

ELECTRIC FIELD MAPPING

Objectives:

- To map the electric field and potential of various charge distributions.
- To derive the electric field from the potential map.

To Do Before Lab:

- Read this lab

Apparatus: Painted conducting paper, rubber sheet, geometry for the sheet in configurations A and C, 6 volt lantern battery, voltmeter, Macintosh computer, electrodes, taped pair of electrodes, Excel

Introduction:

In this lab, you will map the electric field and electric potential around three charge configurations using a digital voltmeter. Knowing the relationship between electric potential and field, you can sketch the electric field lines.

There are three possible configurations to map out. Shown in Fig. 1, they are two dimensional configurations of conductors or electrodes. When two conductors are connected to a power supply, we set up a potential difference. You will observe the potential field using a digital voltmeter.

Procedure Overview:

The electrodes are made of conductive paint. They are affixed to special paper that is impregnated with carbon. While carbon is slightly conductive, it is much more resistive to current flow than a route along the conductive paint. Thus, when the power supply is connected between two different electrodes, each one is essentially at the same potential as the respective power supply terminal. Because there is a potential difference between them, current flows across the sheet from high to low potential just as water flows from regions of high to low gravitational potential.

To map out the electric field you will use the taped pair of electrodes. These taped electrodes allow us to find the electric field vectors using the approximation

$$E_s = -\frac{\partial V}{\partial s} \cong -\frac{\Delta V}{\Delta s}.$$

Note that this equation, and the taped electrodes, give the electric field in the direction of “s”. For these configurations we’ll first explore the field with the taped electrodes, mapping out the electric vector field, then we’ll map the electric potential. Your instructor will demonstrate how to use these taped electrodes effectively.

To map out the electric potential you will follow the equipotentials using a single electrode. That is, you will plot lines showing where the potential is constant. The simplest way to do this is to watch the voltmeter while moving the probe along the paper, attempting to keep the potential constant. It is impossible to do this perfectly, so record how much the meter readings vary. This is your measurement of uncertainty.

The best method is to have one group member trace the equipotentials with the electrode while another group member records the electrode's position on graph paper. It helps if the person moving the probe stops from time to time to allow his or her partner to record the position. You should wind up with enough data points to connect the points of the equipotential. It is vital that you plot equipotential lines at regular **voltage** intervals, such as every 0.5 Volt. A maximum interval of 1 Volt is recommended. Smaller intervals will give greater detail. Be sure to label each line with the potential it represents.

In addition to the plots, you can visualize the electric potential in a closely analogous system, "stretched rubber sheets". By stretching a rubber sheet over a configuration of "heights" similar to the configuration of electrodes, the height of the rubber sheet will be in the same form to the electric potential. In each configuration you will compare the electric potentials to the "rubber sheet solution".

You will study two of the configurations shown in Figure 1. Make sure each group member gets experience mapping the equipotentials and electric fields with the voltmeter probes.

Part I: Parallel Plates

(1) Connect the battery to the electrodes and measure the voltage with the voltmeter. Make sure that the potential is constant along each electrode.

(2) Try out using the taped pair of electrodes. What is the relation between the reading on the voltmeter and the electric field? How do you determine the direction of the field? Map out the electric field on one half of the configuration. Use a piece of graph paper to sketch the electric field vectors at each point.

(3) Take the potential of one electrode to be the reference. Starting at this electrode (roughly in the middle), measure and record the potential at 0.5 cm intervals in the carbon paper toward the other electrode. Now, using the voltmeter, map the equipotentials, which are given by curves along which the potential stays constant. Use the method described earlier to transfer the map onto graph paper. Record the uncertainty in your measurements. Would your equipotentials change if you chose different reference?

(4) Use Excel to plot the potential versus the distance from the electrode for A and fit a straight line. The two dimensional paper electrodes you measured can be taken to model a slice through a set of parallel plates. What does your graph of potential vs. distance show? Does this agree with the "stretched rubber sheet" solution?

(5) Using the pair of probes and a colored pencil, draw electric field vectors on the equipotential map. With this information fill in the electric field *lines*. Indicate the strength of the electric field with the density of field lines. The SI unit for the electric field is volts/meter. What is the average electric field magnitude between the electrodes (include uncertainty)?

Part II: Dipole

- (1) Sketch a prediction of the equipotentials and field lines for configuration B.
- (2) Map out the electric field using the taped electrodes on a sufficient portion of the paper, as before.
- (3) Connect one point to the + and one to the - terminal of the power supply. Find and draw the equipotentials in 1.0 V (or smaller) intervals.
- (4) Find the electric field lines using the same method as in part I. The density of lines should reflect the strength of the electric field, and the direction should be indicated with arrows. How well did you predict the shape of the equipotential and electric fields? Does this agree with the “stretched rubber sheet” solution?

Part III: Parallel Plates with Conducting Ring

- (1) Sketch a prediction of the equipotentials and field lines for configuration C. The center ring is not connected to anything, so it “floats” at its own potential. Predict the effects of a conducting barrier between two electrodes. At what potential do you expect the center disk to float? What do you expect the E-field and potential structure to look like?
- (2) Map out the electric field using the taped electrodes on a sufficient portion of the paper, as before.
- (2) Follow the same method as before to find the potential and electric field for configuration C. How well did you predict the shape of the equipotential and electric fields? What was the electric potential inside the ring? Did it vary? What was the electric field inside the ring? Why? Did the results agree with the “stretched rubber sheet” solution?

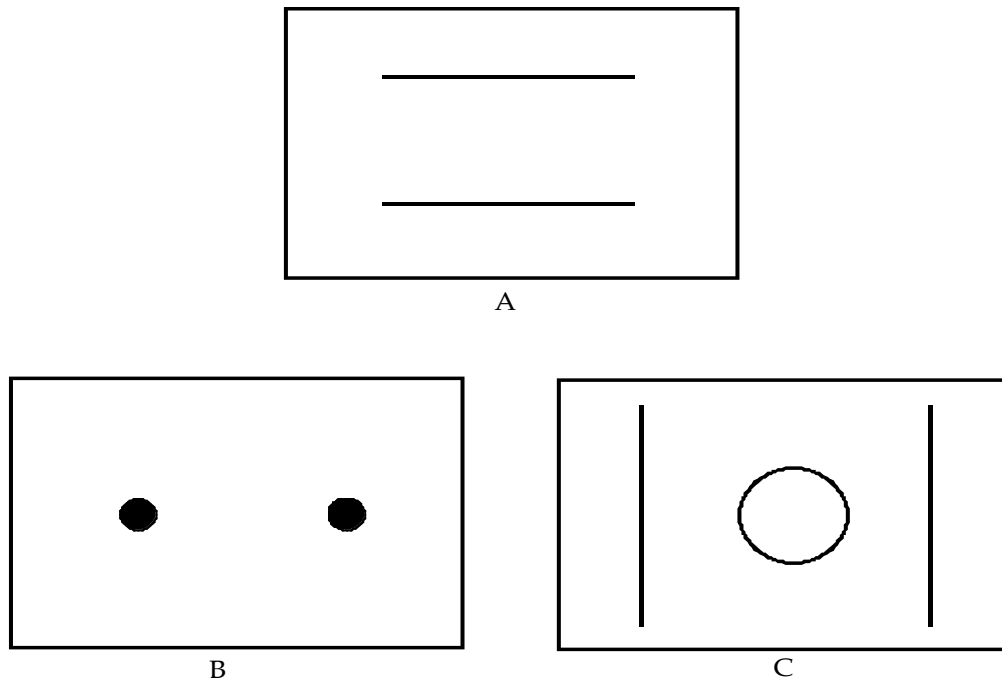


Figure 1. The three electrode geometries.