

Lab
2

Equipotential Surfaces and Electric Field Lines

What You Need To Know:

The Physics In last week's lab you moved charges around by using the ideas of conduction and induction. Charges move because they are in an *electric field*. This electric field is caused by other nearby charges. In this lab you will derive what the *electric field lines* look like for two different *charge distributions*. One distribution will consist of two "point charges" and the other distribution will consist of two "charged lines".

Since you can't measure electric field strengths directly, you have to measure them in a roundabout way. You're going to use the idea of *equipotential surfaces* to derive the electric field lines. Equipotential surfaces are a collection of points in space [or in your case, points on a piece of conductive paper] which have the same electric potential. Unlike electric fields, you can measure the electric potentials directly. To do this you'll use a *voltmeter*. Once you have found enough points on the paper with the same electric potential, you will make a line connecting the points. This line is an equipotential surface [or line]. These equipotential surfaces are actually only simulations of what really occurs for charge distributions in free space [as opposed to the conductive paper]. You can refer to your textbook for diagrams of what the equipotential surfaces and the electric field lines look like for these two charge distributions.

Electric field lines and equipotential lines are always perpendicular. [Your TA will explain why in lab.] So, once you have the equipotential lines on the paper you can determine what the electric field lines will look like.

The Equipment You'll be dealing with three main pieces of equipment: a voltmeter [the yellow box], a power supply [the large gray box], and the black conductive paper. Your lab TA will demonstrate how to use these. The power supply will be set at 10 V for the entire lab so you don't have to alter that. You will be using the voltmeter to take readings of electric potential.

What You Need To Do:

Setting Up Your Lab First, turn on the power supply. It will boot up some software for about 10 seconds. After it boots, push the OUTPUT button below the dial. On the screen for CH1 you should see a reading of 10 V. If not then have your TA show you how to adjust the voltage. Next, turn on the voltmeter and turn the dial so that it's in the DCV area set on 20 V. Before you begin you'll want to make sure that everything is set up properly. Take the probe and touch it to the pushpin that has the red cable going to it. You should get a reading on the voltmeter of 10 volts. If it's not, then grab your TA for help.

Next, while still having the probe on the paper, move the probe slowly to the other pushpin. The reading on the voltmeter should gradually decrease and eventually get to zero once you touch the other pushpin. Everything should now be set for you to find the equipotential lines.

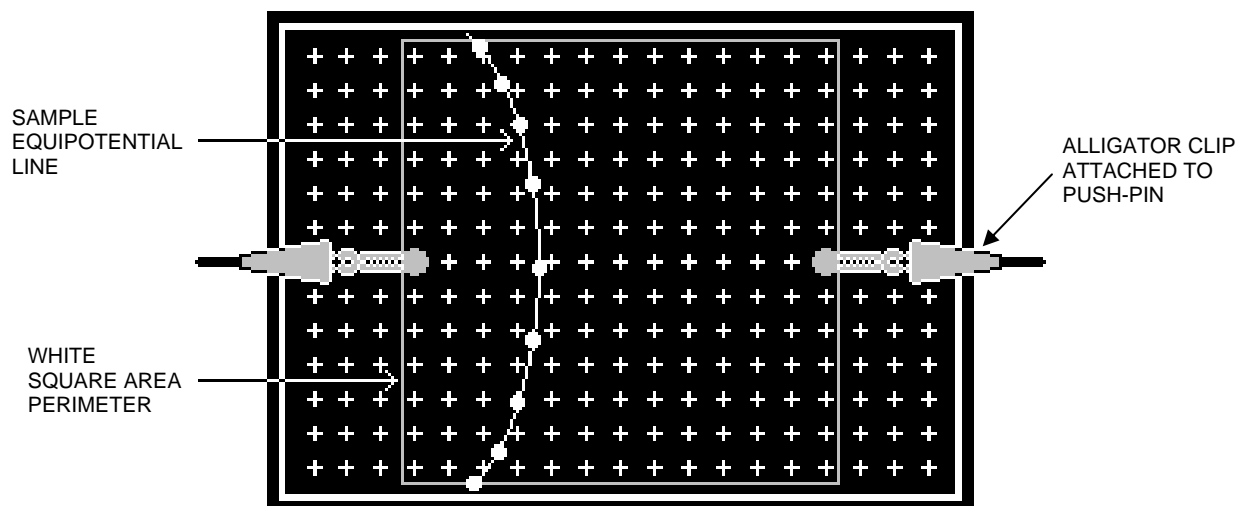


FIGURE 1 - Conductive paper set-up

Part 1 – Finding Your Equipotential Lines The situation you have set up here is a simulation of two point charges in space. See **Figure 1**. One “charge” you have set to act like a low potential [zero volts] and the other is your high potential [10 volts]. In between, you should get potentials ranging from zero to 10 volts. Using the probe, you will find points on the conductive paper that have the same electric potential. After connecting these points, you will have an equipotential line.

Helpful Hints

- Make sure the pushpins are firmly pressed down on the paper so that they are flush with the surface. This will give you better contact and more consistent data. If your data suddenly changes during the lab [like overlapping lines] then you probably nudged a pushpin.
- Make sure that the alligator clips are coming straight out from the pushpins [Like in Figure 1], perpendicular to the edge of the paper.
- If you use the angled part of the tip of the probe, so that more metal is in contact with the paper, you will get better readings.
- If you touch the paper with your hands or fingers while taking a reading, it'll alter your reading.

Make sure to read the **Helpful Hints** before continuing. Take the probe and find a point on the paper that gives you a reading of 1 volt. Take the white pencil and make a dot on the conductive paper at that point. Find another spot nearby that will give you another reading of 1 volt. Continue doing this until you have a line of points all at 1 volt. Connect the dots and label the line “1 Volt”. This is your first equipotential

line. See the sample line in **Figure 1**. NOTE: Make sure when you are making your dots that you stay in the *white square area perimeter* between the pushpins. See **Figure 1**. The alligator clips cause the fields to warp so don't concern yourself with the area outside the square. Repeat this process for lines of potential 2 volts through 9 volts. A common question is, "How many dots should I draw per line?" Answer: As many as you need to get a nice, smooth curve. Just as a reference; for lines of greatest curvature make the dots about 1 cm apart, for lines that are almost straight make the dots roughly 4 cm apart.

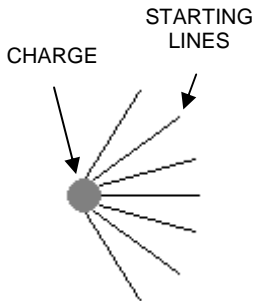


FIGURE 2 –
Initial field
lines

Part 2 – Drawing Your Electric Field Lines Remove the paper from the board. On the left charge, draw lines like in **Figure 2**. They should each be about a 1 cm in length. Use these lines as starting lines for each electric field line you draw. Without making a mark, continue away from the charge along a starting line until you come to the next equipotential line. At that point you probably aren't perpendicular anymore. In that area there will be a point that is perpendicular. Make another small mark at that point. Continue this process until you arrive at the opposite pushpin. Now go back and connect the marks into a smooth curve. This is an electric field line. Check with your TA to make sure you're drawing the lines correctly. Do a total of 7 field lines; one down the center, 3 on top, and 3 on the bottom. Spread your lines out as much as possible, don't bunch them together in the center of the page. On your paper, mark the charges as positive and negative. Also indicate which way the field lines are pointing.

Part 3 – The Lines of Charge Set-up Remove the current conductive paper and replace it with the other conductive paper at your table. This paper is your Lines of Charge set-up as opposed to your Point Charge set-up that you just completed. You are basically going to do the same procedure as above but now the equipotential lines will look different. In some areas the lines will be straight for a certain length and then curve away. Use your own discretion as to how close to make the dots. Once you have all of your equipotential lines then move on to **Part 4**.

Part 4 – Some Number Crunching Using the Lines of Charge paper, you are going to calculate the electric field strength in between the lines. You will use the following equation ...

$$\Delta V = Ed$$

ΔV is the potential difference (in volts)
 E is the electric field strength (in volts per meter)
 d is the distance between potentials (in meters)

Pick two different equipotential lines and measure the distance, d , between them [in meters]. The lines you pick don't have to be next to each other, in fact, it would be better if they are at least a couple of lines apart. For the lines you picked, calculate the potential difference, ΔV , between them using the numbers that you wrote on your conductive paper. Now plug these values into the equation to calculate the electric field strength. Choose another two lines [that are a different number of lines apart than you just did] and do the same thing. Show your calculations on a separate piece of paper.

Question 1 The two field strengths you just calculated for the lines should be close to the same value. Why is that? What can you say about the electric field between the lines?

Question 2 If you tried the Number Crunching part on the Point Charge set-up, would you get numbers that have the same value? What does this tell you about the electric field in between the point charges?

Question 3 Describe [or draw] what the field lines would look like between point charges that are set up with potentials of 20 volts and 30 volts [instead of 0 volts and 10 volts].

What You Need To Turn In:

Questions and Calculations Turn in your sheet with the calculations for the electric fields and the answers to the questions.

The Conductive Paper Take each page of conductive paper and cut them in half along a line vertical in the center of the page. You and your lab partner will each turn in a half.