Name: **Partner's name:** **section:**

Day of the lab:

Lab # 6
Equipotential field lines.

The purpose of the lab is to measure the equipotential field lines in the plane for various charge distributions. From these we deduce the shape of the electric field by using

(1.1) $$\vec{E} = -\overrightarrow{grad} \cdot V$$

- $dV = -\vec{E} \cdot d\vec{s} = 0$ when $\vec{E}$ is perpendicular to $d\vec{s}$.
- Lines for which dV=0 are called equipotential field-lines, or in three dimensions, equipotential surfaces (eps).
- If $d\vec{s}$ is tangential to an eps it follows from dV=0 that the electric field must be perpendicular to the eps. (Scalar product=0)
- As $\vec{E} = -\overrightarrow{grad} \cdot V$ this means that the gradient of V is also perpendicular to the eps. dV is a maximum if $d\vec{s}$ is parallel to $\vec{E}$ *or* $-\overrightarrow{grad} \cdot V$. ($\vec{E} \bullet d\vec{s}$ is max if the two vectors are parallel.)
- Between any two given eps V_a and V_b we have $\Delta V = \text{constant} = -\int_a^b \vec{E} \bullet d\vec{s} = V_a - V_b$
- As there is only one electric field line possible, starting at a perpendicular direction to the first eps in a given point and ending at a perpendicular direction on the second eps, and having the constant value ΔV the electric field line must always be parallel to $d\vec{s}$, thus yielding the maximum value.
- This is why $-\overrightarrow{grad} \cdot V$ is the maximum change of the potential function and points in the direction of decreasing values for V.
- We say that the electric field (or the heat-flow in $\vec{j} = -k\vec{\nabla}T(x, y, z)$) follows its gradient, which means that it follows the direction of maximum change of its potential field.)

Procedure : Tape the black paper to the corkboard. Draw with metallic ink two shapes on opposing sides of the paper. These shapes will serve as conductors at a particular voltage. We attach the positive (red) lead to a 12 Volt DC power supply, and connect it to a metallic tack inserted to the conductive shape on one side of the paper. We connect the other black lead to the negative contact. Make sure that the tacks are in good contact with the metal on the conductive paper. Also make sure that during the experiment you do not touch the paper with your fingers or any other conductor.

We use a DMM (digital volt meter) to measure the voltages on the paper. For this purpose we set the DMM to DC Volts in the range of 10 volts and attach the black reference lead to the negative terminal on the DMM. This will be our ground or 0 Volt line. We use a red lead attached to a metallic probe as our positive electrode with which we are searching for voltages on the conducting paper.

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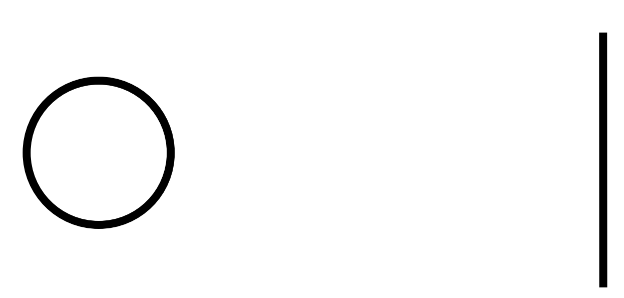
Again: do not touch the paper with your fingers or any other conductor.

Use two different shapes on different sheets of black paper and determine the curves of constant voltage (the equipotential lines) in the following way. **Groups of two students can share the same experimental results**. This means that each group produces two sheets with their results.

Fig.1

Fig.2



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A) Sketch ten of the electric field-lines into the figures above, noting that electric fields are perpendicular to equipotential field lines. Both metallic shapes are such equipotential field surfaces. Electric field lines are oriented from higher to lower potentials. They start at a positive charge and end in a negative charge or at infinity. Consult the book with some sketches in there.

1) Choose an (x,y) origin on the paper. The left lower corner is your (0,0) point. The grid has 1 cm spacings. For fixed values (x_i, y_i) systematically sweep over your page and record the measured values for the voltage. The opposing electrodes are at 0 and 12 (or 9 volts, depending on the battery type) respectively. Enter these data into a table. A good procedure is to pick a voltage, like 7 volts, and then probe the page for 7 Volt points. You should have a rough idea where to "hunt" for those voltages. You don't need to get closer then 2 significant figures with an error margin of 0.5 Volts.

2) On a separate sheet of graph paper (mm paper), draw the electrode shapes, like you had them on the conductive paper. (The mm paper and the black conductive paper have different sizes. Draw your electrodes on the black paper so that they fit on the mm paper.) Then mark the (x,y) coordinates of the field lines, from 1 to 12 volts, if you were able to detect them. Sometimes you can only find the 3, 5, 7 volt lines. As long as you have enough points to estimate the general shape of the potential field lines you are ok. Make sure your electric field lines and equipotential field lines are smooth: no corners.

3) **Calculate the electric field at five different points and draw the corresponding electric field vectors.** They are **perpendicular** to the equipotential lines, and have the value

$$E = -\frac{\Delta V}{\Delta s}$$

Δ V is the difference between two adjacent field lines, and Δ s is the distance between them.

Use the approximate shapes above:

Each student in a group must hand in **one** of the two experimental black sheets with the ink on them, but both mm paper sheets with the equipotential field lines on them and the approximate shape of five electric field lines. In addition, include this present file as the cover sheet. Don't forget to draw the rough shapes of V and E into Fig.1 and Fig.2 as mentioned in A).
Your report must also contain all the data and calculations for the electric fields.
Use these three downloaded pages as your cover sheet for your lab, with your name, your partner's name, section, and date. Write your name on each sheet you hand in.