

## Electric Field Mapping Version 3.0 Instructions

**Apparatus:** field mapping apparatus, we only require 1 plate per group...we have 6 plates so use one of each then repeat as necessary, Power Supplies, one DMM per group, 1 cm cross grid (use the internet), laptops (or PCs) with MATLAB installed

**What to turn in is listed on last page!**

### Goals:

- 1) For a single charge configuration, tabulate  $V$  versus  $(x, y)$  data for every spot on a 1 cm cross grid. Please use a single sheet in Excel with no column or row headings. The data starts in cell A1.
- 2) Save your raw data as a csv file (comma delimited file). Select "Save As" and look for csv...
- 3) Input the data to MATLAB in two ways (cut and paste and using the "csvread" function).
- 4) Create a contour map showing equipotentials in 0.5V increments.
- 5) Compute additional tables of data for  $E_x \approx -\frac{\Delta V}{\Delta x}$  and  $E_y \approx -\frac{\Delta V}{\Delta y}$ .
- 6) Generate a quiver plot in MATLAB showing the electric field arrows.
- 7) Display the quiver plot overlaid on top of the contour plot.
- 8) Save your final image on a flash drive or to the web. As a group you will stand in front of the class and explain the interesting features of your equipotentials and associated electric field map.
- 9) Write answers to the conclusion questions (see last page). Submit a single document for your group (not one document for each member). Handwritten responses only. Answer questions in full sentences. Answers should make clear what question was asked.

### Acquiring Data

Select one person in your group to become the MATLAB expert.

\*The MATLAB expert should skip to the next page while the others complete this section on data acquisition.

Connect the experimental apparatus as demonstrated by your instructor.

\*Please ensure there is a washer between the charge pattern and the screw.

\*Please ensure the screw is tight after you ensure the washer is in place to protect the metal paint on the pattern.

Get some 1 cm cross grid paper off the internet with a web search or by reading the next line.

You can probably find a link to a 1 cm cross grid at <http://www.robjorstad.com/Phys163/163Lab.htm>.

Attach your 1 cm cross grid paper on top of the apparatus.

Use 0.0 V for the low potential and some convenient voltage like 5.0 V or 10.0 V for the high potential.

Move the wand around in an orderly fashion (i.e. do one row at a time, always left to right).

\*At each cross on the grid, *slightly squeeze the wand* until you can get a voltage measurement.

Don't overthink it! Type in a number with three sig figs and move on.

If the third sig fig is unstable, WHO CARES! Take your best guess and move on.

\*If you can't get a number when the wand hits something underneath the board, make an estimate and move on.

Record every voltage for the entire grid. Do not write them on paper; immediately type them into a spreadsheet.

Save the data as a comma delimited file (CSV file) using the save as function.

Once you have gotten this done, you should have all the data required to complete the above numbered list.

Meet up with your MATLAB trainer on page 4...

## MATLAB Expert Instructions

While the others acquire data, your goal is to practice getting data into MATLAB and making the plots using fake data I have created for you. Hopefully you will be done practicing with the fake data before they give you real data for your charge configuration.

Find the fake data sets online at <http://www.robjorstad.com/Phys163/163Lab.htm> if links below are busted.

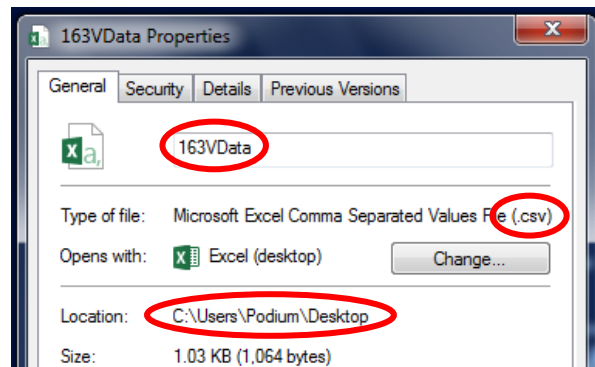
- [IcmCrossGrid.pdf](#)
- Test data for V vs (x,y): [163VData.xlsx](#)
- Partial data for E\_x: [163ExData.xlsx](#)
- Partial data for E\_y: [163EyData.xlsx](#)

Try to get the datasets into MATLAB in two different ways: cut and paste and using the csvread function.

You might be wondering why you should bother with the cumbersome csvread function?

Answer: For large datasets in real science applications it is often impractical to cut and paste.

- 1) Cut and paste directly from Excel into MATLAB.
  - a. Highlight the values in Excel.
  - b. Hit CTRL-C to copy.
  - c. Go to MATLAB and look for a button near the top saying "+ New Variable"
  - d. Click in the top right cell of the new variable (called unnamed at this point).
  - e. Hit CTRL-V to paste the data into MATLAB.
  - f. Rename the dataset in MATLAB by clicking on the name in one of the right windows.
- 2) Save each Excel file as a CSV file using the save as function.
  - a. Verify your data has no text or extra spaces. The data should start in cell A1.
  - b. I recommend saving them to the desktop so they are easy to find.
- 3) Determine the filepath of your CSV file.
  - a. Right click on the desktop icon and select "properties". A pop-up window such as the one at right should appear.
  - b. Usually the 3<sup>rd</sup> or 4<sup>th</sup> line down tells you the *start* of the filepath name. For the screen shot image at right the filepath name is  
**C:\Users\Podium\Desktop\163VData.csv**
  - c. On a piece of scratch paper, write down *your* filepath name.
- 4) Use the csvread function to input the data to MATLAB
  - a. Search the help file in MATLAB (or do a web search) for "csvread".
  - b. Please give your matrix a descriptive name...something other than M.
  - c. Based on my choice of filepath I might type



**Vdata = csvread('C:\Users\Podium\Desktop\163VData.csv')**

- 5) Make a contour plot
  - a. Search the help file in MATLAB for "contour" or do a web search for "MATLAB contour".
  - b. Read carefully and learn how to adjust the number of contours.
  - c. Think: if your data ranges 0 to 5.0 V, what number of contours is needed to get 1 V increments? How about 0.5 V increments? How do your answers change if 0 to 4.0 V is used instead?
  - d. Search the web or the help file to figure out how to add axis labels, titles, etc.
  - e. Figure out how to add the scale bar on the side of the figure.
  - f. Look carefully at the data set versus the figure. Is it flipped vertically, horizontally, both, or neither?

- g. When you print, nothing is in color. I need you to include It will help to add labels to the contour levels. Do a web search to see different ways of getting this done. For my choice of filename, something like this might work:

`contour(Vdata, 'ShowText', 'on')`

**More on next page...**

- 6) Use *your*  $V$  versus  $(x, y)$  data to generate  $E_x$  and  $E_y$  data.
- When you download the fake data for  $E_x$  and  $E_y$ , you will notice half of the data is missing! This download is supposed to help you check your work. Forget about that file for now and read the following bullets to learn how to make the data yourself!
  - The upper screen shot at right shows  $V$  versus  $(x, y)$  data. This is the only full data set of the fake data.
  - The lower screen shot at right shows  $E_y$  data.
  - To compute  $E_y \approx -\frac{\Delta V}{\Delta y}$  in cell **S2** of lower screenshot I used the following equation in Excel:

$$=-(B3-B1)/2$$

- Why the 2? Our grid spacing was 1 cm per cross. I went from the cross above to the cross below. The total spacing is 2 cm.
- Why above to below? This is an attempt to average out errors from calculations using two adjacent points. We will still have large errors for a few points but hopefully this will be a decent estimate.
- Notice all  $E_y$ 's on the edge are zero.** I set them to zero as our Excel formula can't work! For instance, there is no cell **B0** to compute  $E_y$  for cell **S1**.
- Now use the test files (fake data files) to check your results. You'll notice I left about half of the numbers blank to force you to figure out the equation to make it work.

**CHALLENGE:** You could use MATLAB to create the  $E_x$  &  $E_y$  data using operations on matrix elements. It would take a bit of thought and effort but a clever student could surely figure this out. NOTE: that same clever student should be wise enough to wait until after the lab is done to make an attempt...

- Use your  $E_x$  and  $E_y$  data to generate a quiver plot. Search for quiver plot. Figure it out.
- Try to overlay the quiver plot on top of the contour plot. Hint: try a web search for "Combine Contour Plot and Quiver Plot". Wilson Phillips would be proud...

V versus  $(x, y)$  data

	A	B	C	D
1	1.02	1.04	1.02	1.09
2	1.02	1.25	1.50	2.50
3	1.10	1.25	1.50	2.50
4	1.09	1.25	1.50	2.50

Use these two values of  $V$  to compute  $\Delta V$  in the vertical direction

$E_y$  versus  $(x, y)$  data

	R	S	T	U
1	0	0	0	0
2	0	-0.11	-0.24	-0.71
3	0	0.00	0.00	0.00
4	0	0.00	0.00	0.00

Use this  $\Delta V$  to get  $E_y$  in between the two points used

At this point, you should be able to take your actual  $V$  versus  $(x, y)$  data set, generate  $E_x$  &  $E_y$  data, and create a contour plot with quiver plot overlaid on top. In addition, you should be able to train your partners to do the same. Go on to the next page.

### Putting it all together

*Those who acquired data:* give your final data set to the MATLAB trainer. Go to page 2 and learn how to make contour and quiver plots using the instructions. Try to figure it out yourself and leave the MATLAB trainer alone until she or he finishes your final figure.

*MATLAB Trainer:* Make the final plot showing a quiver plot overlaid upon the contour plot. This is showing you the electric field vector on top of the equipotentials. Make sure your final plot has axis labels and contour labels. In addition, somehow figure out a number for your largest electric field arrow in  $\frac{V}{cm}$  and write it on the plot. You could do this by hand if desired by looking at the largest arrow and checking the numbers in the Excel file. Alternatively, you could create a table in Excel of the magnitude of the field given by  $E = \sqrt{E_x^2 + E_y^2}$  then look for the largest number using the MAX function in Excel.

**LAST 45 MINUTES** each group will stand up and show their plot to the rest of the class. Each group has a different plot and we can hopefully learn about each unique charge configuration that way. Expect to show your plot, let people look at it for a minute. Ideally, you will have already completed the questions below. Each lab group member could prepare an answer to give to the class in case I call on you. Each group member should prepare a *different* question in case I have time to ask all each of you to say something.

### TO TURN IN:

Print out a single copy of your final plot. Put all names on it in a corner somewhere.

On a second sheet of paper write all names neatly in upper right hand corner.

Write the class section and class time.

Write answers to the conclusion questions below.

Submit a single document for your group (not one document for each group member).

Handwritten responses only.

Be neat and organized.

Answer questions in full sentences.

Answers should make clear what question was asked.

Basically, re-phrase my question in the answer you give to me.

1. Which way do your electric field vectors point: from high-to-low or low-to-high voltage?
2. Which way should your electric field vectors point: parallel or perpendicular to the equipotentials?  
Optional: can you think of any reasons why your calculated values might not be perfectly parallel or perpendicular?
3. Where is the field strongest/weakest on your plots: close to the electrodes or far from the electrodes? Help me understand your answer by referring to regions on your plot using the  $(x, y)$  coordinates. For example, you might say:  
“The field is strongest along the vertical line  $x = 5.0$  cm and weakest near the point  $(2.0, 6.0)$ .”
4. Is there anywhere on your plot where the electric field is roughly constant in magnitude? Hint: if the field has constant magnitude, what must be true about the equipotential spacing? Again, reference coordinates.
5. For our lab today, there is always a constant *potential* difference between adjacent equipotentials. If the lines are spaced closely together, does this imply a large or small field? Does your data support this?
6. Imagine someone released a proton from rest in the middle of your map. Which way would it accelerate at the instant it is released?
7. If an electron was instead placed in the middle of the map, which way would it move AND would it accelerate faster, slower, or at the same rate? To be clear, we comparing the accelerations of the electron and proton at the instant they are each released from rest in the middle of your map. EXPLAIN WHY FOR CREDIT.
8. If a charge was placed on your equipotential map and released from rest, would it be appropriate to model the motion using the constant acceleration kinematics equations?