Mapping Electric Potential

This lab is due at the end of the laboratory period. Note that the material covered in this lab, as in other labs, is testable and will be on exams.

Purpose: To investigate electric potential and electric fields created by different source charge configurations.

Apparatus

A cork board, two pieces of black conductive paper with grids, conductive push pins, a VEGO multimeter, a pair of wires with pointy probes (black and red), a MEGO power supply with wires.

Introduction

Electric charges change the space around them by creating an electric field. If you bring a test charge into this space, it will experience a force – the electrostatic force. The force on a positive test charge will be in the same direction as the field, and on a negative charge will be opposite the field.

If we view this field from the energy perspective, we say the charges change the space around them by raising or lowering the electric potential in the surrounding regions. If you bring a test charge into this space, it will have an electric potential energy, and the electrostatic force acting on it tends to lower its potential energy. The force on a positive test charge will try to move it from high potential to low potential, and the force on a negative test charge will try to move it from low potential to high potential.

Electric potential and electric field are related by the formulas:

$$\Delta V = -\int \vec{E} \cdot d\vec{r}, \qquad E_x = -\frac{\partial V}{\partial x}, E_y = -\frac{\partial V}{\partial y}, E_z = -\frac{\partial V}{\partial z}$$

In this lab, we will model two different charge configurations with electrodes, measure the potential around them using a multimeter, and then draw the equipotential maps. Based on the equipotential lines, we can draw and calculate the electric fields.

The difference between the “potential” and the “potential difference”

The term “potential” refers to a point, and the term “potential difference” refers to the difference between two points. The potential of any point depends on what we choose as the zero, but potential difference remains the same no matter where the zero is. Take a 1.5 V battery as an example: If we choose the negative terminal to be the zero potential, then the positive terminal has a potential of 1.5 V. If we choose the positive terminal to be the zero potential, then the negative terminal has a potential of −1.5 V. But the potential difference between the two terminals is always 1.5 V. In circuits, the “potential difference” is often called voltage, and can be measured by a voltmeter.

In this lab, we choose the ground terminal of the power supply to be at zero potential. We use a multimeter (as a voltmeter) to measure the potential difference between a point on the conductive paper to the zero, and the value of the voltmeter will be the potential of that point.

Part 1 Mapping the potential around two charge configurations

The parallel-plates model

1. We will first use the conductive paper with the parallel-plates model. Secure the conductive paper to the cork board using the conductive push pins at the electrodes. These connect to the power source as well as hold the conductive paper in place.

2. Connect the two electrodes to the power supply using wires provided (black to the left-side plate, red to the right-side plate). Set the multimeter in DC voltage mode; connect the “COM” to the left plate or the zero potential. Connect a black wire with a pointy probe to the multimeter so it is ready to measure the potential relative to zero. The connected apparatus is shown in Figure 1.

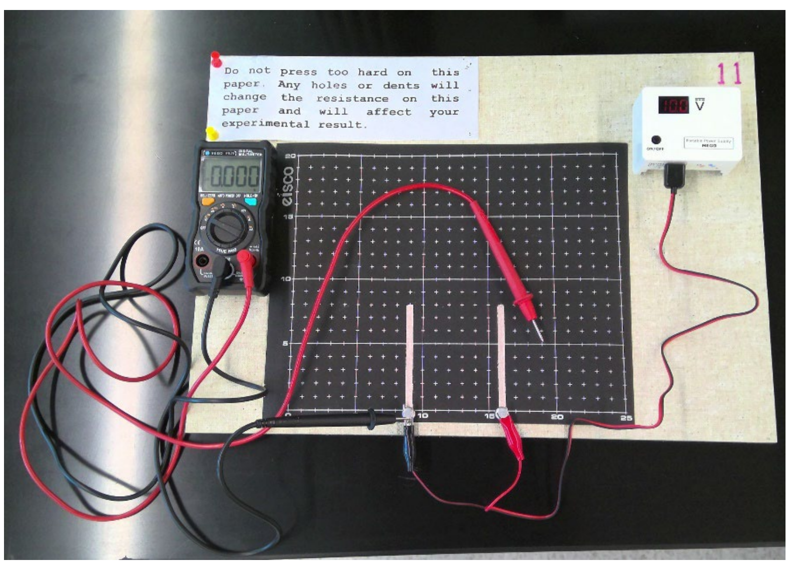


Figure 1
The experimental setup with the parallel plates model.

3. Turn on the power supply. Gently touch the red pointy probe to the right-side plate and adjust the voltage of the power supply with a small screwdriver, so that the multimeter reads 10.0 V (± 0.1 V). This establishes the source of the field that we will map, as shown in Figure 2.

Figure 2

4. Before mapping the potential, hold the red pointy probe and lightly touch the conducting paper, and move it around while watching the readings of the multimeter. This is to get an overall picture of the potential around the plates.

5. Now we will start mapping the potential. A white field mapping paper (with same grid lines as the conductive paper) is provided. Put the red pointy probe on each plate and make sure the readings are 0.0 V and 10.0 V (within ± 0.1 V) for the two plates. Label the electrodes with 0.0V and 10.0V respectively on the white field mapping paper.

6. Next, we map the 2.0V line. Move the red pointy probe gently over the conductive paper, looking for 2.0V (between 1.9V and 2.1V). Once there, your partner should mark down the same location on the white field mapping paper. Make about 3 to 5 dots in between the plates, and 3 to 5 dots just outside the end.

7. Repeat the above step to map the 4.0V, 6.0V and 8.0V lines. Don't forget to label the potential lines.

8. Help your partner to map another parallel plates model, with two plates set to 0.0 and 8.0 V. Map the 2.0V, 4.0V and 6.0V lines.

9. If there is a third partner in your group, have them make a third map of 0.0 to 12.0V, with the 2.0V, 4.0V, 6.0V, 8.0V, 10.0V lines.

The point charge model

Replace the parallel-plates conductive paper with the point-charge paper, and connect the 0.0V to the outer ring, and 10.0V to the inside dot (see Figure 3).

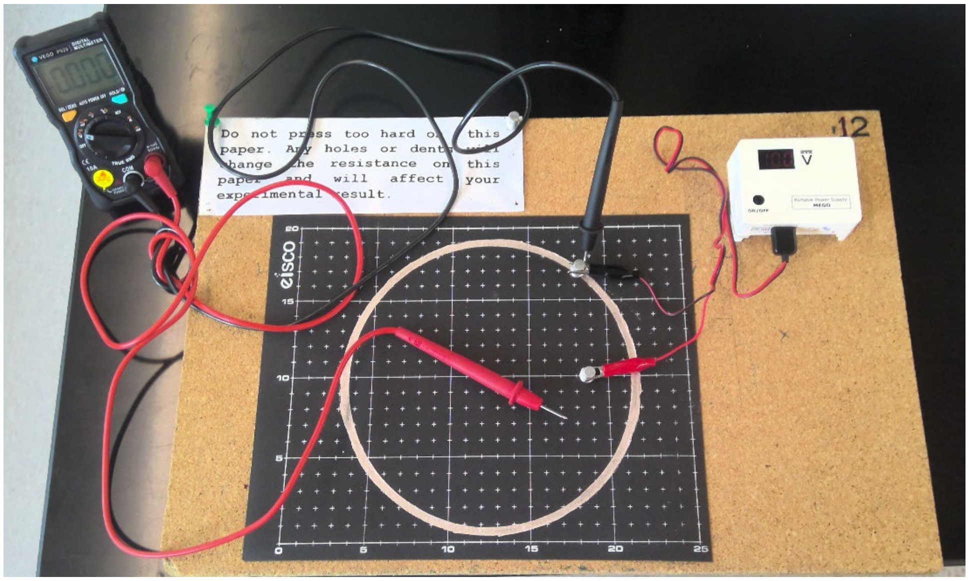


Figure 3
The experimental setup with the point charge model.

Follow the same procedures (as in the parallel plates model) to map the potential at 1.0V, 3.0V, 5.0V and 7.0V. For your lab partner, do another mapping with the power supply set to 8.0V and map the potential at 1.0V, 3.0V and 5.0V.

If there is a third partner in your group, have them make a third map of 0.0V to 12.0V, with the 2.0V, 4.0V, 6.0V, 8.0V lines.

For the point-charge paper, it may be more difficult to hit the exact voltage readings, especially near the point source. To locate the 7.0 V points, aim at the voltmeter’s readings to be between 6.8V to 7.2V.

Part 2 Investigating the electric fields from the potential map

1. On your potential maps, draw the equipotential lines by connecting the dots of the same potential with smooth lines or curves. Mark each equipotential line with its potential value.

2. Draw the electric field lines on your maps, following the rules below:

- When they cross, the electric field lines must be perpendicular to the equipotential lines. (To see why it is so, think whether the electrostatic force can have a component parallel to the equipotential line.)

- The direction of the electric field is pointing from high potential to low potential. (To see why it is so, think of the direction of the electrostatic force on a positive test charge.)

- The density of electric field lines is proportional to the density of equipotential lines. (Assume equal intervals of the potential.) Next activity will illustrate why this is so.

3. Calculate the average magnitude of the electric field at a few representative points and show your calculations on the maps. Your lab instructor will tell you which points to choose. The average magnitudes of the electric field between two equipotential lines can be calculated by $E = \Delta V/\Delta s$, where ΔV and Δs are the potential difference and the perpendicular distance between two adjacent equipotential lines. Because ΔV should be the same (for us $\Delta V = 2.0$V), the closer the potential lines, the higher the electric field. This reflects on your map as the denser the equipotential lines, the denser the electric field lines.
You may want to summarize all your electric field E calculations in a single table (as shown below) for each map.

Point	ΔV	Δs	E (calculations and result)
(unit)	(V)	(cm)	(V/m)
A			
B			
C			

Each student needs to hand in two potential maps: one potential map for the parallel-plates model and one for the point charge model (with different potential setting from your partner). Check that each of your maps has

- ☐ Equipotential lines with values of potential;
- ☐ Electric field lines with directions of the field.
- ☐ The magnitude of electric field at given points between two successive equipotential lines.

Complete the worksheet on the next page, attach your two potential maps to the end of the worksheet and hand it in.

Name: ________________________________

Partner(s): _____________________________

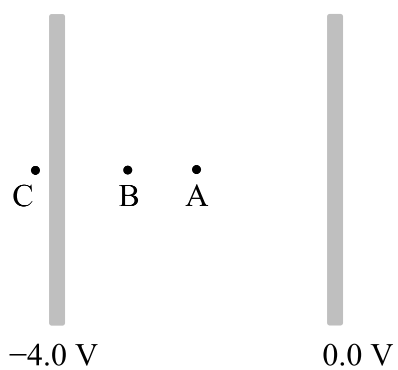
1225 Section: _______

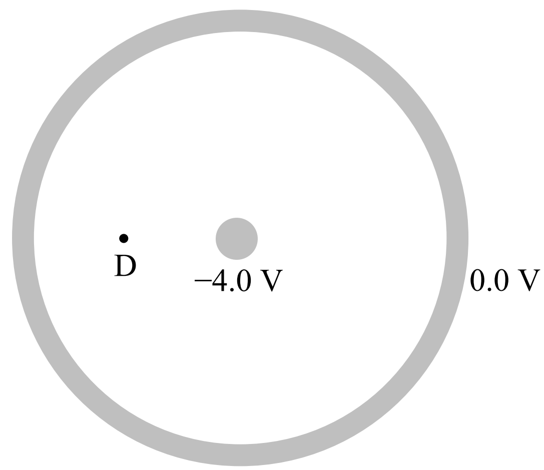
Desk # _____________

Date: _________________

Mapping Electric Potential (Worksheet)

For each configuration below, draw the equipotential lines of −1.0 V, −2.0 V and −3.0 V, and then qualitatively draw the electric field lines. Give the approximate potential of points A, B, C and D.





Point A: __________________

Point B: __________________

Point C: __________________

Point D: __________________

Attach the two field maps to the end of this handout and hand it in.