Electric Field and Electric Potential Mapping

Objectives

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

Theory

Last semester we made extensive use of forces and energy to understand how and why objects move. The force $\vec{F}$ on an object with charge q due to an electric field $\vec{E}$ is given by

$$\vec{F} = q\vec{E}. \tag{1}$$

The concept of an electric field is useful because it allows us to think about the objects that will cause a force (the source charges) separately from the charged object that will experience the force (the test charge).

The potential energy, PE an object with charge q due to an electric potential V is given by

$$PE = qV. \tag{2}$$

The electric potential is useful for exactly the same reason as the electric field, it divorces the source objects from the test object. All of the ideas that made potential energy a useful idea apply to electric potential.

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.

Key things about $\vec{E}$ and V

- $\vec{E}$ 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.

- Electric field lines always start on positive charges and end on negative charges.
- The $||\vec{E}||$ is minus the rate of change of potential in space. This means that the greater the potential gradient (i.e., the more the potential changes) the larger the field. Along the x-axis this is

  $$E_x = -\frac{dV}{dx} \approx -\frac{\Delta V}{\Delta x}, \tag{3}$$

  just as it would be for forces and potential energy.

If at any point you are unsure of what the convention is, think of a positive test charge q and how it would react to $\vec{E}$ or V as appropriate.

Procedure

Overview

You will map out the equipotential surfaces and electric field lines near two different source charge distributions, a dipole and second distribution of your choice. You will also calculate the magnitude of the electric field at a few points on each map.

You will create the electric field and potential by applying a voltage difference between the pair of conductors using a power supply. You will measure the potential difference between one conductor and any point in space using a voltmeter. Infer the Electric field lines from equipotential lines.

Since $\vec{E}$ emanates from positive 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) and potential value labeled.

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:

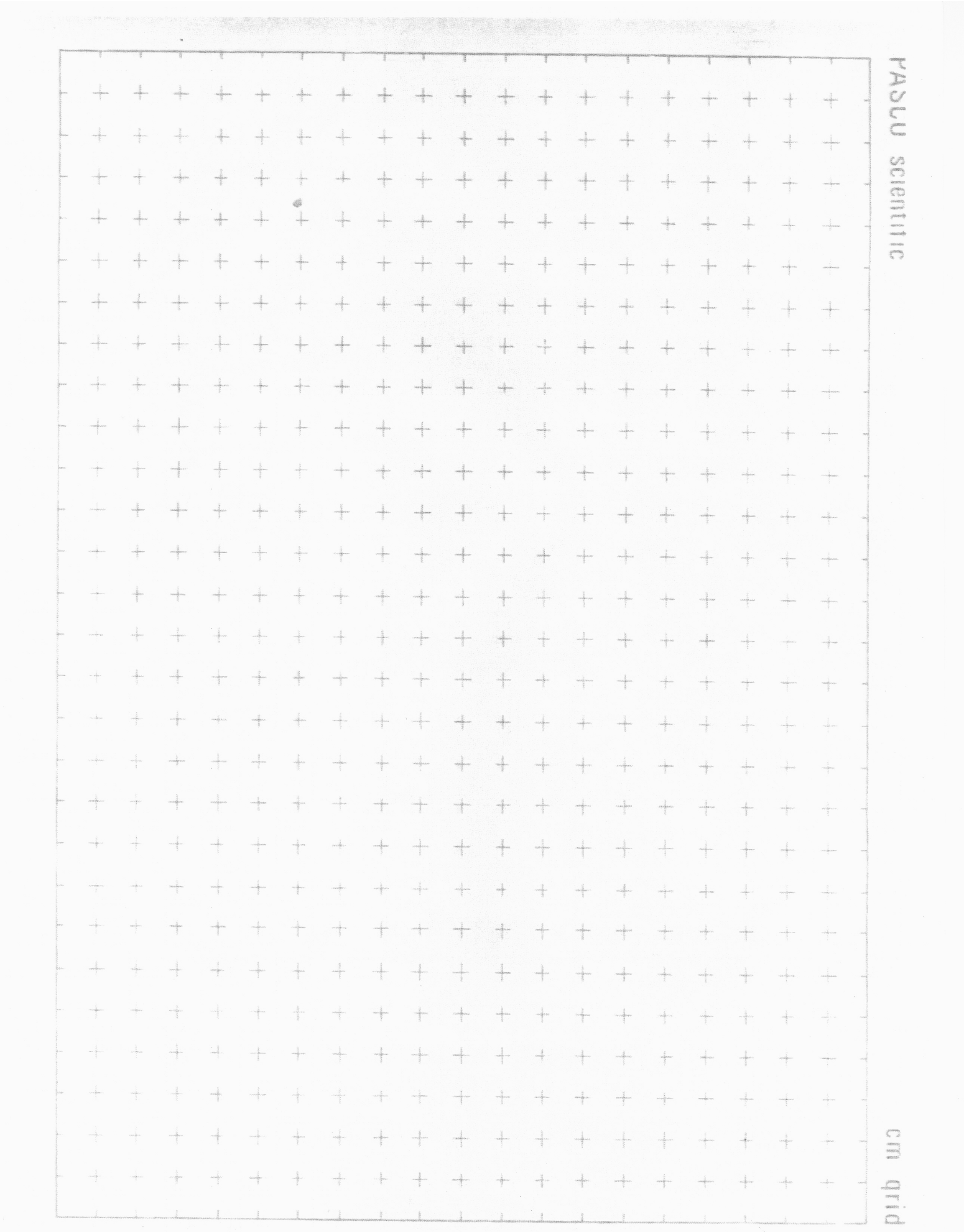
Electric Field Mapping - Dipole

Attach your grid paper to this worksheet.

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

2. Pick 5 points on your map and label the points as P1, P2, etc. Calculate the approximate magnitude of the electric field using Eq. 3. Be sure to use adjacent equipotential lines in order to make the approximation better. The value you find is 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.


PASCO scientific
cm grid

Group Names:

Electric Field Mapping - other conductor shape

Attach your grid paper to this worksheet.

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

2. Pick 5 points on your map and label the points as P1, P2, etc. Calculate the approximate magnitude of the electric field using Eq. 3. Be sure to use adjacent equipotential lines in order to make the approximation better. The value you find is 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.

PASCO scientific

cm grid

Summing it up

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.