Lab 3. MAPPING ELECTRIC POTENTIAL AND ELECTRIC FIELD

1. Problem

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

2. Equipment

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

3. 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 potential field is an example of a scalar field.

We can represent a potential field by drawing curves through sets of points that have 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 constant elevation. Electric field lines point away from the more positive voltages. They "go from high to low potential," in the direction of steepest potential decrease.

4. 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 grounding the negative probe of a voltmeter and touching the paper with the positive probe, and, in this way, trace out a potential map.

The electric field lines can be traced using the bound voltage probes. Touching both probes to the paper, orient the probes to give the largest voltage reading. The electric field then points along the direction from the positive probe to the negative probe. Starting from a positive electrode, trace a field line all the way to the negative electrode. Fill out the map by following field lines originating at different points on the positive electrode.

1.1. 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.

1.2. 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 inked electrodes on the PCP. Do not poke holes in, write on, or scratch the conducting ink. 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.

1.3. 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 backing board. 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. If you can, 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. 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 + probe on the black paper to find enough points at this voltage to trace the isopotential line. Follow the line until it either closes on itself or reaches 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.

1.4. Find the field lines

1. Connect the bound voltage probe pair to the voltmeter.
2. Place the positive probe of the pair on the positive electrode. Pivot the negative probe along the paper about that point like a drawing compass to find the orientation giving the greatest voltage reading on the meter. The two probes now span the segment of the greatest voltage drop.
3. Move the positive probe to somewhere along this segment. Repeat the re-orientation to continue the field line until you reach the negative electrode or the probe leaves the paper. If the probe leaves the paper, reverse the process beginning with the negative probe at the negative electrode.
4. 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.

Find isopotential curves and field lines for at least three different electrode configurations, following the steps in sections 1.3 and 1.4. Every group member should make at least one map.

5. Lab Report

Show your isopotential and field line maps to your instructor. Correct any errors.