# The Field of an Electric Dipole
**Spring 2013**

## 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. In addition, you will become familiar with the use of a multimeter as a voltmeter. 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 the multimeter instructions 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

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

We can measure the electrostatic potential energy per electron by measuring the electric potential (*voltage,* $\phi$) 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

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

or

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

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

## Experiment

0. We will use a *multimeter* throughout the semester to measure voltage, current, and resistance in circuits and their components. We will be using the multimeter as a *voltmeter* in today's experiment. Read through the "Using a Digital Multimeter" document before proceeding. Unplug the pencil probes from the multimeter, and connect the two wires found on your lab bench (by convention, we use a black wire in the "COM" port, and a red wire in the "V/Ω" port). In the steps below, you will familiarize yourself with the operation of the multimeter as a voltmeter:

    a. *Measure the voltage of a 9-volt battery:* Set the multimeter to the "20 DCV" setting so that the meter will measure DC voltage. Touch the red meter wire to the positive terminal of the battery, the black meter wire to the negative terminal and record the value. Reverse the wires (red to negative terminal, black to positive), record the measured value and note the difference.

    b. Switch the meter wires on the 9-V battery again, and change the multimeter to the "2 DCV" setting. Explain why you get this reading on the multimeter (*hint*: refer to "Using a Digital Multimeter"!)

    c. With the meter wires still connected to the battery, change the multimeter to the "200 DCV", and then the "1000 DCV" settings. Record the meter reading at each setting, and briefly explain how each setting affects the measured value.

    d. *Measure the voltage of each screw head on the conducting sheet:* Set the multimeter to the "20 DCV" setting. Plug the black meter wire into the green connector on the lab bench power panel. Touch the red meter wire to each screw head in turn, recording the measured value.

    e. *Gently* drag the red wire around the conducting paper surface. What happens to the measured voltage as you get closer to each screw head?

    f. *Measure the voltage across both screw heads:* if you were to connect the multimeter across both screw heads, what do you think will be the measured voltage? State your prediction, then try the measurement and record the value.

    g. What happens when you switch the wires on the screw heads? Which settings can you use on the multimeter when connected across both screw heads?

    h. *Measure the voltage from an AC outlet:* Insert the *AC-to-banana plug* adapter into the AC outlet on the lab bench power panel. Set the multimeter to the "700 ACV" setting so that you can measure AC voltage. Plug each meter wire into the adapter, and record your measurement.

> *Caution*: Never put any other wire in the adapter. *Always* unplug the wires from the adapter first, never from the meter! Remove the adapter from the AC outlet when finished. And always disconnect wires by pulling on their 'boot', never the wire itself.

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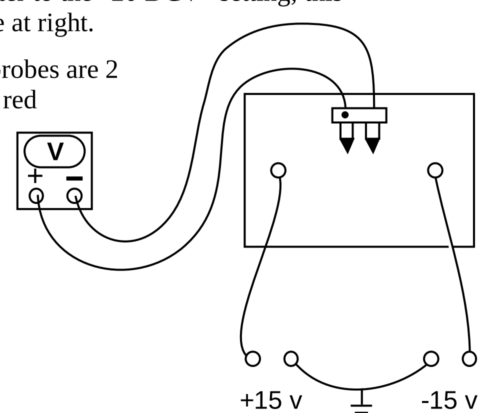
1. Remove the wires from the multimeter, and reconnect the pencil probe, making sure that the wire from the pencil probe with the red dot is connected to the "V/Ω" port. Set the meter to the "20 DCV" setting; this will read voltages to 0.01 V. Your circuit is wired as shown in the figure at right.

    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!*



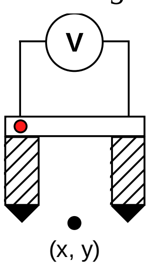

2. Check that the electrode nuts on the board are finger tight.

3. 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.
4. 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?
5. Create a data table in your report using the headers below.

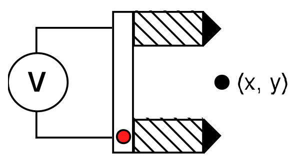
| Coordinates: | | $E_x$ | $E_y$ | $E_{x\ scaled}$ | $E_{y\ scaled}$ |
|---|---|---|---|---|---|
| X | Y | (volts) | (volts) | (cm) | (cm) |

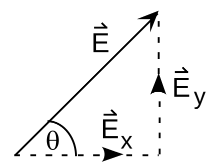
6. Measure the voltage difference for *at least* 20 different positions in the field, by measuring $E_x$ and $E_y$ as shown below. Measure points that are 2 cm or farther from each charge, and spread your measurements around the perimeter of the pair of charges. Calculate the magnitude of the scaled 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 (red dot to the left for $E_x$; on the bottom for $E_y$) 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 4 positions as follows: Rotate the probe, as it straddles the point you are checking, until you get the maximum voltage reading. This will give you the direction and magnitude of $\vec{E}$ at that position. Compare the maximum measured voltage to the calculated value of $\vec{E}$ from the measurements of $E_x$ and $E_y$ at that point.

## Discussion

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

**Please turn the multimeter off when finished**