§ 1 Introduction

In this laboratory you will observe the relationship between the electric potential and the electric field.

§ 2 Background

The relationship between electric potential V and electric field $\vec{E}$ is

$$dV = -\vec{E} \cdot \vec{d\ell}$$

This says that if one moves a small distance in the direction $\vec{d\ell}$ from the position $\vec{r}_i$ to the position $\vec{r}_f = \vec{r}_i + \vec{d\ell}$ then the change in the electric potential between the initial and final positions is $-\vec{E} \cdot \vec{d\ell}$:

$$V(\vec{r}_f) - V(\vec{r}_i) = -\vec{E} \cdot \vec{d\ell}.$$

The displacement $\vec{d\ell}$ must be small enough so that $\vec{E}$ is essentially constant over the path from the initial to final position. If $\vec{E}$ is not constant then the $\vec{d\ell}$ needs to be broken into smaller steps.

Remember that the dot product of two vectors can be computed in a number of ways.

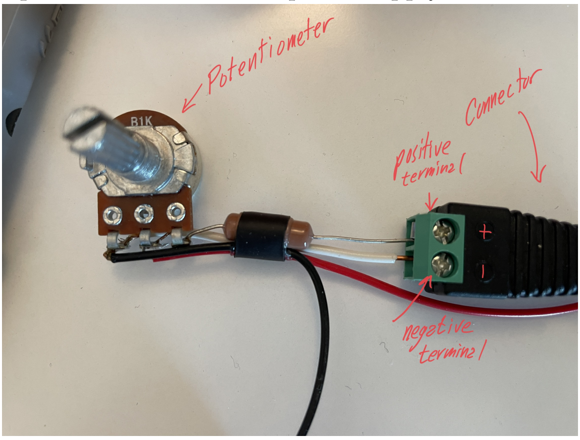
$$\vec{A} \cdot \vec{B} = A_{\|} B$$
$$\vec{A} \cdot \vec{B} = A B_{\|}$$
$$\vec{A} \cdot \vec{B} = AB \cos\theta$$

where $A_{\|}$ is the component of $\vec{A}$ that is parallel to $\vec{B}$, $B_{\|}$ is the component of $\vec{B}$ that is parallel to $\vec{A}$, and θ is the angle between the vectors $\vec{A}$ and $\vec{B}$.

§ 3 Setting up the voltage supply

Procedure 3.a

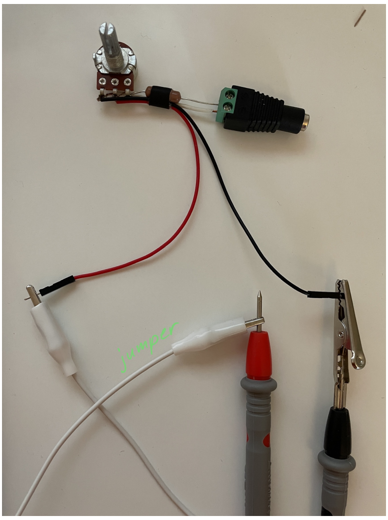
1) Find the potentiometer and the power supply connector.



2) Connect the potentiometer to the connector. The white wire must be connected too the negative terminal of the connector which is marked with a "−" sign. With the included small screw driver loosen the jaws of the connector and insert the wires, then tighten the screws to secure both wires.
3)

Now connect the leads to the digital multimeter (DMM), as indicated in the photo to the right. Turn the dial of the DMM to the position shown.

Next connect the DDM to the potentiometer as indicated in the photo to the right. Connect the alligator clip on the negative lead of the DMM to the black wire coming from the potentiometer, and connect the positive lead of the DMM to the red wire coming from the potentiometer with a jumper wire. This connection will allow the DMM to measure the electric potential at the output of the potentiometer.



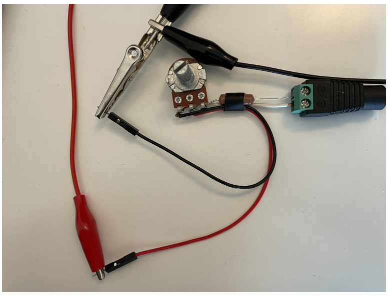
4) Plug the wall-wart power supply into an outlet and then insert the plug at the end of the power supply wire into the connector you attached to the potentiometer. Your circuit is now energized.
4) Turn the know on the potentiometer while watching the display of the DMM.

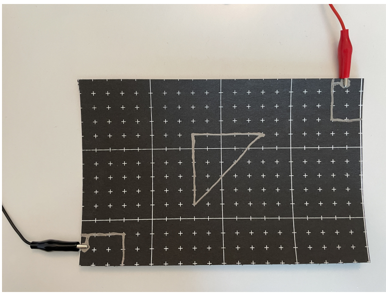
▷ QUESTION 1
What range of electric potentials is possible with this setup?

§ 4 Measuring the electric potential

Procedure 4.a

1) Disconnect the jumper connecting the positive lead of the DMM to the red wire of the potentiometer. Now use two jumper to connect potentiometer to the black paper as shown in the photos to the right and below.



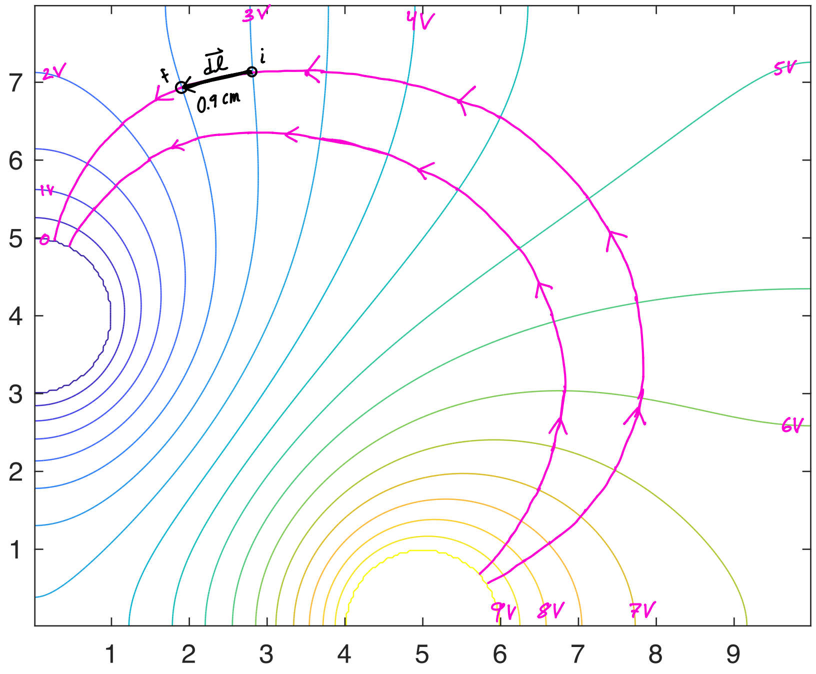


2) While touching the tip of red lead of the DMM to the electrode to which the red wire is connected by the jumper adjust the potentiometer until the DMM reads 9 volts. During the remainder of this procedure periodically check to be sure that the electric potential is still 9 Volts. If the alligator clips move it is possible that the voltage will change and this will throw off the measurement. So if you find the voltage has changed from 9 Volts, adjust the potentiometer so that it returns to 9 Volts. Of course it is best to not have the alligator clips move, which is achievable by stabilizing the wires before starting, and then not moving the paper.
3) Touch the paper in various places with the tip of the red lead and get a general idea of how the electric potential changes over the paper.
4) Find all the points on the paper that are at an electric potential of 6 Volts. This collection of points will form a curved line going from one edge of the paper to the other edge. Use a colored pencil to draw this line on the paper. This line is called an equipotential.
5) Repeat the above for the equipotentials that are at 1, 2, 3, 4, 5, 7, and 8 Volts.
6) Explore the electric potential inside the central triangular electrode.

▷ Question 2
What can you say about the electric potential inside the triangle?

§ 5 Constructing the electric field lines

1) Following the method demonstrated by your lab instructor draw the electric field lines on the paper.



2) Then compute the strength of the electric field at four locations on the paper. Using the diagram above we will now do an example of computing the field strength. Since we have already determined the direction of the electric field we can place the displacement vector $\vec{d\ell}$ parallel to the electric field $\vec{E}$, as has been done. The length was measured and found to be $d\ell = 0.9$cm. Now since we know that $\vec{d\ell}$ and $\vec{E}$ are in the same direction

$$\vec{E} \cdot \vec{d\ell} = E \, \mathrm{d}\ell$$

and so

$$dV = -\vec{E} \cdot \vec{d\ell} = -E \, \mathrm{d}\ell \longrightarrow E = -\frac{dV}{d\ell}$$

But we also know that

$$dV = V_f - V_i = 2.5\mathrm{V} - 3.0\mathrm{V} = -0.5\mathrm{V}$$

so that

$$E = -\frac{dV}{d\ell} = -\frac{-0.5\mathrm{V}}{0.9\mathrm{cm}} = 0.56\frac{\mathrm{V}}{\mathrm{cm}}$$

3) Find the locations on the paper where the electric field strength is great.
4) Find the locations on the paper where the electric field strength is low.
5) What can you say about the electric field strength inside the triangle?

▷ QUESTION 3
Use the definition $dV = -\vec{E} \cdot \vec{d\ell}$ to explain why the equipotentials must be perpendicular to the fields lines. One method is to presume a component of the field parallel to the equipotential and show that this is inconsistent with the definition.

▷ QUESTION 4
Look for places on your sheet where the step between the equipotentials is large enough so that the field is not nearly uniform. This would prevent us from estimating the electric field since $dV = -\vec{E} \cdot \vec{d\ell}$ would fail for a $\vec{d\ell}$ between those two equipotentials. What could you do to enable you to find the field strength in this region?