turn on the DC Power Supply make sure that the voltage knob is turned all the way counter-clockwise, so that you start with 0 volts. Attach the wires as shown in fig. 2. The U-shaped probe wraps around the Field Mapping Board such that the end with the metal contact is beneath the board making contact with the Electrode Configuration Board. At the end of the arm of the U-shaped probe that is above the Field Mapping Board is a hole. This hole is directly above the metal contact and will be used to mark positions of Equipotential. Notice that there are 7 banana-plug jacks across the top of the Field Mapping Board. They are marked E1 through E7. Start with the banana plug wire in E1 (fig. 2 shows the wire in E2) to plot the first Equipotential line.

Adjust the voltmeter dial to the DC volt range. Turn on the DC Power Supply and increase the voltage to 2 volts. Don’t go over 2 volts. You should already have one of the wires from the voltmeter attached to E1 on the Field Mapping Board. Use the U-shaped probe to find several points in which the voltmeter reads 0 volts. While you are doing this guide the U-shaped probe gently about the Field Mapping Board. Do not apply pressure to the U-shaped probe, and avoid squeezing its “jaws”. This causes unnecessary wear on the Electrode Configuration boards. Each time you find a point of 0 potential difference mark the spot through the hole in the upper arm of the U-shaped probe with a pencil. Make enough markings to show smoothly the shape of the Equipotential line, but not so many that you spend too much time. Change the banana plug wire from E1 to E2 and mark enough points for a second Equipotential line. If the line heads towards the edge of the graph paper make sure you map points to this edge. Continue mapping the other Equipotential lines corresponding to E3 through E7.

Once all 7 Equipotentials have been marked on the graph paper remove the graph paper from the Field Mapping Board. Have everyone in your group hand copy these data points onto another sheet of paper. Everyone should have their own set to work from.

Once you have your 3 copies (one for each of the configurations) use a pencil to draw the equipotential lines. Draw smooth curves from one point to the next for a particular Equipotential. Continue this for the other 6 Equipotential lines.

Mark one of the Electrodes with a plus sign to denote “positively charged” and the other Electrode with a minus sign for “negatively charged”. Then draw the Electric Field lines from one Electrode to the other indicating the direction of each of the Electric Field lines with an arrow head. Use the fact that Electric Field lines must cross Equipotential lines perpendicularly. Draw several Electric Field lines to show how it traverses across the entire sheet of graph paper.

All mappings showing Equipotentials and Electric Fields are done individually (data points from the experiment are shared). Scanned reproductions (or full-page photos) of all 3 configurations are to be included in the final lab report in the Results section of the report.

**1. Mapping the Equipotentials and Electric Field of a statically charged dipole.**

This is your first configuration. The two gray circles represent the electrodes while the set of smaller circles represent the marks that are made in following one of the Equipotential lines.

While you are completing the other 6 Equipotential lines remark on the following:

**Answer the following questions in the Results section of your lab report:**

**Question 1**: Comment on the ease, or difficulty, of achieving 0 volts on the voltmeter when determining the points for each Equipotential line.

**Question 2**: Approximately how much uncertainty is there in finding the position of each point drawn? Is this uncertainty a constant value, or is it different depending on the distance away from the Electrodes? Comment on any differences.

Determination of the Dipole Moment.

The following equation represents the Electric Field along a perpendicular bisector, generated by two point charges of equal, but opposite charge, q, separated by a distance 2a. The distance r is how far along the perpendicular bisector the point at which the Electric Field strength is measured.

Where the product of 2aq represents the dipole moment P. Substituting 2aq with P in equation (4) and solving for P….

To make this easier we shall determine the Electric Field strength directly between the two Electrodes. This will result in r having a value of zero.

To determine the Electric Field strength measure the distance between the inside edge of one Electrode to the inside edge of the other Electrode. The Electric Field strength is then equal to the Potential Difference between the two Electrodes divided by the distance between the Electrodes, in meters.

**Record and calculate the following on the Excel Worksheet for this experiment. All calculations/equations must be shown in the appropriate cell on the Excel Worksheet.**

a. Potential Difference between Electrodes

b. Distance between Electrodes (inside edge to inside edge)

c. Distance between Electrodes (center to center, which is equal to 2a)

d. Electric Field strength

e. Dipole Moment P

f. Determine the amount of charge, q, on an electrode

**2. Mapping the Equipotentials and Electric Field of two Parallel Plates.**

This configuration mimics a parallel plate capacitor and shows the uniformity of the Electric Field between the plates. Draw several Electric Field lines between the plates to show how uniform the field is. **Also, show how the Electric Field changes from being uniform near the two “ends” of the plates.**

“ends”

**Answer the following questions in the Results section of your lab report:**

**Question 3**: How are the Electric Field lines situated with respect to each other in between the plates?

**Question 4**: Does the Electric Field strength between the plates change? If they do, where do they change?

**Calculation to be done on Excel Worksheet (must show equation on worksheet):**

Determine the Electric Field Strength midway between the two plates.

**3. Mapping the Equipotentials and the Electric Field between a Point Charge and a Faraday Cup**

In this part of the experiment you will discover how the Electric Field is affected by a conductor that has a shape that is becoming enclosed. The Faraday Cup is enclosed on three sides with the opening towards the Point Charge. Again, map the 7 Equipotentials and draw several Electric Field lines from the Point Charge to the Faraday Cup.

**Answer the following questions in the Results section of your lab report:**

**Question 5**: The closer that the electric field lines are to each other indicate that the electric field is stronger. Describe how the electric field changes in strength as you travel from the point charge to the back wall of the Faraday cup traversing along the dashed line indicated in the above illustration.

**Question 6**: What value would the Electric Field strength be inside the Faraday Cup if the cup was completely enclosed (a rectangular box with 4 walls)?

**Questions to Answer:**

1. A solid conducting sphere (or a disk in two dimensions) is charged positively. Describe what the distribution of these charges is after they come to equilibrium. Drawing a picture would be helpful.

2. A solid conducting sphere (or any shaped conductor), charged either positively or negatively, has no Electric Field inside it. How is this so?

3. A conducting sphere is charged to a value of +2x10-6 Coulombs. What is the potential difference from one side of the sphere to the other side of the sphere? Explain.

4. In part 1 you determined the dipole moment. Why was it necessary to determine the Electric Field by dividing the Potential Difference between the electrodes by the distance from the inside edge of one electrode to the inside edge of the other electrode? Why not use the center-to-center distance as you would for two point charges?