PHYS 40C: Lab 3
Equipotential Mapping
(Includes Pre-Lab Assignment)

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.

Introduction:

These lab activities will focus on equipotential surfaces due to different charge configurations. In this experiment you will use paper with special properties called ***teledeltos*** paper. This paper was originally invented for use in telegraphy – transmitting information, in this case images – by phone lines. It is possible to use an applied voltage at a point on the paper to burn away a tiny part of the paper's surface. By varying the voltage applied at different points on the paper, an "image" could be made and transmitted.

This was a powerful technological advance and enabled black and white photographs to be sent electronically via undersea cable from London to New York in 1939. The paper allows very small amounts of charge to flow along the direction of the local electric field. This makes it neither an insulator nor a conductor, but a member of a very important class of materials called "semiconductors".

In this lab, the semiconducting paper allows us to measure and visualize the potentials around conducting shapes (electrodes). Since we are not interested in transmitting information (and we also don't want to waste the fancy paper), in this lab we will not be using large enough electric potentials to burn the paper.

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.

We learned last week that it is straightforward to measure electric potentials using digital multimeters. Today, we will take advantage of that and use measurements of 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 on your apparatus. Draw the corresponding equipotentials from the field lines you just drew.

1.4: 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.

2. Using The Equipment

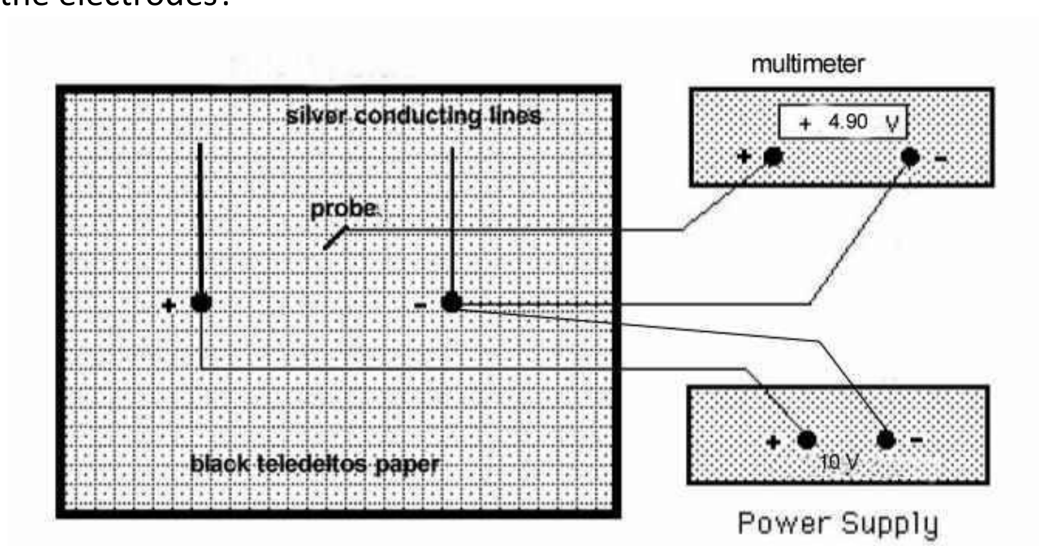
2.1: Each group has a piece of teledeltos paper with different electrode configurations. Trace or copy the four electrode configurations onto the *photocopy* of the teledeltos paper. The photocopy goes into your lab book for your record. Do not make any marks on the black teledeltos paper.

2.2: Select two wires from the stock in the lab, one red and one black. Choose wires that have banana plugs on one end and alligator clips on the other. For the dipole configuration (#1), fasten the red clip to one electrode and the black one to the other.

2.3: Plug the rounded (banana) end of the red wire into the positive (+) terminal on the power supply, and the black wire into the negative (-) terminal. This provides a potential difference across the electrodes. We could use a battery in place of the power supply, just as you could choose to run any electrical appliance with a battery. But using electrical energy from the power grid from the electric company is usually cheaper and easier than using batteries. It also allows us to vary the potential we want just by turning a knob. 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.

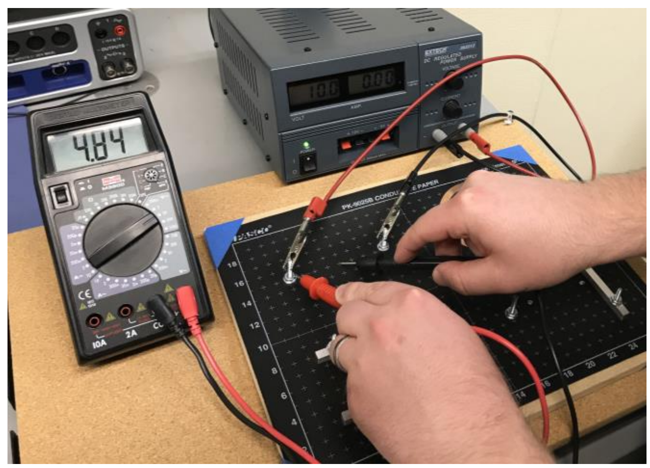
2.4: The teledeltos paper does not conduct charges well. In comparison, the metal electrodes are good conductors. When the power supply is on, charge builds up on the conductors. What path do charges follow between the electrodes?



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 teledeltos paper. Connect the negative terminal of the multimeter to the electrode that is already connected to the negative terminal of the power supply, as shown in the diagram. The positive terminal of the multimeter is now your "probe" and can measure the potential at any point with reference to the negative of the power supply, the common "ground".

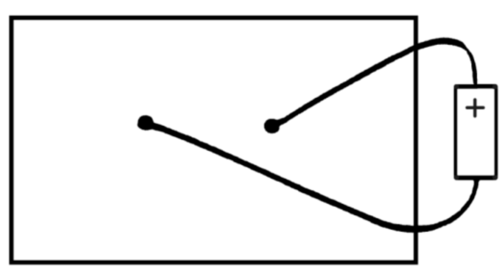
2.6: The multimeter will measure the potential difference between the point probed on the paper and the negative terminal of the power supply (which is also the potential on the negative electrode). To measure this potential difference at a given point, gently touch the red probe to the teledeltos paper *without puncturing the paper*. The value of electric potential at a given point can be read from the multimeter. Check that the multimeter reading agrees with the readout on the power supply.

The picture at right 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 multimeter is reading the potential difference between the left electrode and a point on the teledeltos paper about midway between the electrode.



3. Finding the Equipotential Surfaces

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



3.1: Select the voltages for the equipotential 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 teledeltos paper. Mark the **location** and **voltage** of that point on the *white photocopied page*. Use the grid marks on the black paper to help transfer your readings onto the photocopy.

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 on your apparatus.

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.

Pre-Lab Assignment (1 point)

1. Consider two regions of space containing a static electric field, region A and region B. In region A the equipotential lines are more closely spaced than those in region B. What can be said about the relative strength of the electric field in the two regions?
   A) The electric field in region A is stronger than in region B.
   B) The electric field in region A is weaker than in region B.
   C) The electric field strength is unrelated to the spacing of the equipotential lines
   D) The electric field is directly proportional to the value of the potential in a given region of space. Therefore, more information is required to answer the above question.
   E) Both C and D

2) Equipotential lines are always _____________ to electric field lines.
   A) parallel
   B) perpendicular
   C) at a 45 degree angle
   D) None of the above.

3) In the presence of a static electric field, a conducting surface
   A) contains no charge
   B) contains charge
   C) is an equipotential
   D) Both A and C
   E) Both B and C
   F) none of the above