Electric Field Mapping

Objectives

To determine the equipotential lines and the corresponding electric field lines for a variety of arrangements of conductors in a plane.

Theory

The concept of an electric field, $\vec{E}$, is useful because it simplifies determining the force, $\vec{F}$, on an object with charge q. The electric field at a point in space is due to the presence of other charges. The purpose of this laboratory is two fold, to visualize $\vec{E}$ (and hence $\vec{F}$ on the test charge $\vec{F} = q\vec{E}$) due to various charge distributions and to visualize the lines of constant potential, V, due to the same charge distributions. These lines of constant V are called equipotential lines.

$\vec{E}$ and V are intimately related. Being a vector $\vec{E}$ has both a magnitude and a direction. $\vec{E}$ is ALWAYS perpendicular to equipotential lines. $\vec{E}$ points from higher potential to lower potential. Since $\vec{E} = \vec{F}/q$, $\vec{E}$ at a point in space points in the same direction that a positive charge q at that point would be pushed in. This means that electric field lines start on positive charges and end on negative charges. The magnitude of the electric field is minus the rate of change of potential in space. The greater the potential gradient (i.e., the more the potential changes) the larger the field. For a two-dimensional field as in the lab setup, the electric field is given by:

$$E_x = -\frac{dV}{dx} \approx -\frac{\Delta V}{\Delta x}. \tag{1}$$

In fact this is exactly the same way that force and potential energy are related.

Procedure

Overview

You will use a voltmeter to map out quantitatively, but only in two dimensions, a set of equipotential lines for different charge distributions. The 2-D charge distributions will be set up by applying a potential difference to a pair of conductors painted onto conducting paper. From these equipotential lines the electric field can be determined.

You will have several electrode configurations painted on black conducting papers which have a grid on them. A voltage from a power supply will be applied between these electrodes on the conducting paper. You will use a voltmeter to survey V by locating many points on the black conducting paper for which the voltage differences from the reference (say zero) are the same. You will map out these points on a separate paper with the same grid pattern as the conducting paper. When these points of equal voltage are connected, they form an equipotential line. Other equipotential lines can be found in the same way and taken together they form a map of V over the whole page. A map of $\vec{E}$ can be found from the equipotential map.

Since $\vec{E}$ emanates from electrical charges, higher densities of electric field lines near the electrodes indicate regions of higher charge concentration. From a complete electric field map the charge density variations on the electrodes themselves can be deduced.

General Directions for each electrode configuration

1. On your paper grids provided, carefully draw the outlines of the electrodes at the same positions as they appear on the black conductive paper.

2. Place your conductive paper on the board, connect the $5.0V$ power supply to the two electrodes drawn on the conductive paper. Connect the reference lead (black wire) of the digital voltmeter to the negative electrode (or the negative terminal of the power supply). The red wire from the voltmeter will be your "probe". Label the + and - electrodes on your grid paper.

   CAUTION: PLEASE DON'T MARK WITH PENCIL OR PENS ON THE CONDUCTIVE PAPER OR POKE HOLES IN IT WITH THE POINTED PROBE.

3. Touch the probe to the conductive paper at a few random points. The voltage readings on the voltmeter should lie between $0V$ and $5.0V$. If not, check with your instructor. Note: you need to press firmly, holding the probe at an angle, so as not to press the sharp point into the paper. Voltages will still vary somewhat with pressure, the highest value being the best. Just record two significant figures for voltage.

4. Map out about ten equipotential lines one at a time. First choose some convenient voltage between $0V$ and $5V$, such as $0.5V$. Using the probe find a point on the conducting paper that gives a voltage of $0.5V$. Record this point on the white grid paper. Now move the probe $1cm$ away from the point you just located and search for an other point or points on the conducting paper giving a reading of $0.5V$. Continue this process until you reach the edge of the conducting paper or you run into points already located. Now connect these points with a smooth line (Don't just connect

the dots with straight line segments!), and label this line as $0.5V$. This completes the first equipotential line for this electrode configuration.

5. Repeat the process just outlined to find nine more equipotential curves. Make sure they are equally spaced out (i.e., at $0.5V$, $1V$, $1.5V$, etc).

6. If you have any large unexplored regions on your map (Yar there be dragons there.), choose some intermediate value(s) of potential falling between the voltages of previously drawn equipotential lines and fill in the blanks.

7. Sketch in the $\vec{E}$ lines using the equipotential lines measured previously based on the behavior of $\vec{E}$ field lines as outlined in the Theory section. Since each conducting electrode is an equipotential surface, electric field lines leave or enter the surface of a conductor perpendicular to the surface. A suggestion for sketching the $\vec{E}$ lines is to start at a point on the positive electrode (cathode) and draw a smooth continuous line which crosses all equipotential lines perpendicularly. Continue either until you reach the edge of the paper or the negative electrode (anode). Pick other points on the positive electrode and repeat this process. Be sure to indicate the direction of each field line with arrows. Don't leave any large regions of your "map" devoid of field lines.

Group Names:

Electric Field Mapping - Worksheet

Use a separate sheet for each electrode configuration. Attach your grid paper to this worksheet.

1. Describe in words the nature of the electrode configuration.

2. Pick 5 points on your electric field map and label the points as P1, P2, etc. Calculate the approximate magnitude of the electric field using the relationship between electric field and potential difference given in the theory section. Be sure to use adjacent equipotential lines in order to make the approximation better. When you do this, you are finding the average electric field between the two equipotentials which closely approximates the actual value of the electric field midway between the two equipotentials. For each of your labeled points show the data and calculations used to find the average electric field at the point in the space below.

3. On your grid locate those points you think have the largest (mark with and L) and smallest (mark with and S) electric field.

Name:

Based on observations of all the electric field maps from the different groups and your calculations of the magnitude of the electric field, make some general observations about where the electric field tends to be largest and smallest. Is it possible to predict from the electric field lines alone where the field will be large or small? Explain your reasoning.