The Equipotential Surfaces of a Dipole
Spring 2018

Introduction

The purpose of this lab is to directly measure a system that simulates the equipotential surfaces between two charges. 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”. Be sure to bring these multimeter instructions with you to lab for the next few weeks.

Note: The multimeter will be referred to as the voltmeter (for measuring voltage) or ammeter (for measuring current) in all lab instructions, depending on its use for the experiment.

Background

Figure 1 at right shows the equipment you will use to simulate the potential surfaces around two charges: a conducting paper with wires that connect a voltage source to two bolts on the paper. The paper is attached to two connectors (red and black) on the lab bench power panel, and the negative (COM) terminal of the voltmeter is attached to the green (ground) connector. The positive (V) terminal of the voltmeter has a free wire that you will use to measure the potential (voltage) at different points on the paper.

The red and black connectors on the power panel are connected to a voltage source that maintains one bolt on the paper about +15 volts (red) above, and the other about –15 volts (black) below the ‘reference’ potential (green connector), which is 0 volts. Make sure the electrode nuts (under the paper) are finger tight!

The assumption is that the electric current in the paper (due to these voltage sources) will cause a potential at each point on the paper, which is the same potential you would calculate if the bolts were charges in a vacuum.

Experiment

0. You will first collect some simple measurements to familiarize yourself with the basic operation of the multimeter as a voltmeter. Follow steps (a) through (g) in the exercise on the last page of the document “Using a Digital Multimeter”; record what you did and your measurements in your report. When you have completed the multimeter exercise, return to this document for the rest of the experiment.

Figure 1: Connections

Figure 2: The equipotential surfaces around two charges

Figure 3: Topographic representation of the equipotential surfaces around two charges
1. You will plot your equipotential surface map using the grid found on the last page of these instructions. The grid corresponds to the crosses on the conducting paper, with each major division on the graph equal to two crosses on the conducting paper (x ranges between ±6 units, y between ±4 units). Small dots on the grid indicate the positions where you will take your measurements.

2. Reconnect the very long wire from the negative terminal (COM) of the voltmeter to the green terminal on the lab bench panel. The positive terminal (labeled V/Ω) is connected to the red meter probe that you will use for your measurements.

3. Turn the voltmeter on, and set it to the 200 DCV setting (which displays Direct Current voltages up to 200 volts). Be sure to record this meter setting in your report.

4. Touch the probe to the carbon paper. The voltmeter reading, which is the potential at that point, will depend on where you touch the carbon paper. The voltage along the y-axis (between the charged bolts) should be close to zero. Move the probe around to get a sense of how the potential behaves. Try to keep your hand off of the carbon paper while measuring voltage – it can affect the reading!

5. Now measure the potential for each integer x–y pair (the ‘dots’ on your grid) and record them on the map. Be sure to also measure and record the voltage across each screw head. You might want to collect a few more measurements to find where the electric potential equals zero volts. You don’t need to record the units near each measurement; you should indicate the units used at the top of the field map.

6. Drawing Equipotential Lines. Sketch equipotential lines for the following voltages: 0, ±2, ±4 and ±6 volts (don’t be concerned if the line for 0 volts isn’t along the central vertical axis). Your instructor will show you how to do this by interpolation.

Calculation of Electric Field Vectors

7. The electric field \( \vec{E} \) from the potential \( V \). The point at coordinates (2, 1) typically has an equipotential line close by. Copy the potentials around this point in your report as shown below, and use them to find the components of \( \vec{E} \) for your map (Figure 4 – note the negative sign in the equations!):

\[
\begin{align*}
E_x &= -\frac{\Delta V}{\Delta x} = -\left( \frac{7.3 - 3.1}{3.0 - 1.0} \right) = -2.1 \text{ V/cm} \\
E_y &= -\frac{\Delta V}{\Delta y} = -\left( \frac{4.4 - 9.0}{2.0 - 0.0} \right) = +2.3 \text{ V/cm}
\end{align*}
\]

Figure 4: Calculating \( \vec{E} \) around potential point

8. After finding the components of \( \vec{E} \), sketch them on your field map at the point (2, 1), using a scale of \( 1 \text{ cm} = 2 \text{ cm} \) (drawn on graph). The vector sum of \( \vec{E}_x \) and \( \vec{E}_y \) (the \( \vec{E} \) field at that point) should be perpendicular to the nearest equipotential surface (as shown in Figure 2). Be sure to place the components of \( \vec{E} \) tail to head, as shown in Figure 5 below.

Figure 5: Vector addition (Remember??)
9. Repeat steps 7 and 8 for two more of your measured points within 1 cm of an equipotential line, but not too close to the edge of the paper (where the \( E \) field is very weak). Be sure to follow the same pattern as the example in step 11 for calculating the components, no matter in which quadrant potential points are found.

Discussion

- Briefly summarize what you did in this experiment (not the multimeter exercise), and include comments about the expected vs. actual directions of your \( E \) vectors.
- How does your map of the equipotential surfaces compare with an ‘ideal’ map? Discuss the similarities and differences.

- **PLEASE TURN OFF YOUR MULTIMETER WHEN FINISHED!**