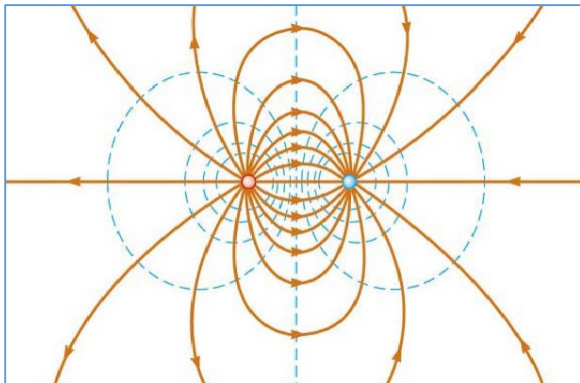


Electrostatic Fields & Mapping of Equipotential Lines

Equipment	Quan
Field Mapper Kit	1
Multimeters	2
Multimeter probe	1

Electric fields are everywhere. The field due to the electric charge of an atomic nucleus attracts electrons, creating the atom, but also atomic bonds (allowing solid matter to exist) and it also drives chemical reactions. And in hundreds of electrical devices, electric fields accelerate electrons. For example, the filaments of a fluorescent light bulb produce fields that send electrons bashing into gaseous mercury atoms, causing them to produce light.

The figure below shows lines of electric flux (solid lines) connecting a positively (left) and a negatively (right) charged particle.



The force on a second positively charged particle in this field is parallel to the field line (and in the direction of the arrows) at the position of the particle. Since a force exists, then work is done if the particle moves along the line, and the particle moves toward lower electric potential. The dashed lines are electric equipotential lines. The particle gains energy as it passes to lines of lower potential, just as a

rock rolling down a hill gains kinetic energy as it moves toward lower gravitational potential.

Since the SI unit of electric potential is the *volt* ($1\text{ volt} = 1\text{ joule/coulomb}$), we can label the potential lines in *volts*. In this exercise, you'll measure the electric potential at many points in the vicinity of a pair of electrodes (one at a potential 15 V above the other) that are printed on a sheet of conducting paper. You'll then use MS Excel to plot a 3D graph displaying electric potential as a function of 2D position on the sheet. This will reveal the electric equipotential lines, from which you'll be able to construct the structure of the electric field lines.

Procedure



1. Find the conducting page with the circular outer electrode. Use pushpins at its corners to secure it to the center of the cork board.
2. There are two wires in your mapping set that can be used with pushpins to connect the two electrodes to the positive and negative DC plugs of the low voltage power supply. Connect the center electrode to the positive plug.
3. Connect the negative plug of the power supply to the COM socket of the multi-meter using a BB wire.
4. Connect the wire that's pinned to the outer electrode to either the ground plug on the power supply or to the wire plugged into the COM socket.
5. Plug a multi-meter probe (the wire with a pointy end) into the $V\Omega$ socket of the multi-meter.
6. Ask the instructor to check your setup before turning on the power supply.

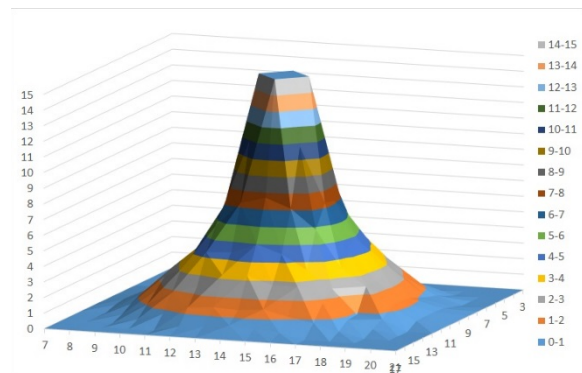
- Turn on the power supply. Set the DC voltage to 15.0 and the DC current knob to the halfway position.
- Since we'll be measuring voltages from 0.0 to 15.0, set the multi-meter to the 20 volt DC setting.
- To check that everything is working, measure the voltage of the center electrode, which should be 15.0 V (if it's not 15.0, turn the voltage knob until the meter reads 15.0). Also check the outer electrode, which should read 0.0 V, and any point in the region between the electrodes should read somewhere between 0.0 and 15.0 V.
- Find the data sheet that's prepared for the circular electrode.
- The conducting paper is labelled with coordinate systems corresponding to the numbers on the data sheets. Your instructor will tell you how many of the table cells need to be filled in for this electrode configuration.
- SUGGESTION: The measurements seem to work better if you press the probe to the paper not with the sharp point, but the side of the cone shaped pointed end.

	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
17															
16				0	0	0.39	0.5	0.65	0.51	0.37	0	0			
15			0	0.36	0.8	1.32	1.43	1.35	1.5	1.12	0.83	0.38	0		
14		0	0.27	1.01	1.88	2.35	3.21	3.26	2.77	2.76	1.8	0.85	0.35	0	
13		0	0.68	1.64	3.1	4.28	4.4	5	4.47	3.55	2.47	0.9	0.71	0	
12	0	0.23	1	2.3	3.58	5.67	7.26	7.7	7.1	5.85	3.53	2.43	1.19	0.41	0
11	0	0.34	1.12	2.68	3.99	6.74	11	15	10.8	7.3	4.36	2.52	1.3	0.44	0
10	0	0.28	1.03	2.45	4.22	7.07	15	15	15	7.16	4.69	2.68	1.23	0.45	0
9	0	0.26	1.05	2.41	3.72	5.66	13.5	15	10.4	6.4	4.13	2.59	0.98	0.38	0
8	0	0.22	0.74	2.01	3.15	4.5	5.75	5.68	6.45	5.15	3.46	2.01	0.73	0.21	0
7	0	0.45	1.16	2.45	3.19	3.83	4.86	4.28	3.97	2.8	1.49	0.56	0		
6	0	0.27	0.83	1.42	2.11	2.63	2.97	3.09	2.8	1.48	0.95	0.24	0		
5	0	0.28	0.8	1.08	1.52	1.31	1.64	1	0.54	0.23	0				
4			0	0	0.33	0.53	0.62	0.54	0.42	0	0				
3					0	0	0	0	0						

- Once all the required cells are filled in on the data sheet, transfer this data to the cells of an MS Excel spreadsheet. It should look something like the figure above, and should include the coordinate numbers from the

conducting sheet (these cells I've changed to blue for clarity).

- When the data is ready in the spreadsheet, highlight the data (including the coordinate numbers) and click on the "insert" icon.
- Choose a surface plot (first click , and then ).
- Right click on the legend, which will appear below the plot.
- Click on "Format Legend."
- Choose "Right." This will place the legend on the right side of the page.
- Right click on the vertical axis labels.
- Click on "Format Axis."
- Change "Major Units" to 1. This will show potential lines at every volt between 0 and 15.
- Your plot should look something like the figure below.



- Repeat the mapping procedure for any other electrode configurations that your instructor requires.


The colors on the plot represent ranges of electric potential (as indicated by the legend on the right-hand side). As a positively charged particle moves away from the center electrode, it moves toward regions of lower potential (think of the analogy of the rock rolling down the hill). Also, we know that electric field is the gradient of the electric potential:

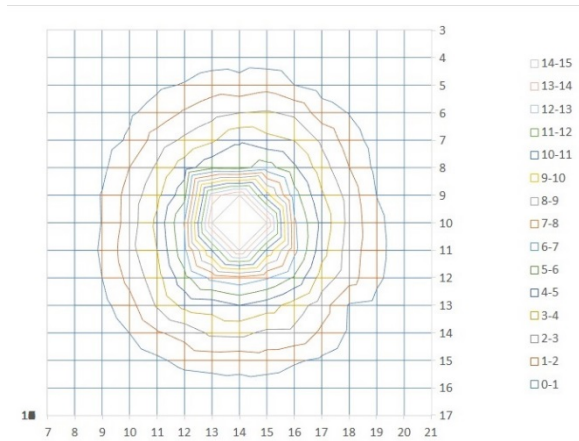
$$\vec{E} = -\nabla V_e$$

This is visually illustrated in our plot. The steepness of the slope in the plot represents the gradient of the potential, and thus the strength of the electric field. The fact that the slope is highest near the center should make sense since you know that an electric field is strongest near a localized charge.

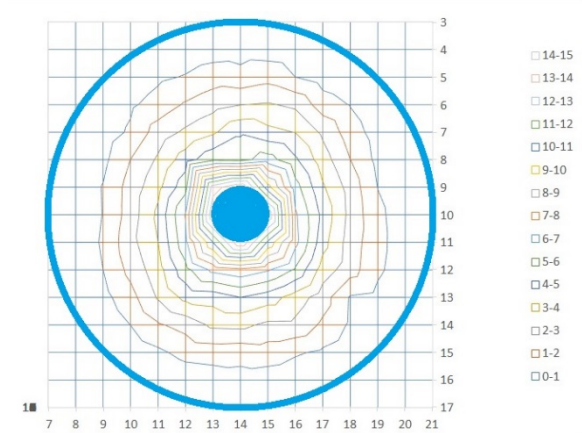
Drawing Electric Field Lines Based on the Equipotential Lines

Since we know that equipotential lines and electric field lines are perpendicular, you can make a diagram of the field using a diagram of the potential field.

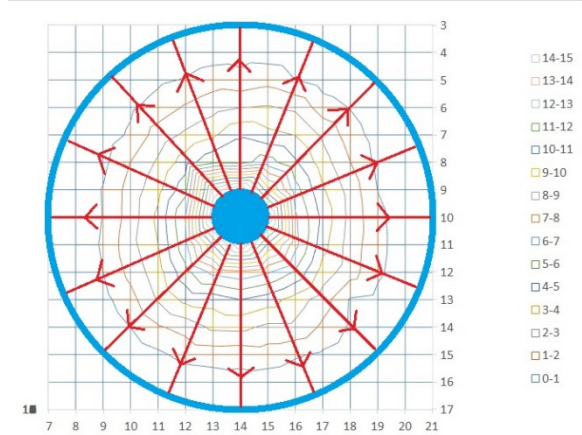
24. Right click on the graph and choose "Change Chart Type."
25. Choose the  icon. This turns your surface plot into a contour plot that you can then print out.



26. You now have a plot of the potential lines, which you can print out and use to draw the electric field lines. It should look something like the figure above.
27. Draw the electrodes on the diagram, as in the figure below.
28. Draw the electric field lines in a different color to make them distinguishable. Remember that the electric field lines are always perpendicular to the lines of equipotential, and that they emanate



from the electrode of higher potential and terminate on the lower one. Since the potential lines on our plots will not be smooth (e.g. the squared off kink to the upper left of the center electrode in the figure above), don't try to follow them exactly. For this configuration, radial lines are sufficient (below).



29. For the parallel electrode configuration, make sure field lines emanate from both sides of the positive electrode and terminate on both sides of the ground electrode.

Questions

1. For each plot, describe in words the location of the strongest electric field (the strongest field is where the slope of the potential surface plot is steepest).

2. Which plot has a region with a highly homogeneous electric field? In other words, where are the field strength and direction constant over a large area?
3. What familiar 3 dimensional electronic component has a homogenous field similar to the one between the two parallel line electrodes?
4. If the two parallel lines were half as far apart as they are, how would the slope of the potential surface (and thus the strength of the electric field) between them compare with the slope that you plotted?