PHYS 1220-02 Group Work
Electric potential and electric field

Equipment

Field mapping board, poorly conducting paper (PCP) with conducting ink electrodes, plastic push pins, silvered push pins, graph paper, digital voltmeter, voltage probes, wire leads (2), voltage source.

Background

A field is a quantity with a specific value at each point in space. In a vector field, that quantity is a vector. An electric field (E field) is an example. A voltage, or potential field (ϕ field), is an example of a scalar field (ϕ is a scalar quantity).

We can represent a scalar field by drawing curves connecting points that are at the same potential. 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 easily find 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.

Method

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.

Voltmeter

The multimeter that you will use has several functions. You will use it as a voltmeter, to measure potential differences between its probes.

1. Plug the black lead into the COM socket and the red lead into the VΩHz socket.
2. Turn the rotary switch to one of the "V" settings, with a value greater than the source voltage.

3. Turn the meter on with the left pushbutton switch under the display screen.
4. Touch the two probe electrodes together and verify that the meter reads zero.
5. Connect the black lead to the black or (–) terminal of the voltage source. The voltmeter is now ready to use.
6. Touch the red lead to the position on the paper whose potential you wish to measure. Do not puncture the paper! Wait for a reading to stabilize before recording it.

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, then press firmly to impress a dot on your blank sheet of paper.
5. Touch the probe only on the solid black areas of the paper as the grid marks may affect the resistance of the PCP in that area and the positions of your points.

Steps

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. Connect the black terminal of the voltmeter to the negative terminal of the voltage source.
2. You will make a map of electric potential and field on graph paper, which will be a scale rendering on graph paper of the experimental setup. The PCP is marked with crosses separated from each other by 1 cm along the x ordinate and the y ordinate. Use these marks to locate positions of interest.

3. Begin by drawing a rectangle on the graph paper corresponding to the PCP grid. Use an appropriate scale, such as two graph grid lines per PCP centimeter. Note the electrodes drawn on the black paper. Find their coordinates and draw them at the corresponding points on the graph paper. Indicate which electrode is positive and which is negative (ground).
4. Set up the digital multimeter as described above. Check that the voltage at the (–) electrode is near zero and that the voltage at the (+) electrode is near the full source voltage. If they aren'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 the first of these values, move the red probe electrode about 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 the rest of your chosen evenly-spaced voltage values. Be sure to label these values on your graph paper.
7. 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. (The edge of each electrode is an isopotential line.) A fairly representative field line may be drawn by first selecting a point on one electrode and drawing a light pencil line from there perpendicular to the electrode to halfway to the next isopotential line. From that point, continue perpendicular to the next isopotential line through 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.
8. Make at least six field lines this way, approximately evenly spaced along the electrode from which they originate. Mark arrows on each line to show their direction.
9. Repeat these steps for a total of three different electrode configurations.

Check-in

Show me the three neatly-rendered graphs of voltage and electric field. The isopotential lines should each be clearly labeled with their values. The electric field lines should each run from electrode to electrode, and have an arrow to show direction. 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. There should be enough electric field lines to visualize the field throughout the map. It should be easy to distinguish between isopotential lines and electric field lines.