AP Physics: Lab #15

Mapping Equipotentials

Name ________________________ Hour ______

Lab Partners ____

Purpose:

* Observe and map equipotentials for various electrode configurations.
* Construct electric field lines from measured equipotentials for various electrode configurations.

Equipment:

Conductive paper
Conductive ink pen
Cardboard Base
Stick Pins
TI-83 Plus or TI-84 calculator
CBL II unit and link cord
Voltage probe
Power supply

Introduction:

When two electrodes carry equal and opposite charge, there exists a fixed potential difference, or voltage, between them. For example, if a pair of electrodes is maintained at a potential difference of 12 Volts, the electrode with the negative charge is said to be at zero potential while the electrode with the positive charge is said to be at a potential of +12 Volts. Any points between the two electrodes will then have a potential difference ranging between zero and +12 Volts. An equipotential line is a convention used to map all points that exist at the same potential difference. Thus, equipotential lines connect all points at which a small test charge would posses the same level of electrical energy.

In addition, the two electrodes are also connected by electric field lines. Electric field lines represent the electrical force that would exist on a positive test charge at that position, and thus are directed towards the negative electrode. Because electric field lines represent a force, they cannot include any component in the same direction as an equipotential line. Thus, electric field lines are perpendicular to equipotential lines at all points.

The magnitudes of the potential difference and the electric field existing between any two points can be related. However, the magnitude of the electric field at any point is the vector resultant of the electric fields created by the two electrodes, and thus is constantly changing. Therefore, the relationship between the magnitude of the potential difference between any two points and the magnitude of the electric field between those two points is expressed in terms of the <u>average</u> electric field and is best used for two points that are relatively close together. By its definition, the electric field exists in a direction that shows a decrease in potential difference. Thus, the relationship between the potential difference and electric field existing between any two points is given by the equation:

$$E_{avg} = -\frac{V}{d}$$

This activity will use two electrodes maintained at a given potential difference on a piece of conductive paper. The potential difference of points between the two electrodes is measured, allowing equipotential lines to be constructed. These equipotential lines can then be used to create the corresponding electric field lines.

Procedures:

Use the conductive ink pen to draw the assigned electrode configurations on the conductive paper. The equipotential lines will be drawn on matching graph paper, not on the conductive paper itself. Each person in your lab group should also sketch the assigned electrode configurations on graph paper. The equipotential line and electric field line sketches will then be completed individually on the graph paper and turned in with your report.

Procedures: *(cont)*

To use the CBL II unit as a voltmeter, plug the voltage probe into Channel I of the CBL II unit. Attach the calculator to the support brackets on the CBL II, and use the link cord to connect the CBL II to the graphing calculator. Then turn the graphing calculator on. Run the application DATAMATE on the graphing calculator. The voltage will be displayed on the calculator screen. If necessary, zero the voltage probes using the SETUP menu.

Attach each lead of the power supply to the metal portion of a stick pin. Also attach the negative lead of the voltmeter to the same stick pin as the negative lead from the power supply. Put the conductive paper on the cardboard base and carefully push the stick pins into the conductive ink electrodes. Turn on the power supply and adjust the potential difference between the electrodes to be 6.0 Volts. Use the positive lead of the voltmeter to measure the potential difference at any point on the paper by touching the probe to the paper. Be sure to touch the probe perpendicularly to the paper so that only the point of the probe touches the paper. Hold the probe securely on the paper, but not so firmly that the probe tip punctures the paper.

To map a 1.0 Volt equipotential line, first use the positive lead of the voltmeter to locate several points on the paper that are at a potential difference of 1.0 Volt with the negative electrode. Then use the coordinates on the conductive paper to mark and label these 1.0 Volt points on the graph paper. When you have located enough 1.0 Volt points to determine the general shape of the 1.0 Volt equipotential, continue with equipotentials of 2.0 V, 3.0 V, 4.0 V, and 5.0 V. Repeat this process for both of the assigned electrode configurations.

Calculations:

On the graph paper sketches, label the positive and negative electrodes for both electrode configurations. Then use a colored pencil to construct and label each equipotential line on the graph paper by connecting all points at that potential.

Using the equipotential lines as a guide, construct several electric field lines on the graph paper with a different colored pencil. Include vectors to indicate the appropriate direction of each electric field line. Calculate the magnitude of the average electric field between each equipotential line along the *x*-axis of both electric configuration sketches. Label these magnitude values on the center electric field line for each sketch.

Analysis:

To summarize the lab report, answer the application questions below in complete sentences. In addition, include a brief statement of the overall results for the lab.

- Do equipotential lines include a direction? Do electric field lines include a direction? Explain the difference between equipotential and electric field lines as part of your answer.
- Can two different equipotential lines ever touch the same point? Can two different electric field lines ever touch the same point? Explain.
- Should the numerical values for potential difference along an individual equipotential line ever change? Should the numerical values for electric field strength along an individual electrical field line ever change? Use your data to support your answers.
- What is the geometric relationship between an equipotential line and an electric field line at a certain point?
- How much work is required to move a test charge along an individual equipotential line? How does this amount of work relate to the geometric relationship mentioned in the previous question?

Lab Report:

Title Page, Objectives, & Overall Report – 5 pts
Procedures – 3 pts
Data – 5 pts
Calculations & Sketches – 7 pts
Analysis – 10 pts