Objectives

Electric fields are important to understand because they tell us how charges interact with other charges, which then gives us the ability to control charge motion and interaction (i.e. to build functional circuits). It is not trivial to measure electric fields, however, though we can easily measure electric potentials. In today’s lab, you will measure equipotential lines to then infer the configuration of electric field lines emanating from different charge geometries.

For the following activities, you will use a physics simulation program. Visit: https://uglabs.physics.ucr.edu/ for lab downloads and links.

Introduction:

The electric potential, just like the electric field, is a property of source charges. A positive charge will have a large positive electric potential value when you are close to it (and a negative charge will have a large negative electric potential value next to it). The unit of electric potential is a Joule per Coulomb which is also known as a Volt, V. Many times electric potential will be referred to as Voltage for brevity.

These lab activities will focus on equipotential surfaces due to different charge configurations. An equipotential surface is a surface where the electric potential value is the same value. In the simulation we will be using semiconducting paper to allow us to measure and visualize the potentials around conducting shapes (electrodes).
1. Predicting Equipotential Surfaces

Electric fields emanate from all charge, but they are very difficult to measure directly. Equipotentials are imaginary lines that connect all points at which the magnitude of the electric field is equal. Recall the relation between electric field and electric potential. Due to the nature of electric fields, the geometric consequence is that all equipotential lines are perpendicular to electric field lines at all points. Additionally, a convention in drawing equipotential lines is to draw them closer together for large electric field magnitudes and further apart for small electric field magnitudes.

Today we will be using multimeters to measure the electric potential around different charge configurations to determine the location of equipotential lines, which we will then use to approximate the location of electric field lines.

1.1: Draw in your notebook the electric field lines emanating from a single positive point charge. Then draw the corresponding equipotentials from the field lines you just drew.

1.2: Now draw the electric field lines for the four electrode configurations provided to you (see Figures 1 through 4 on the following page). Draw the corresponding equipotentials from the field lines you just drew.

1.3: Once you finish, ask your TA to look over your work, as it is essential for the rest of the lab that you understand the relation between electric field lines and equipotential surfaces.
Equipotential Mapping

Fig 1 – Two electrodes

Fig 2 – A metallic circular ring

Fig 3 – Two horizontal bars serving as parallel plates

Fig 4 – Shielding
2. Using the Equipment

2.1: Render the four electrode configurations (Ring, Dipole, Parallel Plates, and Shielding) from the menu at the bottom-left of the screen. Copy these templates into your lab book for your own record.

2.2: Begin by using the dipole configuration.

2.3: Set the voltage from the power supply to 10 V.

NOTE: Whenever you connect a power supply or large battery to a circuit, you should make sure there is some sort of resistance between the positive and negative terminals. If you create a path without any resistance between the two terminals (e.g. connecting the terminals with only a piece of wire or other conductor) you will create what is called a "short circuit" and the high currents that will flow can cause injury and damage equipment.

2.4: The semiconducting paper does not conduct charges well. In comparison, the metal electrodes are good conductors. When the power supply is on, charge builds up on the conductors. What path do charges follow between the electrodes?

2.5: You now have the power supply providing a potential difference across the two conductors. Next, you want to measure the voltage at any position on the semiconducting paper. Your simulation should already have the negative terminal of the voltmeter to the electrode connected to the negative terminal of the power supply, as shown in the picture below:

The positive terminal of the voltmeter is now your “probe”. The red wire that stems from the right-hand side can measure the potential at any point with reference to the negative of the power supply, the common “ground”.
2.6: The voltmeter will now measure the potential difference between any point probed on the paper and the negative terminal of the power supply (which is also the potential on the negative electrode).

To measure this potential difference at a given point, move the end of the red probe onto the semiconducting paper. This can be done by using the mouse cursor or by using your keyboard arrow keys + Shift keyboard key.

The value of electric potential at a given point can be read from the voltmeter. Check that the voltmeter reading agrees with the readout on the power supply.

*Figure 6* - The picture above shows the power supply set at 10 V, connected to dipole electrodes. In this setup, the left electrode is connected to the negative of the power supply and is at 0 V. The voltmeter is reading the potential difference between the left.
2.7 In addition to reading a value of an electric potential, you can also display markers and field lines onto the semiconducting paper.

- To place a marker, hover the probe over a desired location on the semiconducting paper, and type “M” (alternatively, right-click your mouse and select “Add Marker”). A blue dot will appear at the corresponding coordinate.

- To add an equipotential curve, create two markers. Then, select one of the markers and drag the cursor across the screen to the next marker. A blue line will appear.

- To add a field line, left-click on the semiconducting paper and drag the cursor to anywhere you fancy. Once you let go, an orange line with an arrow will appear (see right).

- Both the equipotential and field lines can be curved by pulling their respective midpoints (i.e. the green dot and arrow respectively).

- Changes to the equipotential and field lines can be made by right-clicking individual lines.

- Additional changes can be made through the toolbar on the lower-left corner of the program (see right).
3. Finding the Equipotential Surfaces

For the dipole configuration, find at least three equipotential contours using the following method:

3.1: Select a voltage for the equipotential that you will draw. Choose equally spaced integer voltages covering the range from 0V to the voltage level of the output of the power supply.

3.2: Using your probe, find a point at the selected voltage on the semiconducting paper. Mark the location and voltage of that point in your lab book.

3.3: Repeat step 3.2 until there are a sufficient number of points to “connect-the-dots” and form an equipotential curve. Be sure to investigate all over the quadrant of the paper to find points with equal voltages.

3.4: Repeat for the other voltages selected to show a better picture of the equipotential contours.

3.5: From these equipotential shapes, what do you predict the electric field lines will look like (draw this in your notebook)? Do these predictions agree with the electric field lines drawn in part 1? Why do you think that is?

3.6: Repeat steps 3.1 through 3.5 for the other three configurations provided to you in the template menu.
Write a brief summary of the experiment you performed today. In your summary, think about the following questions:

- Why is measuring equipotential lines an important activity?
- Today we measured equipotentials, which are lines that connect points at which the magnitude of the electric field is equal. Can we tell anything about the *direction* of electric field lines with these measurements? Propose some additional measurements that would allow us to determine directionality.
- In today’s lab, we have measured equipotentials in relatively simple configurations. Can you think of any more complex systems or configurations where this measurement might be important to making an electronic device function properly? Describe your thinking.
1. The diagram below shows three spatial points (A, B, and C) in a uniform electric field that points from left to right in the plane of this page. Each point has an associated electric potential \((V_A, V_B, V_C)\). Rank the potentials for these three points, from least to greatest. Add a point D to this diagram such that it is at a lower potential than point B but at a higher potential than point C (if it is impossible to do so, then state why).

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\begin{align*}
E \text{ field} \\
A^* & \quad C^* \\
B^* & \\
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