PHY 124 Lab 2 - Electric Field Plotting

(Spring 2013: revised 2/6/13)

Important! You need to print out the 1 page worksheet you find by clicking on this link and bring it with you to your lab session. [http://www.ic.sunysb.edu/Class/phy122ps/labs/dokuwiki/pdfs/124elecfldpltworksheet.pdf]

If you need the .pdf version of these instructions you can get them here
[http://www.ic.sunysb.edu/Class/phy122ps/labs/dokuwiki/pdfs/Phy124S13elecfldplt.pdf].

Goals

1. Plot lines of equal potential for two 2-dimensional charge distributions (see Ch16 sheet 15).
2. Construct the corresponding electric field lines (see Ch16 sheet 13).

For useful information and figures, see also the suggested textbook for our course, Knight, Jones, and Field, College Physics: A Strategic Approach, 2nd Ed. (KJF2): Secs. 21.4 and 21.5 and all figures on pp. 686-694. If you don't have a copy of the textbook, you'll find one bolted to a table in the Help Room, A-131 in the physics building. Additional copies are on closed reserve in the Math-Physics Library, on floor "C" of the physics building.

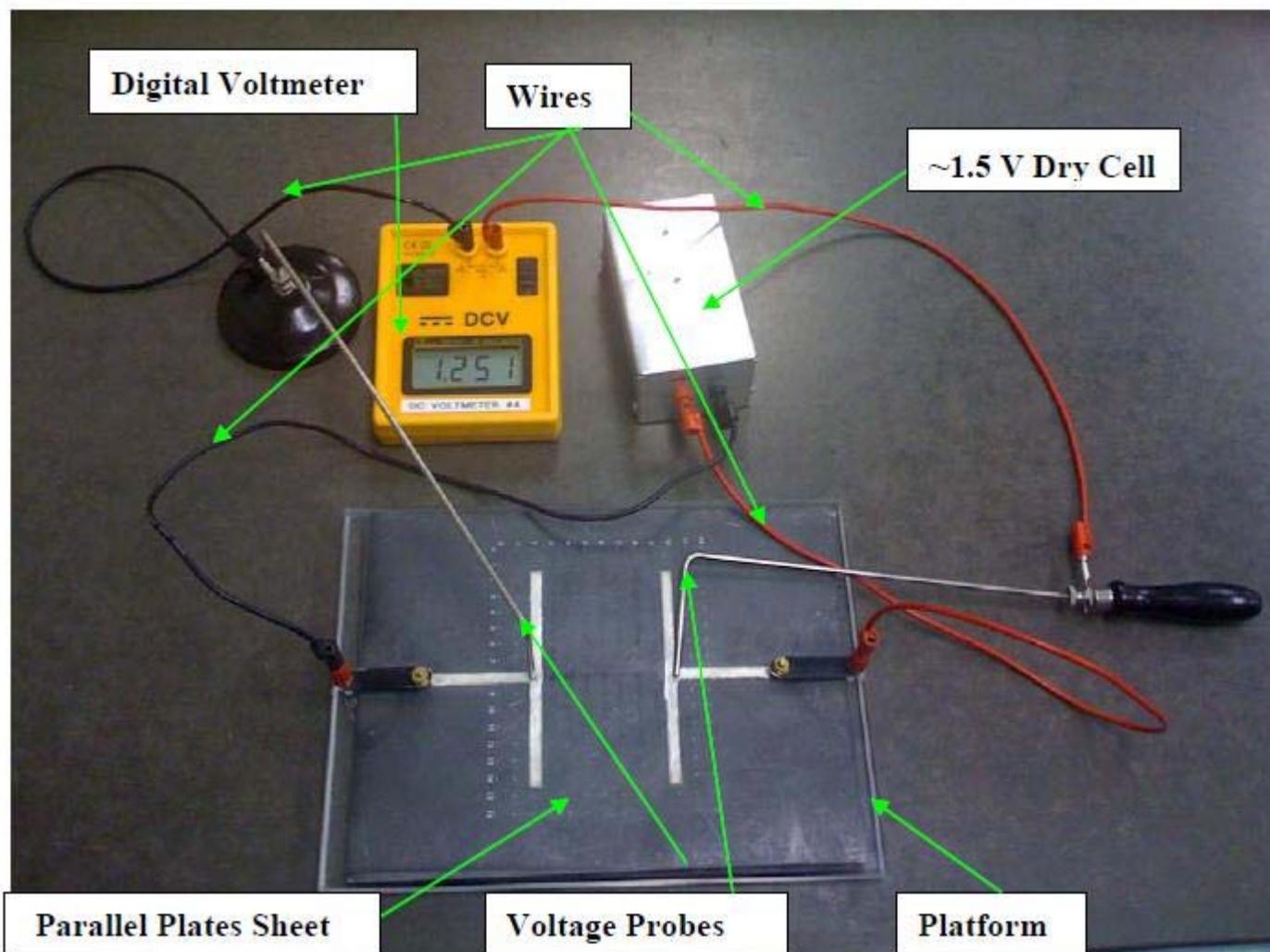## Video (the Lab number in the video is incorrect: this is Lab 2)
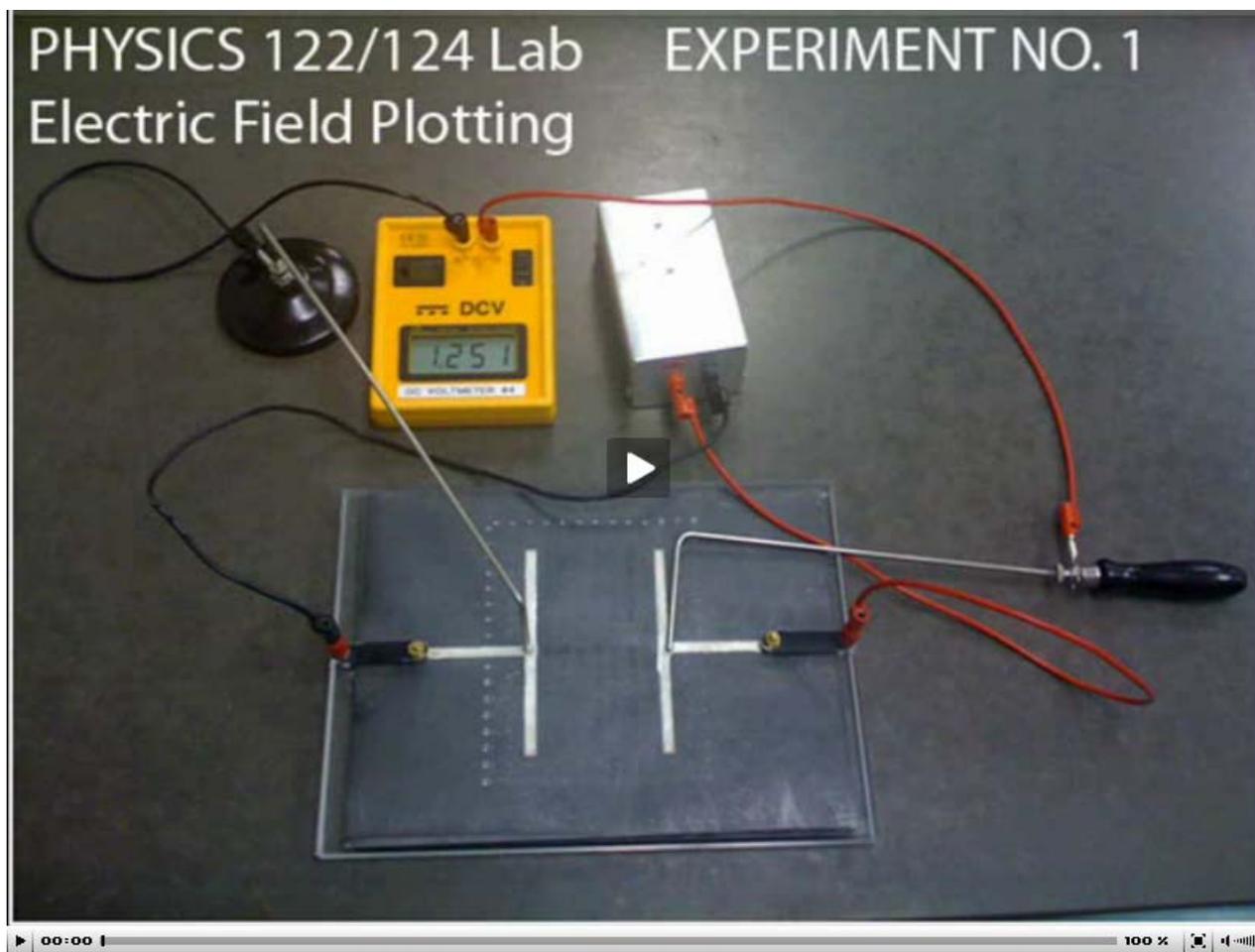
Equipment

- 1 Digital Voltmeter
- 2 Voltage probes
- 1 Platform
- 2 Carbonized Acetate Sheets ("parallel plate" and "electric dipole") to be mounted on platform wires
- 1 Battery (~1.5V)
- 1 Meter ruler
- handed out in lab: photocopied sheets similar to Figs. 3 and 4 in this manual

Figure 1 (Setup) is just below here.

Method

Each carbonized sheet has a certain pattern of highly conducting areas silver-painted onto it. These painted areas are 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 (see Ch 16 sheet 14; see also the dashed lines marked *0 V, 50 V, and 100 V* in the (worked-out) Example 21.9 on p. 693 of KJF2) between them, i.e., they lie on the same equipotential lines; but note that in your experiment, the voltage values don't exceed the ~1.5 V voltage of your battery. Each sheet has a grid of reference marks to make it easy to identify the points between the conductors.

Procedure

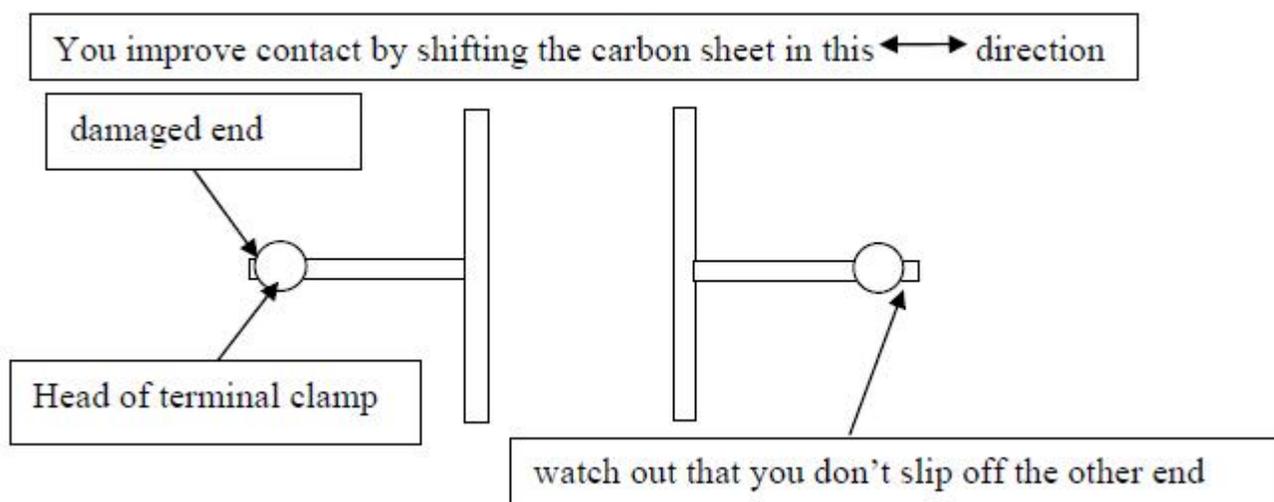## Plotting the equipotentials and field lines for the "Parallel Plates" arrangement

- Connect battery, terminals of the sheet and voltmeter as shown in the diagram above.

- Turn the voltmeter ON and set the scale to 2V. Make sure that you always have both carbon sheets together on the frame, with the sheet you are measuring on the top. (This ensures better contact 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.

- The negative battery terminal is connected to the left "contact" on the sheet and the positive battery terminal to the right "contact". The voltmeter input "-" 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 ~ 1 – 1.3 V. If you see less than ~1 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 as indicated below you should be able to get ~ 1 V or more.

Figure 2 is just below here.

You improve contact by shifting the carbon sheet in this ←→ direction

damaged end

Head of terminal clamp

watch out that you don't slip off the other end

*Record the voltage between the two plates on your Worksheet.
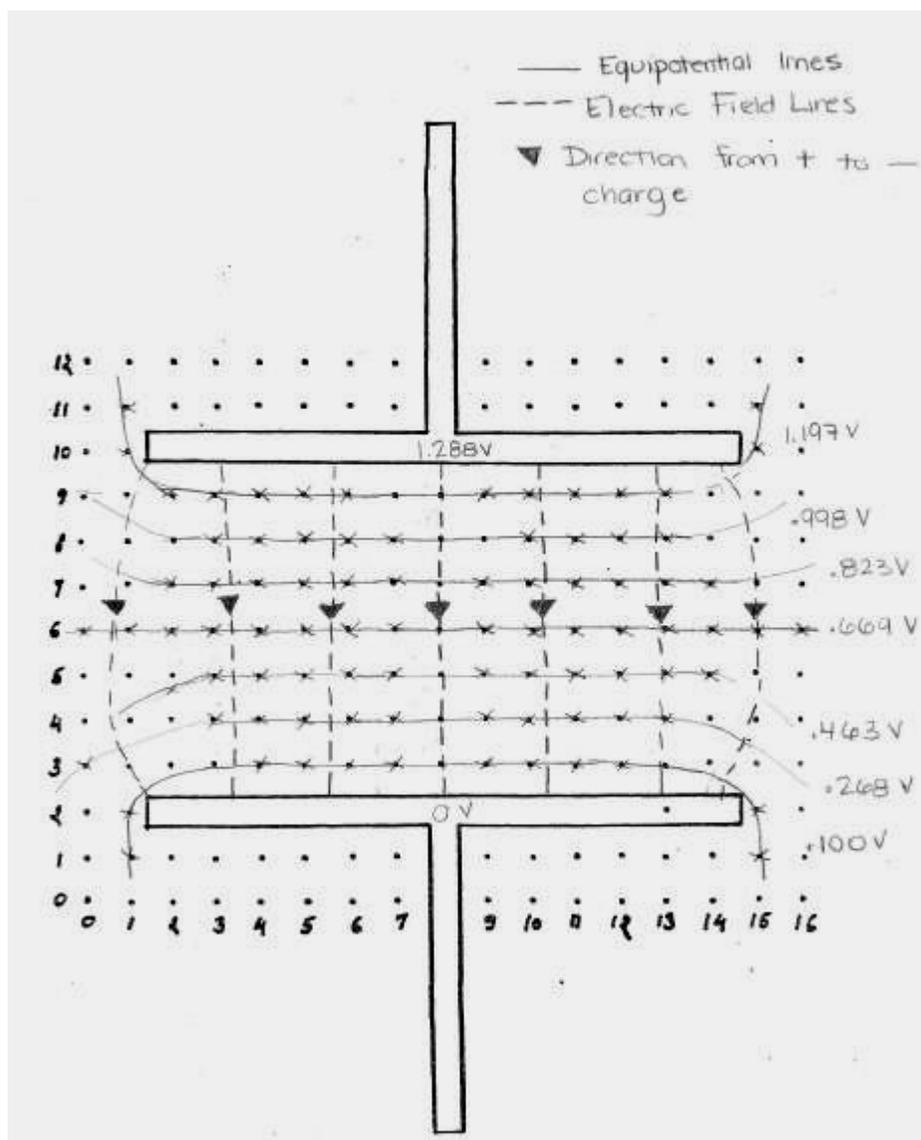
- You are now going to measure the potential at various point and record your results on photocopies of the carbonized sheets (available from the instructor). Do not place the photocopy of the carbon sheet on top of it. Leave it on the side and record the results on this copy. Label the low and high voltage plates on your copy including the voltages on them, i.e. 0 for the low voltage plate by definition and your recorded value from the voltmeter on the high voltage plate.

- 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 paper copy of the set up.

- Now, you want to find points that have no potential difference when compared to point (8,9). Put the standing voltage probe onto point (8,9). Take the handheld voltage probe and place it on nearby points until the voltmeter measures a ~ 0 V potential difference. Mark this point with a cross. Repeat this for a few different points until you have enough to determine the shape of the line. While you do this remember to leave the standing voltage probe on point (8,9).

- 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.

- You are now going to repeat this procedure to obtain several more equipotential lines in between the parallel plates. Again, start by putting the standing voltage probe onto 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. Then move the standing probe onto point (8,8) and use the handheld probe to look for lines with a ~ 0 V potential difference. Mark these and when you have enough, draw the equipotential lines.

- 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.

- 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!

- 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.

When you have finished your diagram should look *similar* to the example below.

Figure 3 (parallel plates) is just below here

—— Equipotential lines
---- Electric Field Lines
▼ Direction from + to – charge

1.288V
0 V

1.197 V
.998 V
.823V
.669 V
.463 V
.268 V
.100 V

Calculating an Electric Field

The electric field E in a uniform part of your diagram can be calculated from the voltage difference between two 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 and using the formula $E = \frac{\delta V}{\delta x}$. (see Ch16 sheet 27p; see also Example 21.9 *Finding the electric field from equipotential lines* on p. 693 of KJF2). 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 sheet with the equipotential lines where you take these measurements and write the voltage and distance values needed for your calculation of the electric field onto your worksheet. Use 5 mV for the uncertainties in the two voltages V_1, V_2. For the uncertainty in δx simply use half of the smallest division of your ruler.

We need to find the uncertainty in the value of the field we have measured from the uncertainty in our measured quantities. You can find the absolute uncertainty in δV by using Eq. (E.6) of the manual *Uncertainty, Error and Graphs*. Then you find the uncertainty in the field by using Eq. (E.7) in the manual to find the *relative* uncertainty in the field $\frac{\Delta E}{E}$. Multiply that by your value of E to find the absolute uncertainty in E.

Complete the table on your worksheet.

Plotting the equipotentials and field lines for the "Dipole" arrangement

- 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 your Execution Sheet and also label the electrodes on your sketch with these values.

- 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.

- Again, start with a point just below the center of the high voltage pole. This should be point (8,9). Obtain the voltage at that point by using the probes to compare it to the low voltage pole (This is exactly how you did it in the first half of the lab). Then look for points with the same potential as (8,9) by leaving the standing probe on (8,9) and moving the handheld probe to other nearby points, noting where the voltmeter reads ~ 0 V. Notice that the points will curve away from (8,9). Mark these points and when you have enough draw and equipotential line connecting them.

- Repeat this process by going down the sheet from the high voltage pole to the low voltage pole in the way that you did for the first half of the lab. When you are done you should have 7 equipotential lines and the voltage for each one.

- Finally, 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.

When you have finished your diagram should look *similar* to the example below.

Figure 4 (electric dipole) is just below here
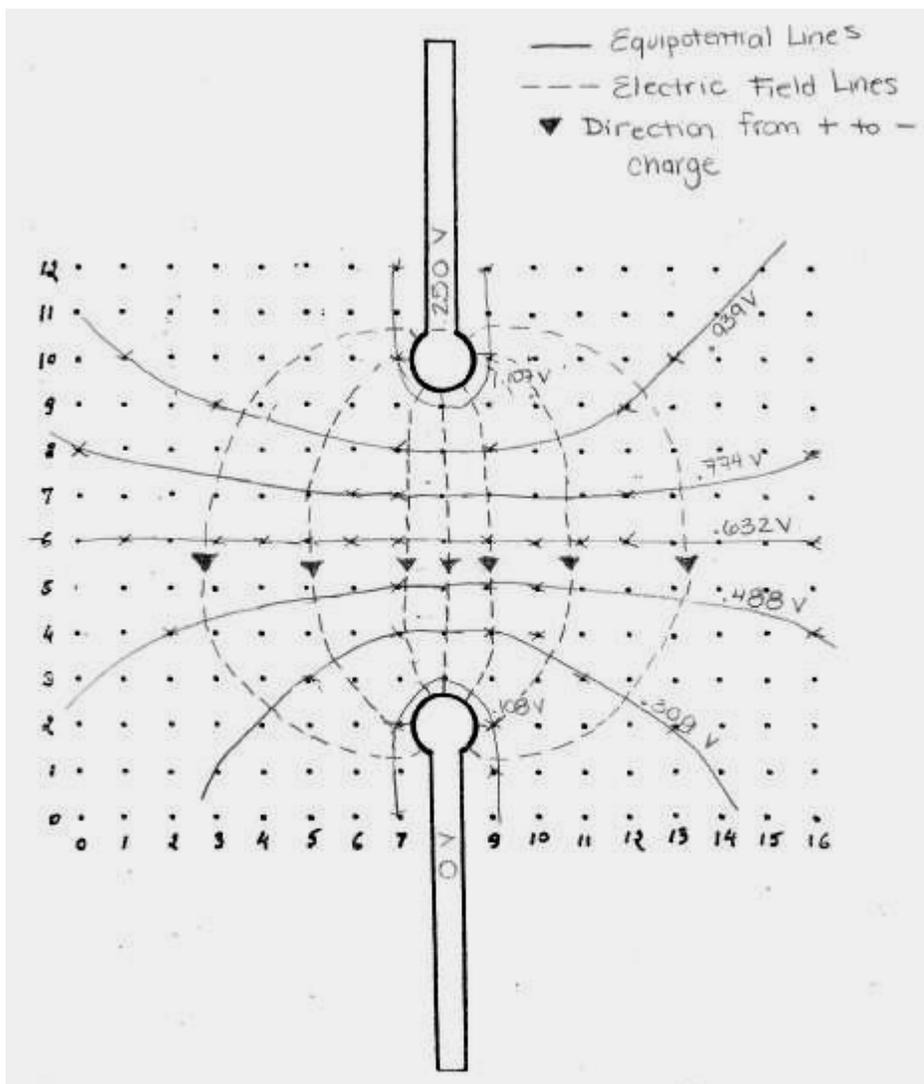
Some questions to discuss with your TAs

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? Compare your observation with the sketch shown in Ch15 sheet 26 and shown in KJF2, Fig. 21.22 on p. 692.

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