Chapter 10

Lab 3: Mapping Electric Potential

10.1 Pre-Lab

- Read this Chapter of the Lab manual
- Complete the Pre-Lab exercises on eClass.
- Bring both a pencil and a pen to class since you will need to draw in at least two different colours. A pencil will be useful for the data collection.

10.2 Purpose

In this lab, you will map out the electric potential between a pair of conductors. You will develop skills in turning a set of measurements into a contour map and finding electric field lines. The point of this work is to help you relate the drawings you see in your textbook to what they actually mean in terms of measurements.

10.3 Introduction

Two conductors at different electric potentials will create an electric field between them. The shape of that electric field is determined by the shapes of the individual conductors. We usually draw the electric field as field lines from the positive electric charges to the negative electric charges. These field lines are perpendicular to the *equipotentials*. The goal of this lab is to measure the shape of the electric field for a pair of conductors and relate the numbers measured for the field to the equipotential contours and the field lines.

If the geometry of the conductors is simple, the electric potential may be compared directly with predictions of Gauss's law. In general, a contour map consisting of lines of constant potential difference can be used to construct corresponding electric field lines. By analyzing the field patterns, you can obtain some insight regarding the strength of the electric field between conductors. In addition, the distribution of the charges on the surfaces of the conductors may be determined.

Electrostatics considers the relation between electric fields, electric potentials, and charge distributions under static conditions. Electric fields are generated by charges and extend into the region surrounding them.

The electric field $\mathbf{E}$ is defined so that, if a test charge q is placed into an electric field, it experiences a force $\mathbf{F} = q\mathbf{E}$. If the charge is moved a distance Δs parallel to this electrostatic force, an amount of work $W = F\Delta s = qE\Delta s$ must be done. Since this force conserves energy, the potential energy must decrease by $\Delta U = -qE\Delta s$. The electric potential V is defined as the potential energy per unit charge $V = U/q$, and the set of points having the same electric potential is called equipotential. Electric potential at every point around a conductor could be easily measured using a voltmeter. The direction of the electric field in this region is perpendicular to the equipotentials. Moreover, the magnitude of the electric field at a point is related to the electric potential difference by

$$E = -\frac{\Delta V}{\Delta s} \tag{10.1}$$

10.4 Lab setup

In this lab, you will select a circuit drawn on conductive paper. The paper acts like a resistor so that a weak current will flow from the positively charged conductor to the negatively charged conductor. A simple diagram of this circuit is shown in 10.1.

1. Use the grid provided to sketch out your conductor.
2. Connect the DC power supply to the conductors and set the output voltage of the supply to +4.5 V.
3. Using the multimeter, measure the potential difference between the grounded side of the conductor and the points on the grid paper. Annotate the values on the worksheet. You do *not* need to fill out all the numbers on the grid but you should have enough that you know the shape of the potential. The more grid points you measure, the easier it will be to discern the shape of the potential. If you're worried about time, you can begin with a coarse grid and then fill in the finer details as time permits.
4. Draw in contours of equal values of the potential (i.e., *equipotentials*). A contour is a smooth line that indicates where a specific value of the potential is found. Draw contours for 1, 2, 3, and 4 V. You may have to "interpolate" the data. For example, if you have two grid points at +3.9 V and +4.1 V, you would draw the contour for +4 V in between those two points. If you need to measure some more values to improve your mapping, you can go ahead and do so.

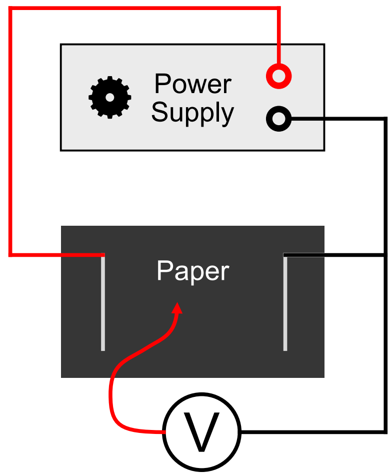

Figure 10.1: A diagram representing the circuit. The power supply and conductive paper are connected in series, and a voltmeter (V) is connected in parallel. So that we only have to move one probe, the common (ground) port of the voltmeter is directly connected to the negative terminal of the power supply.

5. Using a different colour (or pencil vs. pen), draw in some electric field lines from the positive to the negative conductor. Make sure you indicate arrows showing the direction of the field. Electric field vectors are perpendicular to the equipotentials and smooth. Thus, draw some perpendicular lines to each of the contours and estimate a smooth curve that would go from the positive conductor, perpendicular to all the equipotentials and terminating at the negative conductor.

6. Find two points on contours with a 1 V difference that are connected by an electric field line. Measure the physical distance between these two points with a ruler. Use this information to calculate the magnitude of the electric field between these points using Equation 10.1. Indicate which two points you used for the measurement on your diagram.

10.5 Assignment

In a single PDF answer, complete the Introduction, Methods, Results, Discussion, and References and Acknowledgements sections and upload it to eClass; you do not need to include a Conclusion section. Your image of the potentials map can be hand-drawn but anything else should be typed. There is a limit of 4 pages. Your Results section should include any calculations and:

1. Include an image or a scan of your potential map. Your potential values should be written on the map at as many grid coordinates as necessary along with equipotential lines for 1, 2, 3, and 4 V. In a different colour to your equipotential lines, sketch the electric field lines; include arrows to show their direction. Include a caption that describes the figure, how the data was collected, and how the equipotential contours and electric field lines were created.

Since there is no "theoretical" value to compare to, your Discussion section should include the following for full marks:

1. Where do you expect to find the highest electric field strength. Why?
2. Calculate the electric field strength for at least 5 different points on the graph. Explain how you chose your points. You only need to show one sample calculation. The data should be presented in a captioned table.
3. Estimate the uncertainty in your electric field strength for the same point you did the sample calculation in the previous question. What factors did you consider in determining the uncertainty, and which (if there's more than one) do you think would most affect your measurement?