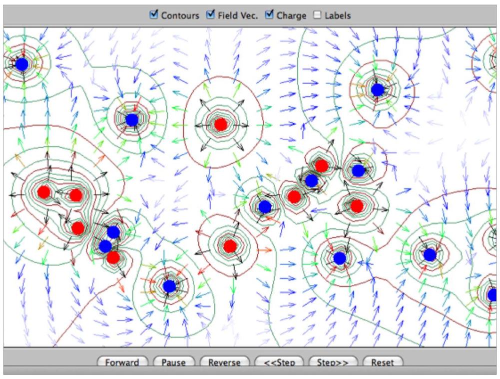
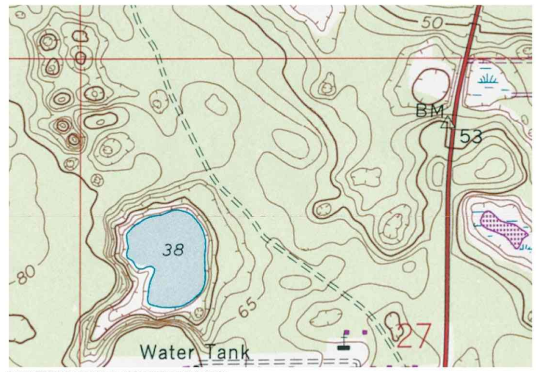
University of Calgary

Department of Physics and Astronomy

PHYS 259, Winter 2017

Labatorial 5: Electric Potential





The figure on the left shows equipotential lines (i.e. lines of constant electric potential) for a distribution of charges that was created with the applet charges_generator that you have used before. The figure on the right shows contour lines (i.e. lines of constant elevation) for a landscape. Both figures give you, for example, information about the direction of steepest descent. Both physical situations can be described using the same mathematical tools.

Learning Goals:

To understand the relationship between the electric potential and the electric field. To understand and be able to draw different graphical representations of the electric potential. To understand equipotentials.

Preparation:

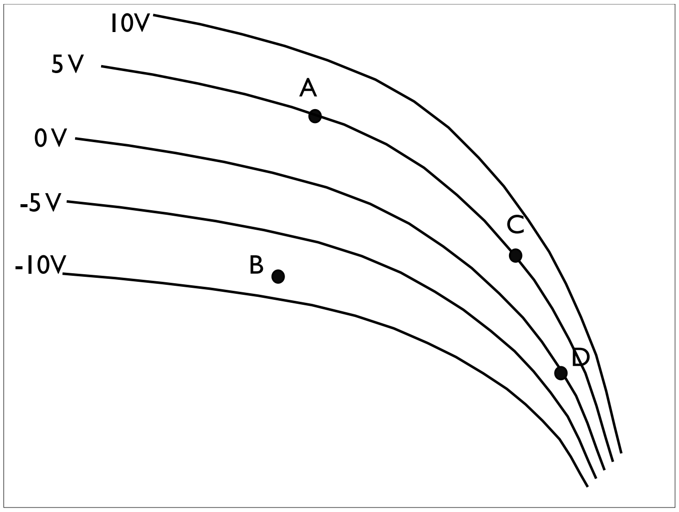
Halliday, Resnick, and Walker, "Fundamentals of Physics" 10th edition, Wiley: 24.1-7.

Equipment:

Computer with LoggerPro, multimeter, power supply, field probe, potential mapping apparatus, parallel plate conductor board, connecting cables, potential mapping graph paper, tape, ruler.

Note that there is an equation sheet at the end of this worksheet.

1 General properties of the electric field and electric potential



Question 1: This figure shows some equipotential lines.

a) Indicate the direction of the electric field in the figure by drawing four field lines.

b) Is the magnitude of the electric field constant along each of the equipotential lines? Explain.

c) Rank the electric field strengths at the points A-D.

Question 2: Assume that the electric field between two charged parallel plates has a magnitude of 200 V/m. Find the change in potential as a proton moves from one point to another in the electric field, for the following three cases:

a) 20 cm in the direction of the electric field

b) 20 cm in a direction perpendicular to the electric field.

Question 3: If an electron moves 3 cm in the direction of the electric field, then 4 cm orthogonal to the field, and then 5 cm back to its original position, what is the change in its potential energy?

Question 4: a) Since the electric field component in a certain direction is proportional to the change in potential, ΔV, in that direction, what is the magnitude of the electric field component in the direction of an equipotential line? Explain.

b) Based on your answer to part (a), what is the direction of the electric field, relative to the equipotential lines? Explain.

Question 5: What can you say about the field strength in a region where the equipotential lines are close together, as opposed to a region where they are far apart? Explain your answer using the mathematical relation between the field and the potential, $E = -dV/dx$.

STOP **CHECKPOINT 1: Before moving on to the next part, have your TA check the results you obtained so far.**

2 Getting familiar with the equipment for the experiment

In this labatorial, you will measure the equipotential lines for the parallel plate capacitor. Actually, you will use a board with two flat electrodes that represent a two-dimensional cut through the parallel plate capacitor, as shown in Figure 1.

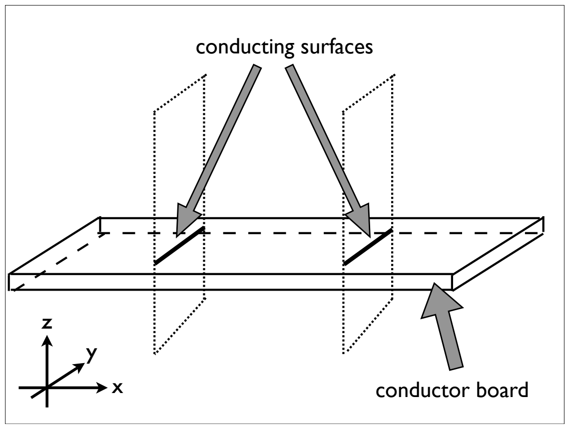


Figure 1: A cut through the three-dimensional configuration.

During the experiment, the conductor boards will be mounted on the field mapping apparatus that you see in Figure 2 (the figure shows the underside, because that's where the conductor board will be mounted). The field mapping apparatus serves several purposes: It holds the conductor board in place while providing a surface on which you can draw the equipotential lines you will measure. It provides the voltage to the two electrodes on the board, and it provides seven reference points (the seven connectors that are placed in a row along one side of the field mapping apparatus) for measuring the potential.

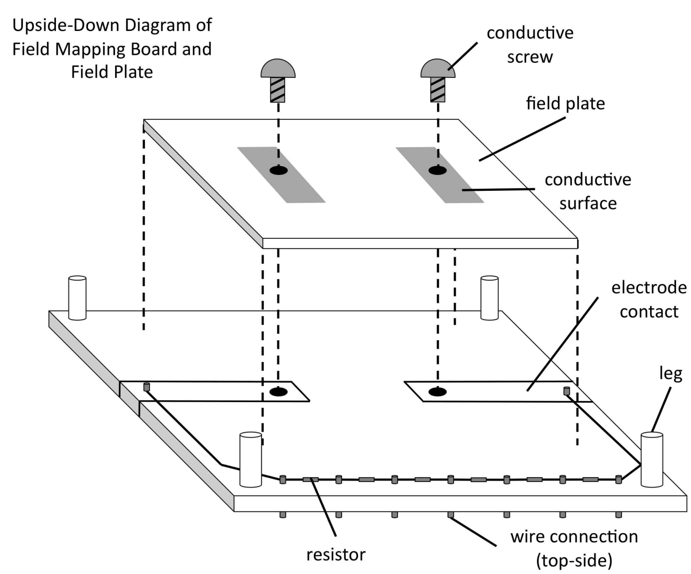


Figure 2: How to mount the conductor board on the field mapping apparatus.

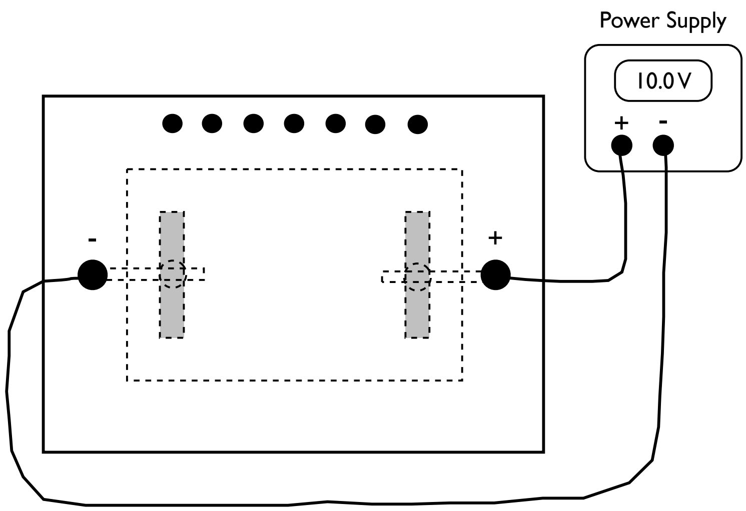


Figure 3: The field mapping board seen from above.

Question 6: Connect the power supply to the field mapping apparatus, as shown in Fig. 3. We will call the two connectors the positive and negative terminals from now on. Set the power supply to 10.0 V (with the current at its maximum value) and switch it on.

a) Use the voltmeter to measure the voltage of each of the terminals **with respect to the negative terminal of the power supply**. Write the values next to the terminals in Figure 3.

b) Use the voltmeter to measure the voltage of each of the seven reference connectors with respect to the negative terminal of the power supply. Record these values in Figure 3.

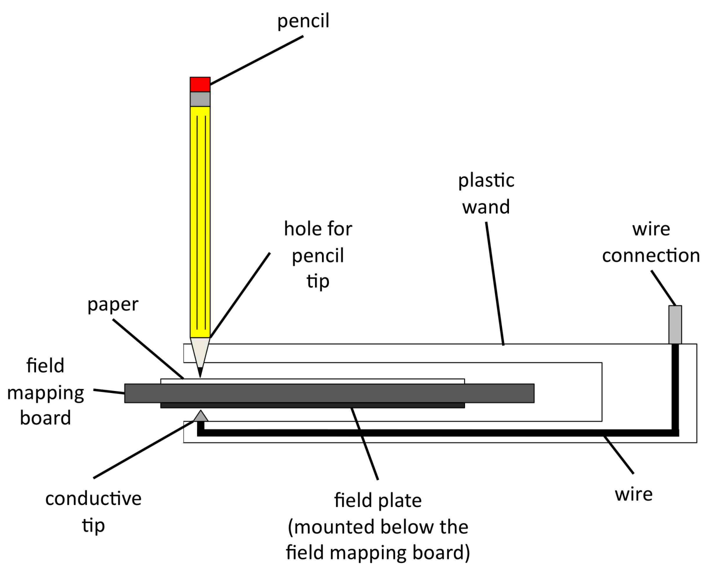
c) Explain the values you found in part (b) by referring to the combination of resistors on the bottom of the field mapping apparatus - that is, what do these resistors do with the total voltage?

Question 7: The dashed lines in Figure 3 show where the conductor board will be mounted on the bottom of the field mapping apparatus, and where the "parallel plates" (grey) will be located. Sketch what you expect the equipotentials to look like in Figure 3.

CHECKPOINT 2: Before moving on to the next part, have your TA check the results you obtained so far.

3 Finding equipotential lines for the parallel plate conductor board

Turn off the power supply. Mount the parallel plate conductor board on the field mapping apparatus, as shown in Fig. 2. Ask your TA for a piece of paper with the outline of the conductors as you see them on your parallel plate board. Tape this piece of paper to the top of your field mapping apparatus. Connect the power supply to the field mapping apparatus, as before, and switch it on.



Since we want to mark the positions where we measure the potential, we will not simply use the wire from the voltmeter anymore. Instead, we will use the potential mapping probe, shown in the figure on the left. It allows you to measure the potential at a certain point and to mark this point on the paper. One arm goes under the field mapping apparatus and makes contact with the conductor board. The other arm goes above the mapping board and has a hole for a pencil right above the point where you measure the voltage. You will use those marks to create a map of the electric potential.

Question 8: Now find the equipotential lines for the reference points by following the steps below:

Connect the two wires from the voltmeter to the first reference point and to the field mapping probe. Move the probe around on the board until you find a place where the potential difference is zero. Mark the paper at that point. Then, find more points with potential difference zero, and mark them. When you have enough points, connect the dots, and you will have found your first equipotential line.

Remove the wire that connects the probe to the first equipotential reference connector, and plug it into the second. Find the equipotential line for this point with the same method as above. Repeat this procedure for all the equipotential reference connectors.

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4 Finding the electric field from the equipotential lines

Question 9: How do you find the direction of the electric field between the plates from your data for the potential?

Question 10: Copy your measurement results from Fig. 3 into the second column of Table 1. What additional measurements do you have to make in order to be able to calculate the magnitude of the electric field between the plates? Explain (below), then do the measurement and enter the values into the first column of Table 1. Also, complete the column header by writing what you are measuring.

your measurement of:	electric potential (in Volts)

Table 1: Data for the parallel plate conductor board.

Question 11: Use LoggerPro to enter your values and fit an equation to your graph. Write down the equation for the fit. What is the magnitude of the electric field that you obtain from your fit?

Last Checkpoint! Clean up your area, and put the equipment back the way you found it. Call your TA over to check your work and your area before you can get credit for the labatorial.

Equations and constants

$$
\begin{aligned}
F_g(r) &= G\frac{m_1 m_2}{r^2} \\
U_{grav}(y) &= mgy \\
K &= \frac{1}{2}mv^2 \\
v_x(t) &= v_{0x} + a_x t \\
x(t) &= x_0 + v_{0x}t + \frac{1}{2}a_x t^2 \\
v_x^2(t) &= v_{0x}^2 + 2a_x(x(t) - x_0) \\
\omega &= \frac{d\theta}{dt} \\
v &= \frac{2\pi r}{T} = \omega r \\
a_{rad} &= \frac{v^2}{r} = \omega^2 r \\
F_C(r) &= \frac{1}{4\pi\epsilon_0}\frac{|q_1 q_2|}{r^2} \\
\vec{E} &= \frac{\vec{F}}{q} \\
\vec{E} &= -\vec{\nabla}V \\
\Delta V &= -\int \vec{E}\cdot d\vec{l} \\
\Delta U &= q\Delta V
\end{aligned}
$$

$$
\begin{aligned}
g &= 9.81\frac{m}{s^2} \\
G &= 6.67\times 10^{-11}\,\frac{Nm^2}{kg^2} \\
\frac{1}{4\pi\epsilon_0} &= 8.99\times 10^{9}\,Nm^2C^{-2} \\
\epsilon_0 &= 8.85\times 10^{-12}\,C^2N^{-1}m^{-2} \\
e &= 1.60\times 10^{-19}\,C \\
m_e &= 9.11\times 10^{-31}\,kg \\
m_p &= 1.67\times 10^{-27}\,kg \\
m_n &= 1.67\times 10^{-27}\,kg
\end{aligned}
$$

$$
\begin{aligned}
\int \frac{dx}{(x^2 \pm a^2)^{3/2}} &= \frac{\pm x}{a^2\sqrt{x^2 \pm a^2}} \\
\int \frac{x\,dx}{(x^2 \pm a^2)^{3/2}} &= -\frac{1}{\sqrt{x^2 \pm a^2}} \\
\int \frac{dx}{x^2 + z^2} &= \frac{1}{z}\arctan(\frac{x}{z}) \\
\arctan(x) &= -\arctan(-x)
\end{aligned}
$$