LAB 4
Electric Field Mapping

OBJECTIVES

1. Determine the location of equipotential surfaces in the region around various electrode arrangements.
2. Construct electric field lines from the measured equipotential surfaces.

EQUIPMENT

Field mapping apparatus, electrode plates, templates, paper, DC Power Supply, digital multimeter.

THEORY

Consider two electrodes of arbitrary shape some distance apart carrying equal and opposite charges. There will then exist a fixed potential difference between the electrodes. Suppose that this potential difference is 15 V. If the electrode with the negative charge is arbitrarily assumed to be at zero potential, then the electrode with the positive charge is at a potential of +15 V Given these assumptions, in the space surrounding these electrodes there will exist points that are at the same potential. For example, for the case described above, there exist some points for which the potential is +9 V, other points for which the potential is +12V, and still other points for which the potential is +6 V. In a three-dimensional space, all points at the same potential will form a surface, and there will be a different surface for each value of the potential between 0 V and 15 V. In fact, there exist an infinite number of such surfaces because one could divide the 15-V total potential difference into an infinite number of steps. Each of these surfaces with the same value of potential is called an "*equipotential surface*." In this laboratory, the equipotentials for a few simple, but often used, electrode configurations will be determined.

In addition to the equipotential surfaces that exist in the region around charged electrodes, an electric field is also present. By definition, the electric field is a vector field, which can be represented by lines drawn from the positively charged electrode to the negatively charged electrode. The electric field lines must always be perpendicular to the equipotential surfaces. This can be derived from the fact that it takes no work to move an electric charge on an equipotential surface because along the surface, $\Delta V = 0$. If the work is zero, then the electric field *along* the equipotential surface must be zero.

A direct-current power supply will provide the source of potential difference and will serve to keep the voltage between the two electrodes fixed at whatever value is chosen from the power supply. The electrode to which the negative terminal of the power supply is attached will arbitrarily be chosen to be the zero of potential, and all measurements will be made relative to that electrode. A voltmeter will then be used to find the points on the paper in the region of the electrodes that are at some given value of potential. Once enough points at that potential have been located to establish the shape of the equipotential, the equipotential line can be constructed by joining the points with a smooth curve.

PROCEDURE

Field Mapping for different Electrode Arrangements

(a) Mount a conducting plate on the bottom of the field mapping table and a piece of graph paper on top. Use the template to draw your conductor configuration on the graph paper.

(b) Connect the power supply to the field-mapping table and adjust the output voltage of the power supply to 15 V using your voltmeter. This will produce a small current that flows through the slightly conducting coating on the board.

(c) Connect the black lead of the voltmeter to the ground terminal of the power supply. To explore the voltages on the conducting board, you will measure voltage differences or potential differences between your voltmeter's red and black leads. The black lead is *always* kept at the ground terminal of the power supply and the red lead will be moved from one location to another in order to measure different potentials. When a series points have the same potential, it is called an *equipotential line*.

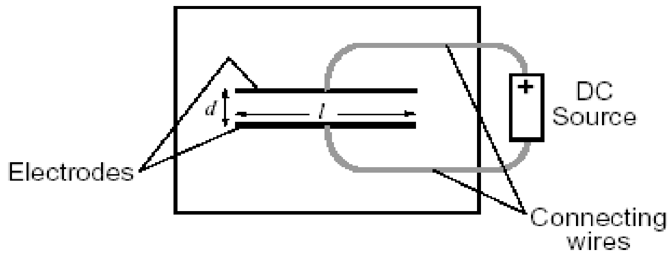
(d) In order to make a contour map of equipotential lines on the paper, connect the V-Ω lead from the meter to the probe on the field-mapping board. Systematically search for a number of points whose potential is about 9 V. Mark them, and draw a smooth line connecting them (*don't* connect the dots with straight lines!). Then find the 3V, 6V, and 12V points. Each smooth line is the "equipotential" for its voltage. Label each one right after you create it.

(e) ***For each of the three electrode arrangements, perform the following steps***:

- *Make a detailed sketch of what you expect the electric field lines around the electrodes to look like. You can use your textbook as a guide. From the electric field lines, sketch in your prediction for what the equipotential surfaces should look like.*
- *Draw in the equipotential surfaces for each electrode arrangement. Study the spacing between your equipotential lines and, with your partners, identify regions of strong and weak electric field. Explain your reasoning for each electrode arrangement.*
- *The E-field lines, which go from the positive conductor to the negative conductor, are always perpendicular to the equipotential lines. Draw in the E-field lines using dashed lines. Clearly indicate the direction of the electric field at several positions on each plot. This will produce a map of the E-field for your conductors.*
- Make sure to draw the correct spacing (approximately) between the field lines. The E-field is strong where the field lines are close together and weaker where they are far apart.
- Repeat the mapping experiment for **all three** electrode arrangements.
- *Answer all questions referring to each electrode arrangement.*

Electrode Arrangements

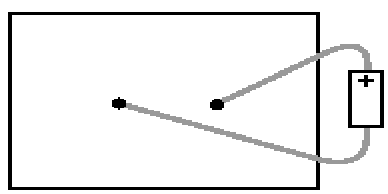
1) Parallel Plate



Questions:

- According to theory, the E-field in the region between the plates should be a constant. *Calculate the E-field using* $E = -\Delta V / \Delta s$ *at three different points in-between the plates. Are the values of the E-field at the points approximately constant within the experimental uncertainty?*
- *What is the field outside the parallel plates?*

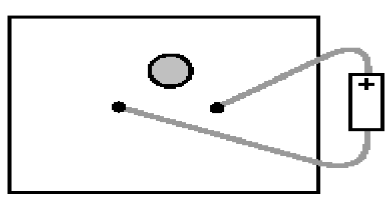
2) Electric Dipole



Questions:

- *Compare the electric field with the electric field from a dipole in your textbook. Comment on their similarities and differences, if any.*
- *Would it make any sense for field lines to cross? Explain your answer.*

3) Electric Dipole with Conducting Circle



Questions:

- *What is the potential inside the conductor?*
- *What is the electric field inside the conductor?*

(f) Go to the following website using Chrome:

https://johnw.org/physicsapps/fieldmapping.html

Use the website to check the results of your three different electrode arrangements.

(g) Use the applet to map out the equipotential surfaces and electric field lines for two positive charges place next to each other. *Draw a detailed sketch of the equipotential surfaces and electric field lines.*

(h) Design an interesting arrangement of electrodes (including both V+ and Ground) and several conductors of different shapes. Use the applet to map out the equipotential surfaces and electric field lines for this arrangement. *Draw a detailed sketch of the equipotential surfaces and electric field lines.*