Lab 17. ELECTRIC POTENTIAL AND ELECTRIC FIELDS

Problem

- How are electric field and potential related?
- How do electric field and potential change with position?

Equipment

Field mapping board, poorly conducting paper (PCP) with conducting ink electrodes, source-paper connectors, graph paper, digital voltmeter, voltage probes, voltage source, wire leads (2).

Background

A field is a quantity whose value can vary from point to point in space. This may be a vector field, that is, the quantity may be a vector. An electric field (*E* field) is an example. A voltage, or potential field, is an example of a scalar field.

We can represent a scalar field by drawing curves through sets of points that are at the same potentials. These lines are called isopotential lines and are completely analogous to contour lines on a topographic map. In a topographic map, contours are lines of equal elevation. Electric field lines point away from the more positive voltages. They "go from high to low potential."

You can construct the *E* field from a potential map by following these two rules:

1. The *E* lines are always perpendicular to the isopotential lines.
2. The *E* lines are closer together where the isopotential lines are closer together.

Activity

Isopotential lines are easier to determine experimentally than electric field lines. Our apparatus allows us to find isopotential lines by measuring potentials around electrodes drawn in conducting ink on poorly conducting paper (PCP). The paper has an electric field on it set up by the negative and positive electrodes. You can find the potential at any point by touching the paper with the positive probe of a voltmeter, and, in this way, trace out a potential map. The electric field lines can then be drawn from this map.

Set up and use the voltmeter

1. If you are using a multimeter, set it to voltmeter mode. Use the most sensitive setting that is greater than the source voltage.
2. Touch the two probe electrodes together and verify that the meter reads zero.

3. Connect the black lead of the voltmeter to the black or (–) terminal of the voltage source. The voltmeter is now ready to use.
4. To measure voltage, press the edge of the red lead to the position on the paper whose voltage you wish to measure. Do not puncture the paper! Wait for a reading to stabilize before recording it.

Preserve the paper and electrodes

Maintain the paper and painted electrodes to get the best measurements.

1. Preserve the high resistance of the black poorly conducting paper (PCP) and its grid. Do not write on the PCP with pen or pencil. Use only the metal probes to find the points for your isopotential lines.
2. Preserve the low resistance of the silvered electrodes on the PCP. Do not poke holes in, write on, or scratch the silvered electrodes. When pinning the metal contacts from the power supply to the electrodes, use the hole already there if there is one. Press the pin flush to the paper so that it makes good contact to the metallic ink. Do not drag anything, such as a pin, pen, pencil, or voltage probe, across the inked electrode.
3. Once you have positioned the metal contacts on the electrodes on the PCP, do not move them or the paper packet until you have completed all of your measurements for that particular configuration.
4. When making your equipotential measurements, lightly drag the probe across the PCP until you get the reading you are looking for.
5. Touch the probe only on the solid black areas of the paper, because the grid marks may affect the resistance of the PCP in that area and the positions of your points.

Find the isopotential curves

Each group member must make their own field line maps on graph paper. Each group member must take the voltage measurements for one electrode configuration.

1. Mount the poorly conducting paper (PCP) on the cork board. Use plastic push pins to secure the corners of the paper and one silver push pin for each of the two inked electrodes. Connect one terminal of the voltage source to one of the inked electrodes and the other terminal to the other electrode. Install the voltmeter as directed.
2. Set the voltage source to a convenient voltage that allows you to conveniently draw at least five isopotential curves. For example, if you want exactly five isopotential curves, 6.0 V source voltage would allow you to draw isopotential curves for 1.0 V, 2.0 V, 3.0 V, 4.0 V, and 5.0 V.
3. Each person in the group will make a map of electric potential and field, atop a scale rendering on graph paper of the experimental setup. The PCP is marked with crosses separated from each other by 1.00 cm along the x and y directions. Use these marks to locate positions of interest. Your graph paper is marked in about the same way as the PCP, so it should be easy to find the spot on your graph paper corresponding to any spot

on the PCP. Find the locations of and draw the electrodes and other conductors at the proper locations on the graph paper. Indicate the positive and negative electrodes.

4. Check that the voltage at the (–) electrode measures near zero and that the voltage at the (+) electrode measures near the full source voltage. If they don't, check all your connections, especially to the inked electrodes.
5. Choose several evenly-spaced voltage values between the two electrode voltages to find isopotential lines. For each of these values, move the red probe on the black paper to find enough points with this voltage to trace the isopotential line. Follow the line until it either closes on itself or goes off the edge of the paper. Mark the corresponding points on the graph paper and connect them with a smooth curve.
6. Repeat the above step for the rest of your chosen evenly-spaced voltage values. Be sure to label these values on your graph paper.
7. Have a different group member repeat these steps with another piece of conductive paper painted with a different electrode configuration. Repeat until each group member has mapped one. If your group has fewer than three members, map at least three different electrode configurations per group.

Draw the field lines

1. Construct a field line by drawing a single line from one electrode to the other so that it is perpendicular to each and every isopotential line that it crosses where they cross. The edge of each electrode is an isopotential line. (Why?) A fairly representative field line may be drawn by first selecting a point on one electrode closest to the other and drawing a light pencil line from there perpendicular to the electrode to halfway to the next isopotential line. From that point, continue perpendicular through the next isopotential line to halfway to the isopotential line beyond it. Continue until you reach the other electrode. Redraw the line smoothly through the points of intersection with the isopotential lines.
2. Make at least six field lines this way, approximately evenly spaced along the edge of the electrode from which they originate. Color or otherwise indicate the field lines so that they can easily be distinguished from the isopotential lines. Mark arrows on each field line to show its direction.

Lab Report

Abstract

Summarize the apparatus, measurements, and what you used the data to find.

Purpose

Identify the knowledge and skills this lab should introduce or reinforce.

Theory

Explain the relationship between electric field and electric potential. Explain the meaning of electric field lines and of isopotential surfaces.

Experimental

The experimental procedure is in these instructions; report in your own words what you did. Report any difficulties you had taking readings, and what you did to get reliable measurements. Report who took the voltage readings and who traced the isopotential lines for each map.

Observations and Data

Your isopotential map constitutes your data. The isopotential lines should each be clearly labeled with their values. There should be at least five evenly-stepped isopotential lines between the electrodes, and each isopotential line should either close on itself or run to the edge of the diagram.

Analysis and Discussion

Your field line map constitutes your **analysis**. The electric field lines should each run from the positive electrode to the negative electrode, and have an arrow to show direction. There should be enough electric field lines to visualize the field throughout the map. It should be easy to distinguish isopotential curves from electric field lines.

For your **discussion**, explain the relationship between isopotential surfaces and field lines, and how this relationship is exemplified by each of your maps. Discuss any noteworthy or interesting features of the electrode configurations you studied.

Conclusion

Did the lab exercise achieve its purpose? Briefly explain your judgment.