PHY152H1S – Practicals 4 and 5: Electric Potential, Electric Field

Don't forget:

- List the NAMES of all participants on the first page of each day's write-up. Note if any participants arrived late or left early.
- Put the DATE (including year!) at the top of every page in your notebook.
- NUMBER the pages in your notebook, in case you need to refer back to previous work.

Note that the activities below have numbers which refer to numbers in the Electricity and Magnetism Module 3 at http://faraday.physics.utoronto.ca/Practicals/ .

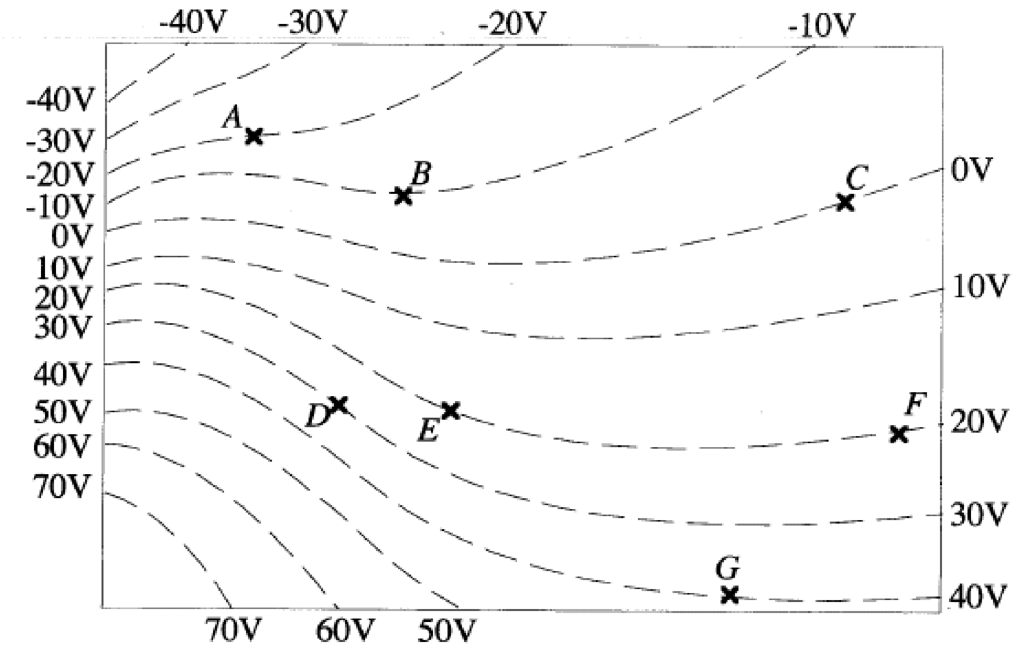
Important Note About Formal Lab Reports

You will be responsible for writing individual lab reports based on Activity 9. Plan ahead. Extra copies of your data is advised. The basic measurements of Activity 9 involve a certain pattern painted in silver paint onto a sheet of conductive paper. Your team will perform measurements on 3 or 4 different patterns. Every member of your team must base your formal report on ONE of the patterns you measure, and you cannot do the same pattern as another member of your team.

You have two weeks to finish all the measurements for this experiment. During these two weeks, you will also be preparing for your midterm. The formal report will be due March 11, and will be officially assigned during Practical 5.

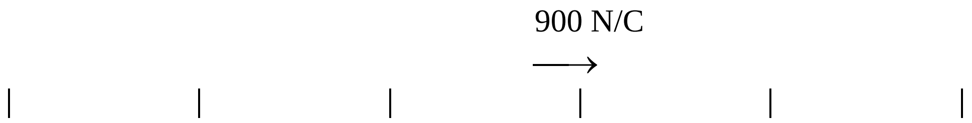
Activity 8

The dashed lines in the figure below show equipotentials in a region in which there is an electric field. A positive point charge is placed at each of the seven labelled points in turn. On the diagram, draw vectors to show the direction of the force on the charge at each of the labelled points. Briefly explain your reasoning.

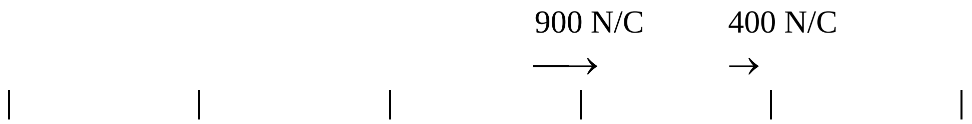


Activity 2 (If you have time at the end..)

A. The electric field of a point charge (not shown) is given below at one point in space. Can you determine whether the charge is positive or negative? Explain why or why not.



B. In the figure below, the electric field of a point charge is shown at two positions in space. Now can you determine whether the charge is positive or negative? Explain why or why not.



C. Can you determine the exact location of the charge? If so, draw it on the figure shown in Part B. If not, explain why not.

Activity 9 - Electric Field Mapping

In this experiment, charges will be placed on conducting surfaces and the electric field set up by these charges will be mapped. In Module 2 you used a battery as a source of voltage. Here you will be using a DC power supply, which has exactly the same functionality.

Work Done When a Charge Is Moved In an Electric Field

Recall that work = force × displacement, where "force" is the component of the force in the direction of the displacement. Suppose a positive charge q = 5 x 10^{-6} C is placed at point A in Figure 1. The electric field strength E is assumed to be constant, E = 7 N/C, in the direction indicated by the arrows. The unseen charges which set up the electric field are responsible for the push on the charge q, and the net force on the charge is F = qE = 35 x 10^{-6} N. Assuming the distance through which the charge q moves from A to B is d = 2 m, the work done by the electric field is W = Fd = 70 x 10^{-6} Joules.

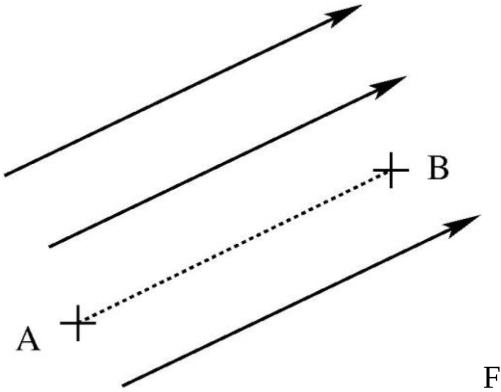


Fig.1

The situation is quite different in Figure 2. There, the path along which the charge moves is perpendicular to the electric field. This means that the force exerted on q by the charges which set up the electric field is perpendicular to the displacement of the charge, so the component of the electric force along the direction of the displacement is zero.

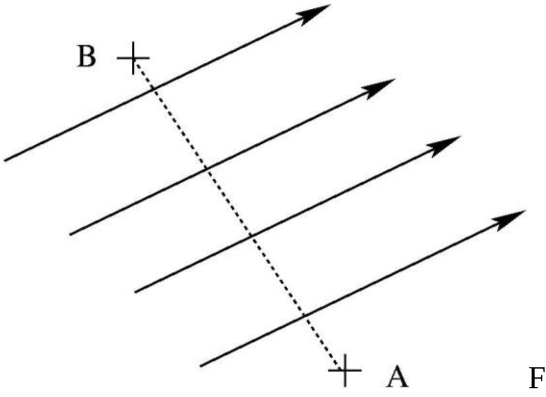
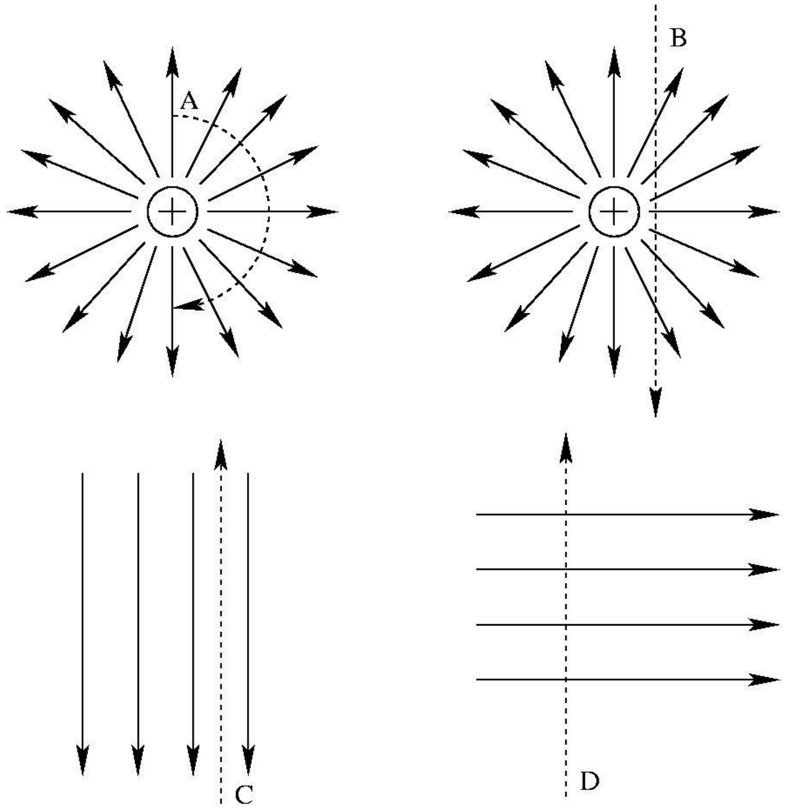


Fig.2

Thus, the electric field does no work on the charge q as it moves from point A to point B. Since no force resists the motion along the path, we are free to imagine that virtually any small force whatever could have moved the charge q along this path; the cause of this force is irrelevant. The point here is that *the electric field does no work on any charge moved along a path that is everywhere perpendicular to the electric field*.

Part A

Along which paths A, B, C, and D, shown in the figure below, is work done by the electric field (indicated by the arrows) on a positive charge moved along the path, and along which paths is zero work done?



Using a Multimeter to Find Paths of Zero Work

A multimeter in the DC-V (direct current, voltage) mode can be used to map paths of zero work in an electric field. It's done this way: the negative lead from the black jack is connected to some object whose charge state is constant; this is often the earth ("ground"), which is so large that its surface charge may be regarded as constant. Other objects can be treated as if they were ground, and with the negative lead connected to them.

The lead from the red jack (the positive jack) of the multimeter is then used as a probe to pick a point--any point--and measure its voltage; then the probe is moved over the region to find points in space which provide the same voltage reading. *Paths made up of points which are at the same voltage are paths along which zero work would be done if any charge is moved along this path.*

Voltage is sometimes referred to as "potential", so the lines or curves of equal voltage are called "equipotential paths", or "equipotential curves", or "equipotential lines". If one can map the equipotential curves of an electric field, one then has only to draw perpendicular curves or lines which intersect the equipotential curves at right angles in order to specify the electric field.

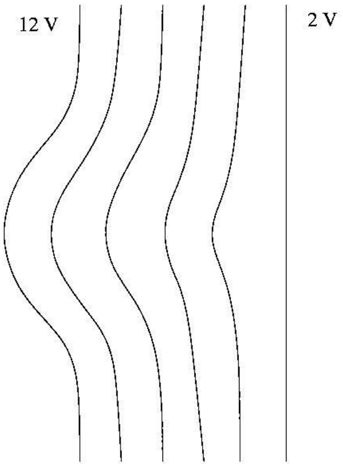
How is the Direction of Electric Fields Determined?

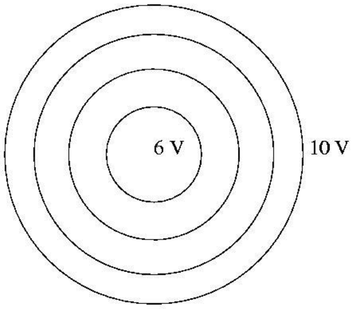
The direction of the electric field lines may be shown by arrows on the field lines; they point toward regions of *lower* potential, or voltage.

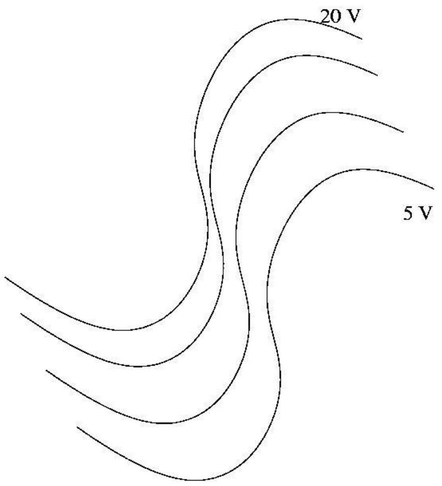
Note: Additional copies of the figures in Parts B and C are provided at the end of this Student Guide. Draw your vectors on that pull-out copy and attach it to your lab notebook at the appropriate place.

Part B

Sketch several representative lines representing the electric field pattern for the three equipotential patterns shown below. Draw arrows on the lines to show the direction of the electric field.

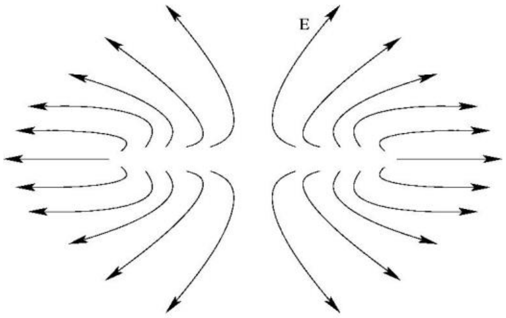


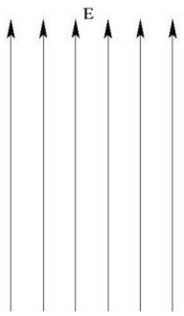


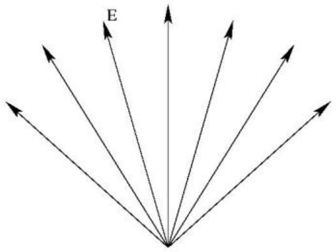


Part C

Sketch the equipotential patterns corresponding to each of the electric field patterns shown below. Label three of the equipotential curves in each diagram "20 V", "10 V", and "5 V"; these are completely arbitrary. Remember, the electric field lines point toward regions of *lower* potential.







Experimental Procedure

You are going to map the electric field patterns set up by pairs of objects that are oppositely charged. One object will be negatively charged, and will be referred to as "ground"; the other object will be positively charged. The pairs of objects are:

1. two dots
2. two parallel lines
3. circle with a dot in the middle
4. two dots with a large rectangular border around the edges
5. a straight line and a V-shape with wings

You will be provided with two sheets of black conductive paper that are capable of carrying small current and have painted with conducting silver paint. Since the charged paths will actually be conductive ink electrodes, they will be referred to as electrodes.

1. Choose one of the sheets and place it on your corkboard.

NOTE: The traces for parallel lines have a large silver pad at the midpoint of each line. Use these pads as electrical contacts for the parallel electrodes.

2. Select the <u>red</u> wire with a banana plug on one end, and a ring terminal on the other. Insert the banana plug into the red (positive) jack of the power supply, and place the ring terminal on top of one of the silver pads on the conductive paper. Ensure the flat side of the ring terminal is the side touching the paper, and press a conductive push pin through the ring terminal into the corkboard. <u>Make sure that good metal-to-metal contact is made between the ring terminal and the silver pad.</u>

3. Select the <u>black</u> wire with banana plug and ring terminal, this time connecting the black (negative) power supply jack to the other electrode with another push pin.

4. On the diagram in this handout (not on the black paper), label the corresponding electrode "20 V", and the other one "0 V"; it doesn't matter which one is positive, and which is negative.

5. Select the wires (one red, one black) with a banana plug on one end and a pointed metal rod on the other. These are the probes for the multimeter. Connect the red banana plug to the V-ohm jack and the black banana plug to the COM (common) jack on the multimeter.

6. Switch on your multimeter and select DC-V to enable measurements of voltage (potential). If the display shows "batt", replace the battery of the multimeter.

7. Plug in the power supply, turn it on, and set its voltage to about 20 Volts. You can check the voltage using the multimeter. To prevent the highest voltages to be out of range for your multimeter, use the 200 V setting.

8. The power supply acts just as a DC battery would, so the objects on the corkboard are now charged and have an electric field in the region between them.

9. When measuring potential of a point on the conductive sheet using the multimeter, bring and hold the black probe in contact with the push pin connected to the negative (-) jack of the power supply, bring the red probe in contact with the point of interest, and observe the reading on the multimeter.

When the circuit is complete, it should look something like the photo below.

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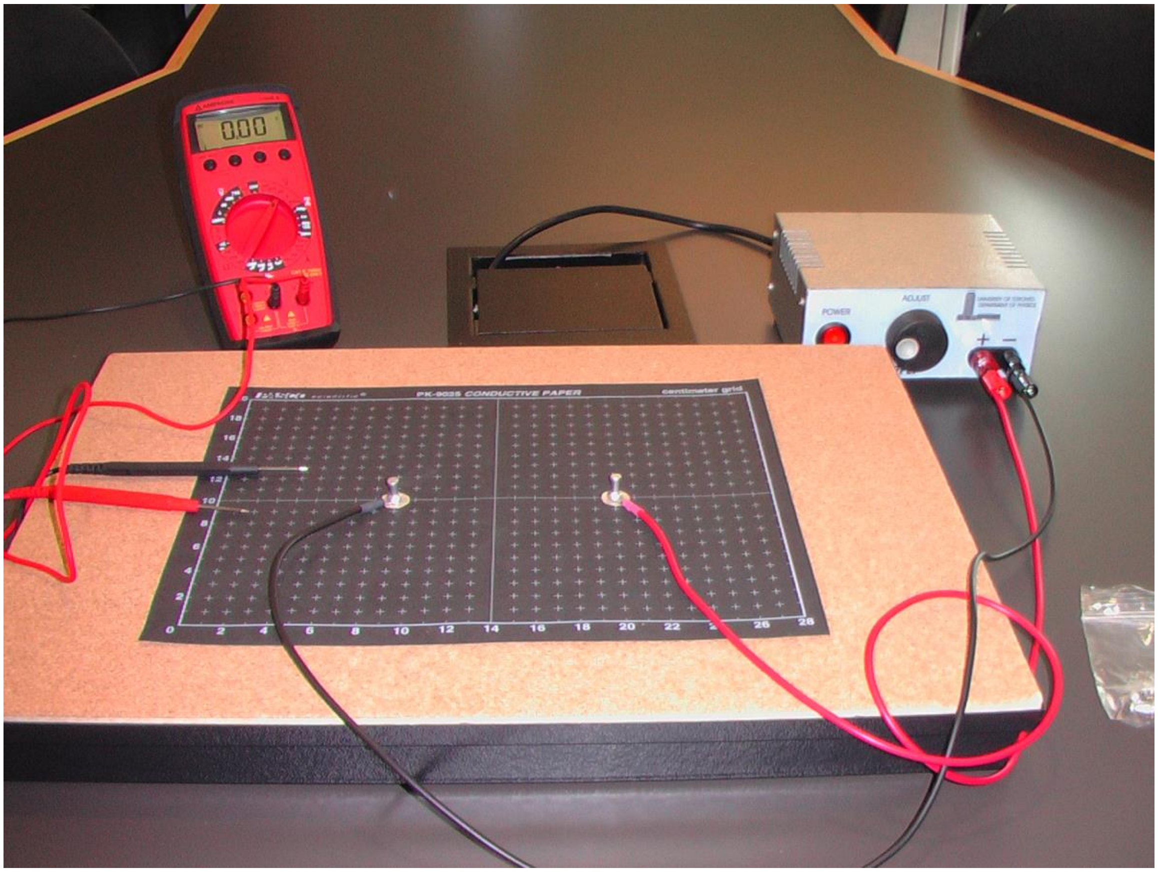


10. Gently scrape the banana plug over the paper between the two objects until you find a point at which the potential (voltage) is about 5 Volts; don't make any pencil or pen marks on the black paper. Next, find the path from this point along which the potential stays constant at 5 Volts; follow this path wherever it leads, even if the path curves around behind the edges of the objects. This path traces a curve or line called the "5-Volt equipotential line". You may find it easier to plot a series of points rather than tracing a continuous line. For example, you could work across each row of the grid to find the location of the 5-Volt potential, mark these points, and then connect them to obtain the 5-Volt equipotential line.

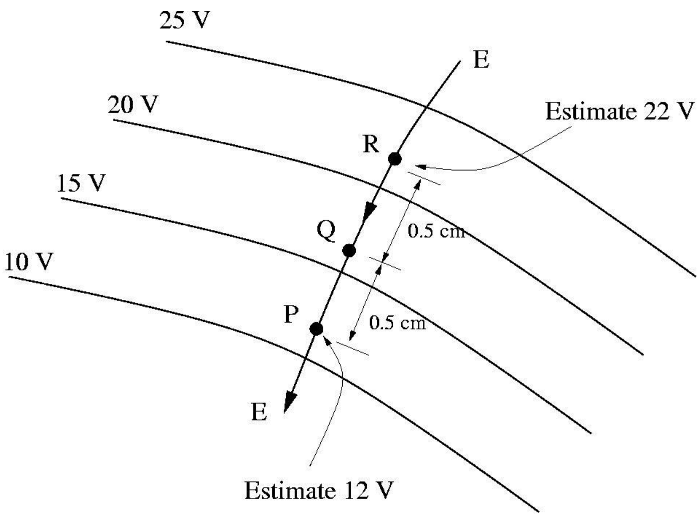
11. After you have located the 5-Volt equipotential line, sketch its approximate shape and location on the diagram below; it is not necessary to be exact. Label this line "5 V".

12. Repeat Steps 9 and 10 to find the 10-V amd 15-V equipotential lines.

Keep in mind, as you plot the equipotential lines, that *the electric field is strongest in those regions where the equipotential lines are most closely spaced*. This is because the electric field E is related to the gradient of the potential field: $E = -\Delta V/\Delta r$, where ΔV is the change in the potential which occurs over a change in location Δr.

13. The electric field pattern consists of lines or curves which cross the equipotential curves at right angles. Sketch a representative number (15-20) of these electric field lines, and place arrows on a few of them to indicate the direction along which a positive test charge would move if one were placed at that point. Make sure that an electric field curve passes through each of the six small circular points shown on each pattern.

14. Find the electric field at the following locations on the conductive page: (x, y) = (13, 13), (13, 18) and (23, 8). Note that the sheets have the word PASCO written at a location of approximately (x, y) = (2, 21). This calculation is illustrated in the figure at the right for Point Q. Locate two points 0.5-cm on either side of Point Q along the electric field line passing through it. Estimate the potential at Points P and R, and subtract the smaller from the larger to get ΔV. Divide this potential difference by Δx.



Make sure you clearly document everything you are doing and how that is getting you the information you need. Do not forget to discuss the ***uncertainties*** of your values. All of this will be very useful to you when you go to write your formal reports!

Finally, discuss the results of some of your observations. Specic things to consider:

- What difference does the large rectangle around the two dots make? That is, compare it with the two dots with no border. Discuss both near the center of the page and near the edges of the page.
- The second and third sheets are imitating capacitors. How does the strength of the electric field inside the capacitors compare with the strength outside?
- The last sheet is imitating a lightning rod. Where is the electric field strongest on this sheet? Can you make a generalized statement about how the electric field strength near a conductor depends on the shape of the conductor?

Advice for improving your formal report

Take more data. Find the electric field (vector) at more than just the three locations required for the lab. Specifically, you should ask a question and then take data to answer it. Example questions are:

- For the sheet with just two dots, how does the electric field behave along the line which is equidistant from the two points?
- For the sheet with two parallel lines, how does the electric field behave along the line which is equidistant from the two lines?
- For the sheet with a circle and a dot, how does the electric field behave along the circle which is equidistant from the dot and the painted circle?
- For the sheet with the rectangular border, how does the electric field behave along a straight line which is 2 cm from one of the long borders?
- For the last sheet, has does the electric field behave along a straight line through the x = 13 cross marks?

This Guide was written in October-November 2007 by Kimberly Strong, Dept. of Physics, Univ. of Toronto.

Activity 1 is based on *ILD 10, Representation as Communication: Fields*, University of Maryland Physics Education Research Group (Spring 2003) and *The Electric Field Mapping* experiment, by Joseph Alward and Jason Harlow, Introductory Laboratories, Physics Department, University of the Pacific (2004). Activities 2, 3, and 4 are taken from Randall D. Knight, **Student Workbook** (Pearson, 2004). Activities 5, 6, 7, and 8 are taken from Curtis J. Hieggelke et al., **E&M Tipers: Electricity and Magnetism Tasks** (Pearson Prentice Hall, 2006). Activity 9 is based on *The Electric Field Mapping* experiment, by Joseph Alward and Jason Harlow, Introductory Laboratories, Physics Department, University of the Pacific (2004).

Activity 9 was modified by Jason B. Harlow, Dept. of Physics, Univ. of Toronto.

Last revision: August 3, 2010 by Kausik Das.