

The Field of an Electric Dipole Spring 2008

Introduction

In this lab you will measure the electric field around two oppositely charged electrodes (an electric dipole) at enough points to map the field. Since this is the first experiment in which you will use a multimeter, be sure to print and read the document "Using a Digital Multimeter". Bring this document with you to lab each week while we are working on circuits.

Background

The power supply pushes electric charge onto one electrode and pulls it from the other, making one electrode positively charged relative to the other. There is an electric field caused by these charges, which pulls on the electrons in the (conducting) carbon paper, causing them to move. The force on the electrons is:

$$\vec{F}_e = q\vec{E}$$

The electrons in the carbon paper drift slowly in a direction opposite to the \vec{E} field (why?). The power supply remains connected to replenish the (-) charge as it seeps away from the negative electrode.

An electron traveling through a displacement \vec{d} from one point in the field to another in the \vec{E} field will experience a change in electrostatic potential energy equal to

$$\Delta V_e = -\vec{F} \cdot \vec{d} = -F_e d \cos \theta$$

We can measure the electrostatic potential energy per electron by measuring the electric potential (*voltage*, ϕ) between two points separated by a distance d . The voltage between two points is defined as

$$\phi = \frac{\Delta V_e}{q_{test}}$$

so we can find \vec{E} between any 2 points as

$$\phi = -\frac{qE \cos \theta}{q} = -\vec{E} \cdot \vec{d}$$

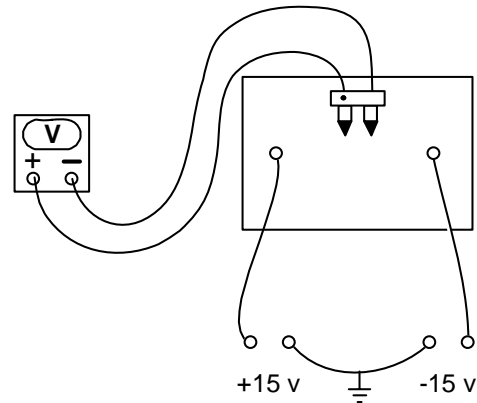
or

$$E = \frac{-\phi}{d}, \text{ with direction determined from } \theta.$$

We can use this relation to map the electric field around a dipole.

Experiment

- We will use a *multimeter* throughout the semester to measure voltage, current, and resistance in circuits and their components. Unplug the pencil probes from the multimeter, and connect two meter probe wires (in the “COM” and “V/ Ω ” ports). Familiarize yourself with the operation of the multimeter by measuring the voltage across *i*) a battery, *ii*) the DC power panel, *iii*) the AC power outlet, *iv*) across *both* screw heads on the conducting paper, and *v*) across each screw head and the green terminal on the power panel (one screw at a time). *Be sure that the meter is properly set to read DC or AC voltage before taking your measurement; if you’re not sure which you should use, ask for assistance.*
- Remove the probe wires from the multimeter, and reconnect the pencil probe, making sure that the wire from the pencil probe with the red dot is connected to the “V/ Ω ” port. Set the meter to the “20 DCV” setting; this will read voltages to 0.01 V. Your circuit is wired as shown in the figure.



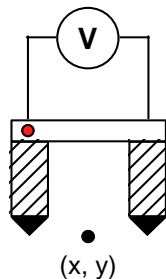
Make sure you can identify the various components of the circuit. The probes are 2 pencil points permanently mounted a distance d apart. The probe with a red “dot” on it will be your reference point, and you will measure all voltages with respect to that probe, as described in step 6 below. *Be sure that your hand does not rest on the conducting paper while measuring the voltage!*

- Check that the electrode nuts on the board are finger tight.
- Draw a full-scale copy of the electrodes and carbon paper on centimeter ruled graph paper, to use for recording your results. Do NOT write on the carbon paper.
- With the multimeter turned on, move the probes around the conducting paper, getting a sense of how the potential varies at different positions in the field. What happens when you reverse the probe points?
- Create a data table in your report using the headers below.

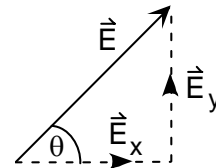
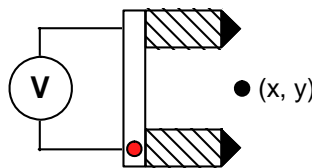
Coordinates:		E_x	E_y	E_x scaled	E_y scaled
X	Y	(volts)	(volts)	(cm)	(cm)

- Measure the voltage difference for *at least* 15 or 20 different positions in the field, by measuring E_x and E_y as shown below. Calculate the magnitude of the scaled components (a good scale is 1 volt = 2 cm), and *lightly* draw the scaled components on the graph paper. Draw a dark vector for \vec{E} , which is determined by adding the components graphically. Note that orientating the probe as shown below will give the correct sign to the vector components:

Measuring E_x



Measuring E_y



(Note: Since the electric field is proportional to the voltage, you can simply plot your voltage measurements!)

7. Check your calculations for 2 or 3 positions by holding the grounded side of the probe at a constant position and rotating the + side until you get the maximum voltage reading. This will give you the direction and magnitude of \vec{E} at that position. Calculate the magnitude of \vec{E} from these measured voltages, and compare them to the vectors plotted on your map.

Discussion

- Your discussion should briefly summarize what you did, and what the results were. Compare your picture to figure E2.4 in Moore.