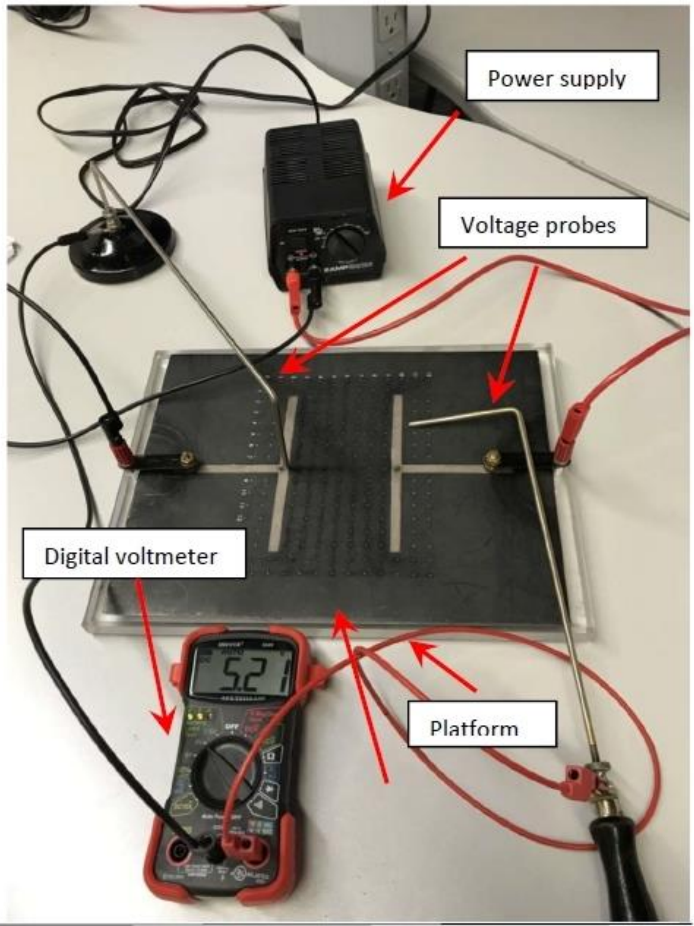
Electric Field Plotting

The goal of this lab is to find equipotential lines between a two-dimensional arrangement of conductors set to different electric potential. We will also construct the electric field lines. We will do this in two configuration, called "parallel plates" and "dipole".



Equipment

- Digital Voltmeter
- Power supply
- Two voltage probes
- Platform
- Carbonized acetate sheet for "parallel plates"
- Carbonized acetate sheet for "dipole"
- Worksheet for "parallel plates"
- Worksheet for "dipole"

Method

Each carbonized sheet has a certain pattern of highly conducting areas silver-painted onto it. These painted areas have to be connected to the terminals of the battery which supplies charge to the conductors and maintains a constant potential between them. A current flows through the resistive carbon film from one conductor to the other. By probing the area between the conductors with the digital voltmeter, we will find sets of points that have zero potential difference between them, i.e. they lie on the same equipotential lines.

Each sheet has a grid of reference marks to make it easy to identify the points between the conductors. Using the grid we will transfer the information to a Xerox copy of the sheet, and we will make drawings of equipotential lines and electric field lines.

Procedure: Parallel Plates

1. Connect power supply, terminals of the sheet and voltmeter as shown in the photo above. Pay attention to the proper connection of the voltmeter (which 2 of the 3 terminals will you use). Always have both carbon sheets together on the frame, with the sheet you are measuring on the top. This helps to make better contacts with the terminals. The sheet with the plates is oriented such that the row numbers increase with increasing voltage, from low to high. The column numbers step in the direction along the parallel plates.

2. The negative battery terminal is connected to the left contact on the sheet and the positive battery terminal to the right contact. The voltmeter terminal "-" is connected to the left parallel plate via the free standing stationary voltage probe and the terminal "+" is connected to the right parallel plate via the voltage probe with the handle. This will be the probe you use for measuring voltage on the sheet, between the parallel plates. Make sure you have good contact between the terminals and the conducting strips leading to the plates. You should see on the voltmeter about 5.5V. If you see less than 5.0 V, your contact with the terminals is bad, most likely due to damage of the end of the conducting parallel plate shapes. By shifting the carbon sheet a bit you should be able to get 5.0 V or more.
3. Switch ion the power supply and set it to 6V.
4. Turn the voltmeter ON and set the scale to 9V.
5. Record the voltage between the two plates on the worksheet below.
6. You are now going to measure the potential at various point and record your results on Xerox copies of the carbonized sheets. The Xerox copies are available from the instructor and each student in the group should have his/her own recording. Do not place the Xerox copy of the carbon sheet on top of it. Leave it on the side and record the results on this copy. Label the low and high voltage plates on your copy including the voltages on them, i.e. 0.0V for the low voltage plate by definition and your recorded value from the voltmeter on the high voltage plate.
7. Next, leave the low voltage probe fixed at the low voltage parallel plate and put the handheld voltage probe in the center of the line of dots just below the high voltage parallel plate. This should be column 8, row 9, which will be expressed as (8,9) from now on. Record the voltage from the voltmeter next to that point on your Xerox copy of the set up.
8. Now, you want to find points that have the same potential as point (8,9). Take the handheld voltage probe and place it on nearby points until the voltmeter measures approximately the same value as you recorded for point (8,9). Mark the corresponding point on the Xerox copy with a cross. Repeat this for a few different points until you have enough to determine the shape of the equipotential line.
9. Once you have enough points, connect them to show the shape of the equipotential line. You can make your job quicker by thinking about the symmetry of the diagram to help you predict where the lines should go.

10. You are now going to repeat this procedure to obtain several more equipotential lines in between the parallel plates. Again, make sure that the standing voltage probe is on the low voltage parallel plate. Put the handheld probe down to the center of the next row, point (8,8). This will give you the voltage of the next equipotential line. Follow the procedure outlined above to draw the line.
11. Repeat this process going down the sheet until you are just above the low voltage parallel plate. When you are finished you should have 7 equipotential lines between the two parallel plates. While you are doing this, pay attention to points that lie outside of the parallel plate configuration, because once outside of the two plates, the equipotential lines will no longer be parallel.
12. When the equipotential lines have been drawn, you will be able to sketch the electric field lines. To do this, draw lines that are perpendicular to the equipotential lines. Draw several of these lines inside the parallel plates and one by each of the ends of the plates. Remember that electric field lines should also be perpendicular to the surface of any conductors on your sheets!
13. These lines are electric field lines for the parallel plate charge distribution. Indicate with arrows how the electric field begins on areas with positive charge and ends on areas with negative charge.

Calculate the electric field and answer the questions

The electric field E can be calculated from the voltage difference between 2 equipotential lines, $\delta V = V_2 - V_1$ and the distance between them $\delta x = x_2 - x_1$ taken in a direction perpendicular to the equipotential lines: $E = \delta V / \delta x$. Note that the distance between the dots on the carbonized sheets are 1.0 ± 0.5cm

Choose a region with a uniform electric field in your parallel plate drawing. **Is this region close to the edge of the plates or is it in the interior of your plot?** Indicate on your Xerox sheet the equipotential lines where you take these measurements and write the voltage and distance values needed for your calculation of the electric field in the Table in the worksheet (last page of this notes). Use 0.1V for the errors in the two voltages V_1 and V_2.

You need to find the error in the value of the field we have measured from the error in our measured quantities. You can find the absolute error in δV by using equation Eq.6 of the Guide to estimating uncertainty. Convert that to relative error and find the relative error in the field by using Eq.7. Multiply that by your value of E to find the absolute error in E. Complete the Table in the worksheet with calculated values.

How does the electric field change between various locations in the middle area between the plates? Will the electric field get higher or lower if you move closer to the edges?

Procedure: Dipole

1. Repeat the search for equipotential lines for the "dipole" charge distribution. Orient your carbon sheet on the platform as you did for the parallel plates. First, obtain the voltage between the 2 poles by putting the standing probe on the low voltage pole and the handheld probe on the high voltage pole. Record this on the worksheet and also label the electrodes on the Xerox copy with these values.
2. Next, you will be finding equipotential lines. The procedure for this is very similar to the first part of the lab, but you must be careful. The shape of the equipotential lines is very different and you cannot just look for points on a straight line.
3. Draw electric field lines from this configuration by drawing several lines which are always perpendicular to both the equipotential lines and to the surface of any conductors. Make sure to use arrows to note the direction the field travels across the sheet.

Answer the following questions:

Looking at the electric field lines you drew for the "dipole" arrangement, where are lines the most dense, close to the + and - charges or closer to the horizontal center line of the graph? Since a pictorial measure of the strength of an electric field is given by the density of the electric field lines, the above question is equivalent to asking where is the electric field of a dipole strongest?

If you were to replace the negative charge in the dipole by a positive charge (or to replace the positive charge by a negative charge), would the pattern of the electric field lines be the same as measured for the +/- dipole?

Worksheet for Electric Field Plotting

Parallel plates:
The potential difference between the plates is: __________ V

	V_1	V_2	δV	δx	E
Unit					
Value					
Relative Error	----------------	----------------			
Absolute Error					

Dipole:
The potential difference between the metallized dots is: __________ V