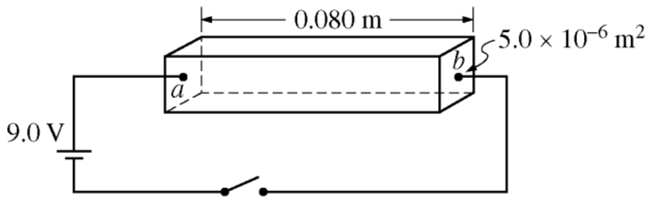
Student #: ____________________ Student Name: ____________________

AP PHYSICS C: MAGNETISM, HALL EFFECT AND MAXWELL'S EQUATIONS
SECTION II
3 Questions



1. A 9.0 V battery is connected to a rectangular bar of length 0.080 m, uniform cross-sectional area 5.0×10^{-6} m^2, and resistivity $4.5 \times 10^{-4}\ \Omega \cdot$ m, as shown above. Electrons are the sole charge carriers in the bar. The wires have negligible resistance. The switch in the circuit is closed at time $t = 0$.

   (a) Calculate the power delivered to the circuit by the battery.

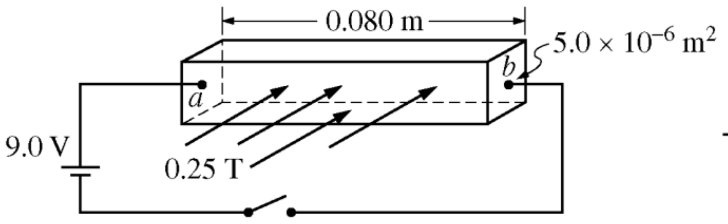
   (b) On the diagram below, indicate the direction of the electric field in the bar.

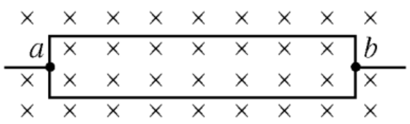
Side View

   Explain your answer.

   (c) Calculate the strength of the electric field in the bar.

   A uniform magnetic field of magnitude 0.25 T perpendicular to the bar is added to the region around the bar, as shown below.





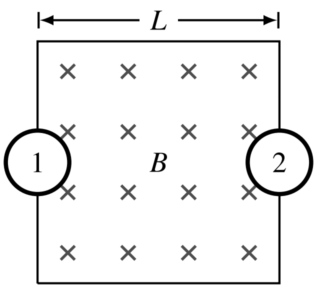
Side View

   (d) Calculate the magnetic force on the bar.

   (e) The electrons moving through the bar are initially deflected by the external magnetic field. On the diagram below, indicate the direction of the additional electric field that is created in the bar by the deflected electrons.

Side View

   (f) The electrons eventually experience no deflection and move through the bar at an average speed of 3.5×10^{-3} m/s. Calculate the strength of the additional electric field indicated in part (e).



2. A square conducting loop of side L contains two identical lightbulbs, 1 and 2, as shown above. There is a magnetic field directed into the page in the region inside the loop with magnitude as a function of time t given by $B(t) = at + b$, where a and b are positive constants. The lightbulbs each have constant resistance R_0. Express all answers in terms of the given quantities and fundamental constants.

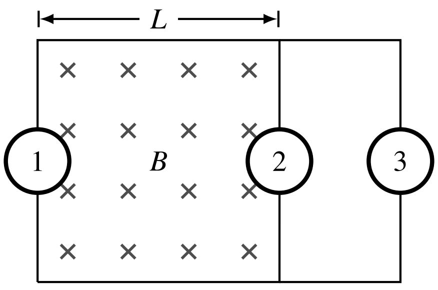
   (a) Derive an expression for the magnitude of the emf generated in the loop.

   (b) i. Determine an expression for the current through bulb 2.

   ii. Indicate on the diagram above the direction of the current through bulb 2.

   (c) Derive an expression for the power dissipated in bulb 1.

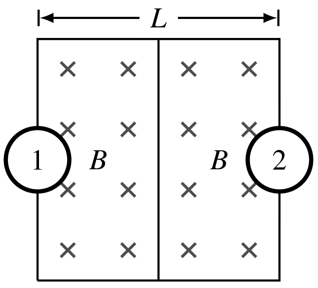
   Another identical bulb 3 is now connected in parallel with bulb 2, but it is entirely outside the magnetic field, as shown below.



   (d) How does the brightness of bulb 1 compare to what it was in the previous circuit? Justify your answer.

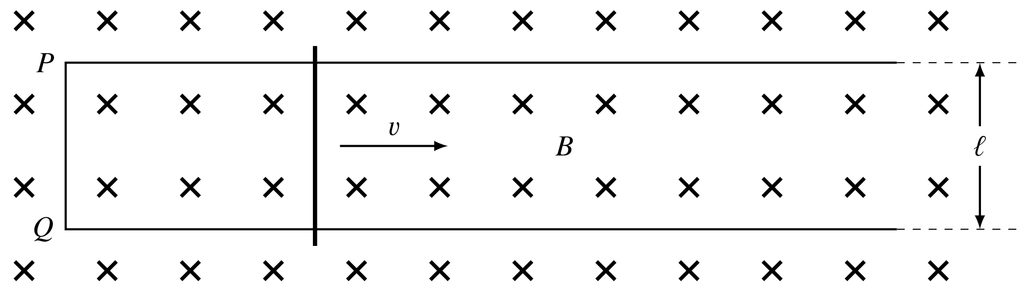
   _____ Brighter _____ Dimmer _____ The same

   Now the portion of the circuit containing bulb 3 is removed, and a wire is added to connect the midpoints of the top and bottom of the original loop, as shown below.



   (e) How does the brightness of bulb 1 compare to what it was in the first circuit? Justify your answer.

   _____ Brighter _____ Dimmer _____ The same



Top View

3. In the diagram above, a nichrome wire of resistance per unit length λ is bent at points P and Q to form horizontal conducting rails that are a distance ℓ apart. The wire is placed within a uniform magnetic field of magnitude B pointing into the page. A conducting rod of negligible resistance, which was aligned with end PQ at time $t = 0$, slides to the right with constant speed v and negligible friction. Express all algebraic answers in terms of the given quantities and fundamental constants.

   (a) Indicate the direction of the current induced in the circuit. Justify your answer.

   _____ Clockwise _____ Counterclockwise

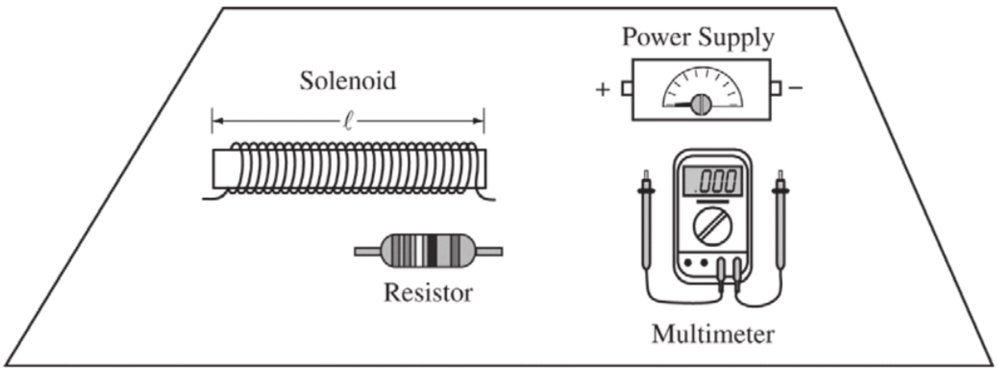
   (b) Derive an expression for the magnitude of the induced current as a function of time t.

   (c) Derive an expression for the magnitude of the magnetic force on the rod as a function of time.

   (d) On the axes below, sketch a graph of the external force F_{ext} as a function of time that must be applied to the rod to keep it moving at constant speed while in the field. Label the values of any intercepts.

   (e) The force pulling the rod is now removed. Indicate whether the speed of the rod increases, decreases, or remains the same. Justify your answer.

   _____ Increases _____ Decreases _____ Remains the same



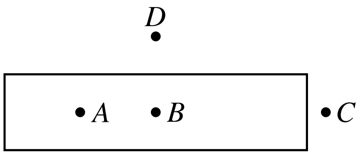
4. When studying Ampere's law, students collect data on the magnetic field of two different solenoids in order to determine the magnetic permeability of free space μ_0. The solenoids are created by wrapping wire around a hollow plastic tube. The solenoids of length ℓ with N turns of wire will be connected in series to a power supply and resistor. A multimeter will be used as an ammeter to measure the magnitude of the current I through the solenoids. The main components for the setup with one of the solenoids are shown in the figure above.

(a) i. On the figure above, draw wire connections between the solenoid, power supply, resistor, and multimeter that will complete the circuit and allow students to measure the magnitude of the current through the solenoid.

ii. Using the connections you made in part (a)i above, what will be the direction of the magnetic field inside the solenoid?

________ Toward the top of the page ________ To the left ________ Out of the page
________ Toward the bottom of the page ________ To the right ________ Into the page

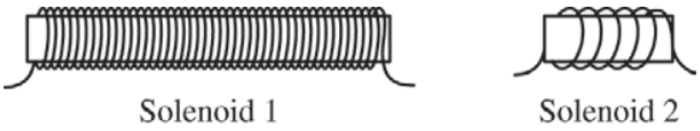
The rectangle shown below represents the solenoid (the loops of wire are not shown). Points A, B, and C are along the central axis of the solenoid with point B at the middle of the solenoid. Point D is directly above point B.



iii. From the choices below, select the point where you would place a magnetic field probe (a probe that can measure the magnitude of the magnetic field) to best measure the strength of the magnetic field of the solenoid in order to determine the magnetic permeability of free space μ_0. Justify your answer based on the model for a simple solenoid.

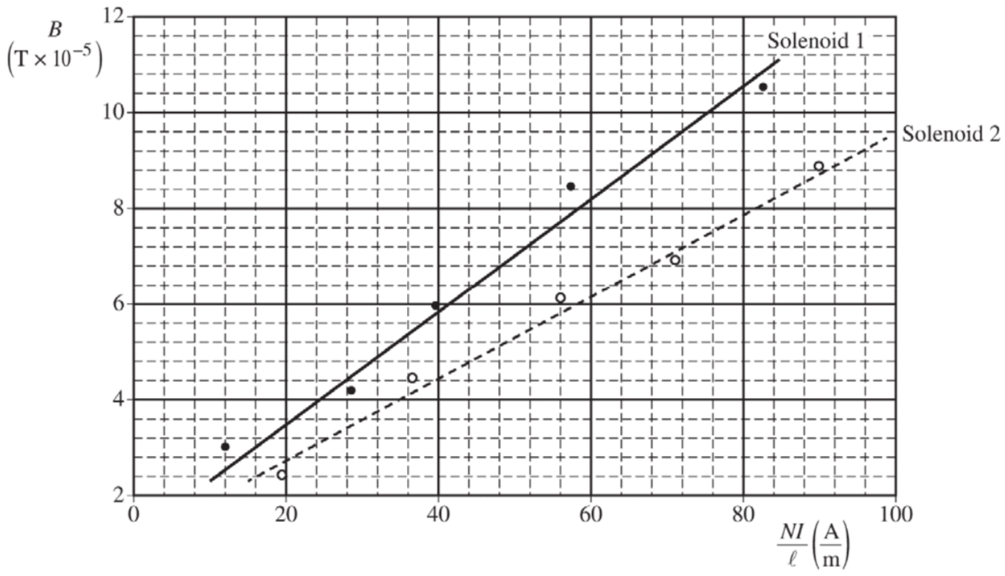
_______ A _______ B _______ C _______ D

The figures below show two different solenoids that will be connected in the circuit above. Solenoid 1 has a length $\ell = 25\,\text{cm}$ with $N = 100$ turns. Solenoid 2 has a length $\ell = 5.0\,\text{cm}$ with $N = 5$ turns.



Note: Figures not drawn to scale.

A graph of the magnitude of the magnetic field B as a function of NI/ℓ is shown below. The best-fit lines for the data are shown as a solid line for solenoid 1 and as a dashed line for solenoid 2.



(b) Which solenoid's best-fit line would give the best results for determining a value for the magnetic permeability of free space μ_0? Justify your answer.

_______ Solenoid 1 _______ Solenoid 2

(c) i. Use the slope of the best-fit line for the solenoid chosen in part (b) to calculate the magnetic permeability of free space μ_o.

ii. Calculate the percent error for the experimental value of the magnetic permeability of free space μ_0 determined in part (c)i.

(d) i. What is a reasonable physical explanation for a best-fit line that does not pass through the origin?

ii. Suppose a student connects the solenoid in a closed circuit similar to the circuit in part (a)i but without the resistor. The student notices the multimeter stops functioning after the power supply is turned on. Explain what causes the failure of the multimeter.