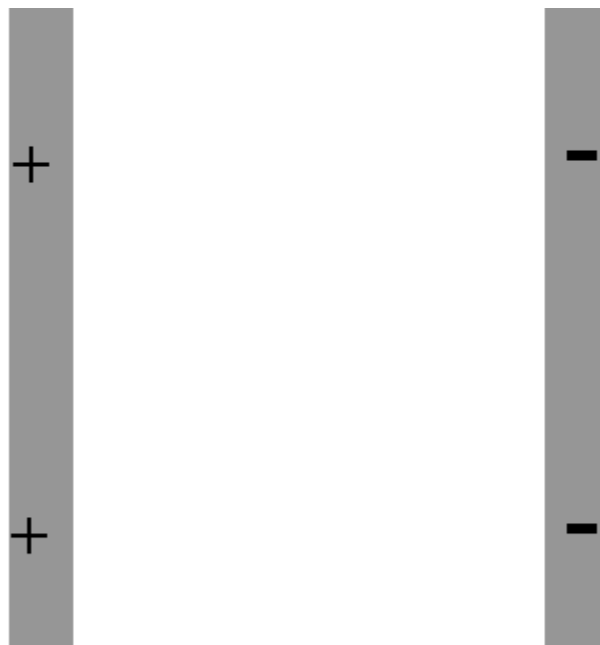


**Pre-lab Quiz/PHYS 224**  
**Electric Field and Electric Potential (A)**

**Your name**\_\_\_\_\_

**Lab section**\_\_\_\_\_

1. What do you investigate in this lab?
  
  
  
  
  
2. In a uniform electric field between two parallel plates, a potential probe records the electric potential changing from  $2.0$  to  $2.8$  V when it moves  $1.0$  cm along the direction perpendicular to the plates. Calculate the electric field between the plates. (Answer:  $E=80$  V/m)
  
  
  
  
  
3. In the following figure, the electric potential difference between the two parallel plates is  $5.0$  V. Draw four equipotential lines with  $1$ -V difference between two neighboring lines and label each line with the corresponding voltage. Also draw four electric field lines in the figure.



# Lab Report/PHYS 224

## Electric Field and Electric Potential (A)

Name \_\_\_\_\_

Lab section \_\_\_\_\_

### Objective

In this lab, you study the electric field between two parallel metal bars, map the equipotentials, determine the electric field, and plot the electric field lines. The electric field is not exactly but resembles uniform electric field.

### Background

In electrostatics, electric field ( $\vec{E}$ ) and electric potential ( $V$ ) are two interchangeable physical quantities for describing electric force, although the former is vector and the latter scalar.

If placing a test electric charge of charge  $q$  at Point P in space, it experiences an electric force given by

$$\vec{F} = q\vec{E}, \quad (1)$$

where  $\vec{E}$  is the electric field at Point P. When moving the test charge from Point P to Point Q, the electric force on the charge varies proportionally with the electric field along the pathway. The total work done by the electric force can be obtained by integrating the work along the pathway. Because the electrostatic force is conservative, the total work however depends only on the starting and ending points of the pathway but not on which specific pathway the charge traverses. One can thus introduce the electric potential difference between the two points which is related to the total work ( $\Delta W$ ) done by the electric force, as described by equation

$$\Delta W = -q\Delta V = -q(V_Q - V_P). \quad (2)$$

Therefore, if one maps out the electric field in space, one can calculate the electric potential in space (apart from a common constant as the reference potential), and vice versa.

As a vector quantity, electric field at a point must be described by its magnitude and direction, altogether requiring three numbers. To visualize  $\vec{E}$  in space, one normally draws electric field lines (each line with an arrow to designate its direction) in space. The direction of  $\vec{E}$  at a point is parallel to the tangent of the electric field line passing through the point. The magnitude of  $\vec{E}$  at any point is proportional to the line density at the point.

As a scalar quantity, electric potential at any point requires only one number to describe, apart from a common constant as the reference potential. As such, to plot electric potential in space, one can simply find and draw equipotential surfaces (often simply referred as equipotentials). On each equipotential, the electric potential is the same at every point. Clearly, it is much easier to map and plot electric potential in space. Normally, one draws a series of equipotentials, with the same potential difference between any two neighboring equipotentials. To obtain electric field from the plot of equipotentials, one uses the following rules. **At any point on an equipotential, the electric field must be perpendicular to the tangent of the equipotential at that point, and electric field points from high potential to low potential. The magnitude of the electric field is inversely proportional to the distance between two neighboring equipotentials. If the potential difference between two infinitely close points B and A is  $\Delta V = V_B - V_A$  and their distance is  $\Delta d$ , the component of the electric field projected in the direction pointing from A to B is given by  $E = -\Delta V / \Delta d$ .**

A uniform electric field can be induced between two parallel conducting plates a and b. The

plates are separated by distance  $d$  and maintain electric potential difference  $\Delta V_0 = V_a - V_b$ . This is simply a parallel-plate capacitor. Electric field is uniform between the plates, perpendicular to the plates and with the magnitude given by

$$E = |V_a - V_b| / d . \quad (3)$$

Thus, equipotentials are parallel with the plates. The potential difference between two equipotentials is linearly proportional to their distance. In fact, in uniform electric field pointing along the x-axis, the electric potential difference between any two points is given by

$$\Delta V = E \Delta x , \quad (4)$$

where  $\Delta x$  is the difference of the x-coordinate between the two points.

**The SI units for the above equations are:  $E$  in volts per meter (V/m);  $d$  or  $r$  in meter (m);  $V$  in volt (V).**

## EXPERIMENT

### Apparatus

Fill the rectangular tray with 0.5-inch of water. Two “L” shaped metal bars are used as electrodes to study uniform electric field. They are 6.75 in long. Of the three point probes with a round supporting base, two (P1 and P2) are to be connected to a DC power supply of 12 V and also connected respectively to either pair of electrodes. The other point probe (P3) and a hand-held point probe (P4) are used to map equipotentials. **Because the length and the height of two metal bars are not much larger than their separation, the electric field between the two metal bars cannot be exactly considered as uniform. Therefore, as you will find, your measurements in this lab should not completely follow Equations (3) and (4).**

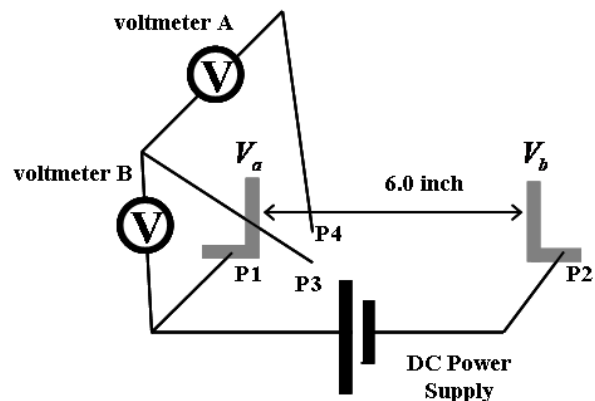


Figure 1

### Procedures

#### 1. Set up the circuit (Figure 1)

Place the rectangular graph paper underneath the tray. Place the two “L” shaped metal bars inside the tray, and let their right-angle edges face each other. Align their right-angle edges parallel with the shorter lines of the graph paper and make their centers approximately match the centers of corresponding shorter lines. Align the right-angle edge of one bar with the shorter 0-inch line (the  $x=0$  line) of the graph paper, and connect P2 to the ground of the DC power supply and gently place its tip on this bar (Bar b). Align the right-angle edge of the other bar with the shorter 6-inch line (the  $x=6$  line), and connect P1 to the positive terminal of the DC power supply and gently place its tip on this bar (Bar A). Note: the tips of P1 and P2 should be under the water surface and do not move the two bars again.

Figure 2 displays only part of the graph paper (not to scale). The x-axis is parallel with the longer lines of the graph paper and the y axis is parallel with the shorter lines. The x coordinate is measured from the right-angle edge of the 0-V bar. The y-coordinate is measured from the center of shorter lines. Note: the units for the x and y coordinates are inch.

Connect P1 to the positive lead of Voltmeter B and connect P3 to the negative lead of Voltmeter B. Connect P3 to the positive lead of Voltmeter A and connect P4 to the negative lead of Voltmeter B. Note: the sensitivity level of the voltmeters should be set properly. Place P3 and P4 (their tips should also be under the water surface) inside the tray and between the two bars.

**Ask your TA to check the circuit!**

## **2. Investigate Electric Potential-versus-Distance**

Set the output voltage ( $V_a - V_b$ ) of the DC power supply to 12 V (Actually, it may not allow you to set the voltage exactly to 12 V). Turn off Voltmeter B, and turn on Voltmeter A. Place the tip of probe P3 at point ( $x=2.0$  in,  $y=0$ ). Place the tip of probe P4 at points with  $y=0$  and in turn with  $x'=2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8$ , and  $4.0$  in. Read the correspondingly potential difference ( $\Delta V$ ) between the P4 and P3 from Voltmeter C. Record them in Table 2. Calculate  $\Delta V / (x' - x)$  and record the ratio values in Table 1. (Note: 1 inch= 0.0254 m.)

**TABLE 1**

$x'$ (inch)	Potential difference $\Delta V$ (V)	$\Delta V / (x' - x)$ (V/m)
2.2		
2.4		
2.6		
2.8		
3.0		
3.2		
3.4		
3.6		
3.8		
4.0		

## **3. Map the first equipotential**

Turn on only Voltmeter B. Move the tip of probe P3 to point ( $x=2$ ,  $y=0$ ). Read its potential from Voltmeter B. Mark the point on the rectangular paper (Figure 3). Record it in Table 2.

Turn off Voltmeter B. Turn on Voltmeter A, and move the tip probe P4 along the  $y=+1$  line until Voltmeter A reads 0 V. This means that the tips of P3 and P4 are place on the same equipotential. Read out the  $y$  coordinate of the tip of P4 and mark the point in Figure 3. Record it in Table 3.

Repeat the measurement by moving the tip of P4 respectively along the  $y=+2$ ,  $-1$ , and  $-2$  lines until Voltmeter A reads 0 V. Read out the corresponding  $x$  coordinates of the tip of P4 and mark the corresponding points in Figure 3. Record them in Table 2.

Draw a line through the five points. At the edge of this line, write down the potential value.

## **4. Map four more equipotentials**

Repeat step 3 to map four more equipotentials by moving the tip of probe P3 respectively to points ( $x=2.5$ ,  $y=0$ ), ( $x=3.0$ ,  $y=0$ ), ( $x=3.5$ ,  $y=0$ ), and ( $x=4.0$ ,  $y=0$ ). Record the data in Table 2.

## **Analysis**

Calculate the averaged x coordinate of the 5 points for each equipotential. Using the averaged x coordinates and the measured corresponding potentials, calculate the average electric field values  $\bar{E} = \Delta V / \Delta \bar{x}$  between every two neighboring equipotentials. (Note: 1 inch= 0.0254 m.)

Between the 1<sup>st</sup> and 2<sup>nd</sup>:  $\bar{E} =$

Between the 2<sup>nd</sup> and 3<sup>rd</sup>:  $\bar{E} =$

Between the 3<sup>rd</sup> and 4<sup>th</sup>:  $\bar{E} =$

Between the 4<sup>th</sup> and 5<sup>th</sup>:  $\bar{E} =$

In Figure 2, draw five electric field lines.

**TABLE 2**

<i>Tip of P3</i>	<i>potential</i> (V)	<i>x for</i> <i>y=0</i>	<i>x' for</i> <i>y=+1</i>	<i>x' for</i> <i>y=-1</i>	<i>x' for</i> <i>y=+2</i>	<i>x' for</i> <i>y=-2</i>	<i>Average</i> <i>x' &amp; x</i>
(x=2.0, y=0)		<b>2.0</b>					
(x=2.5, y=0)		<b>2.5</b>					
(x=3.0, y=0)		<b>3.0</b>					
(x=3.5, y=0)		<b>3.5</b>					
(x=4.0, y=0)		<b>4.0</b>					

## Questions

- For the measurement by step 2, is the measured  $\Delta V$  linearly proportional to  $(x' - x)$ ?
- Within 10% error, do the measured electric field values infer a uniform electric field between the metal bars?
- Does the result change when you place the tip of P2 at different points on the 12-V bar?

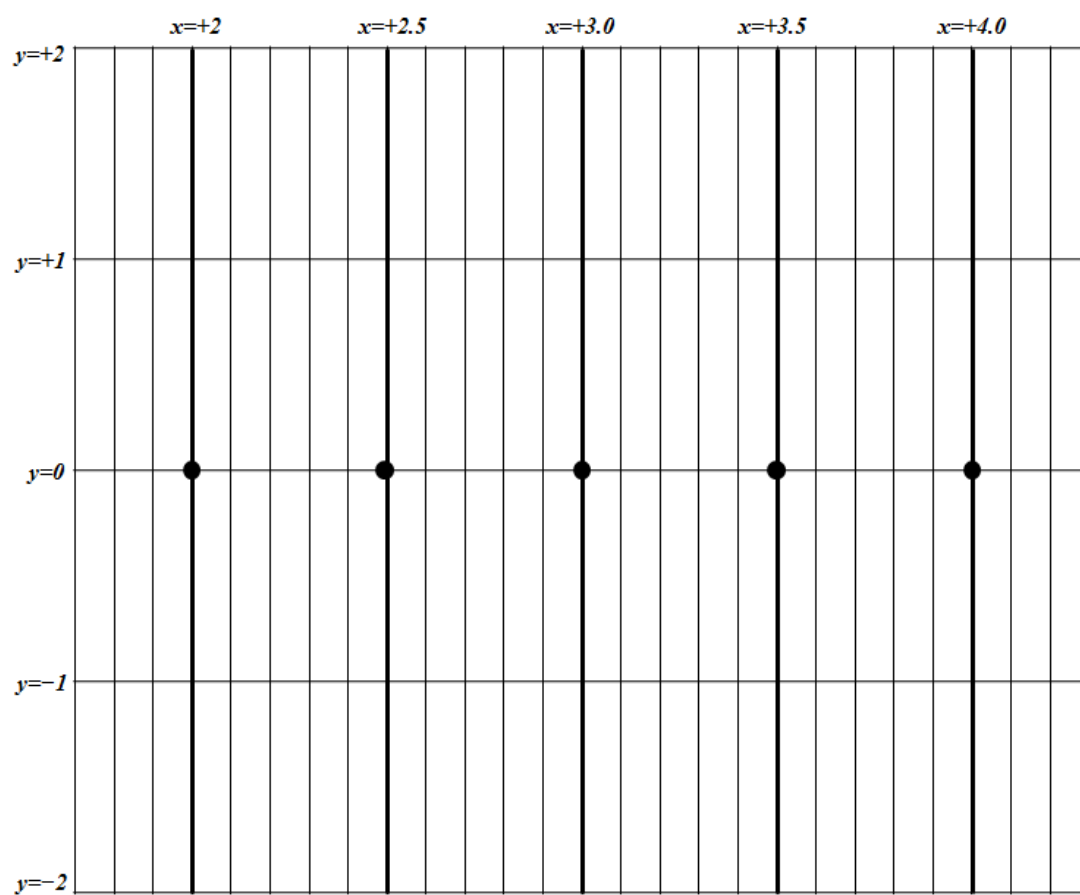


Figure 2