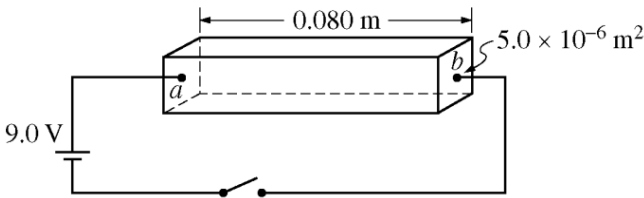**AP PHYSICS C: MAGNETISM, HALL EFFECT AND MAXWELL'S EQUATIONS**
**SECTION II**
3 Questions

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 4.5×10^{-4} Ω · 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
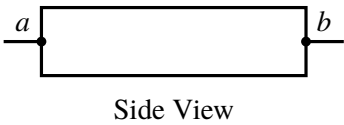
   Explain your answer.

   (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.
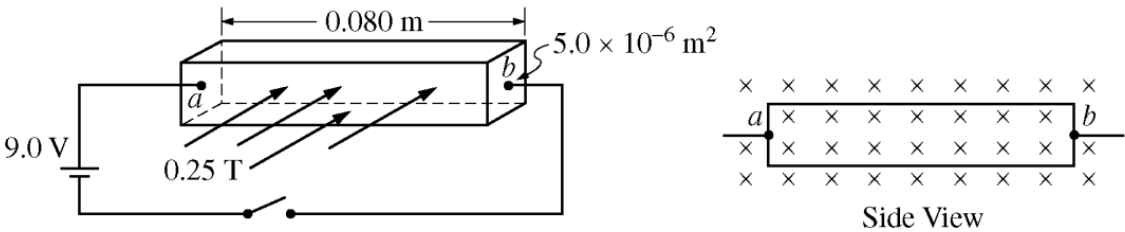
   (d) Calculate the magnetic force on the bar.

   (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
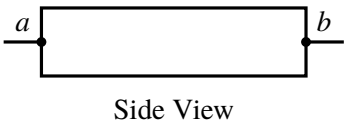
   (f) The electrons eventually experience no deflection and move through the bar at an average speed of 3.5×10^{-3} m/s. Calculate the strength of the additional electric field indicated in part (e).
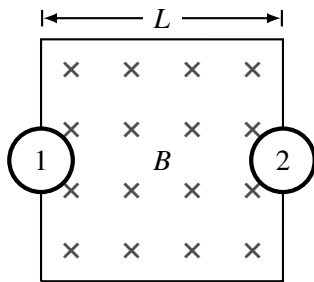
2. A square conducting loop of side L contains two identical lightbulbs, 1 and 2, as shown above. There is a magnetic field directed into the page in the region inside the loop with magnitude as a function of time t given by $B(t) = at + b$, where a and b are positive constants. The lightbulbs each have 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.
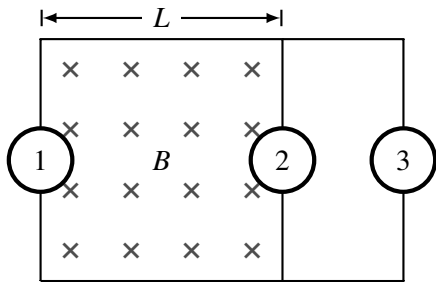

(d) How does the brightness of bulb 1 compare to what it was in the previous circuit? Justify your answer.

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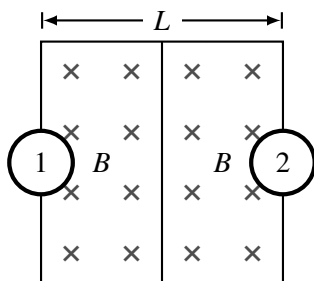
(e) How does the brightness of bulb 1 compare to what it was in the first circuit? Justify your answer.

_____ Brighter   _____ Dimmer   _____ The same

Top View
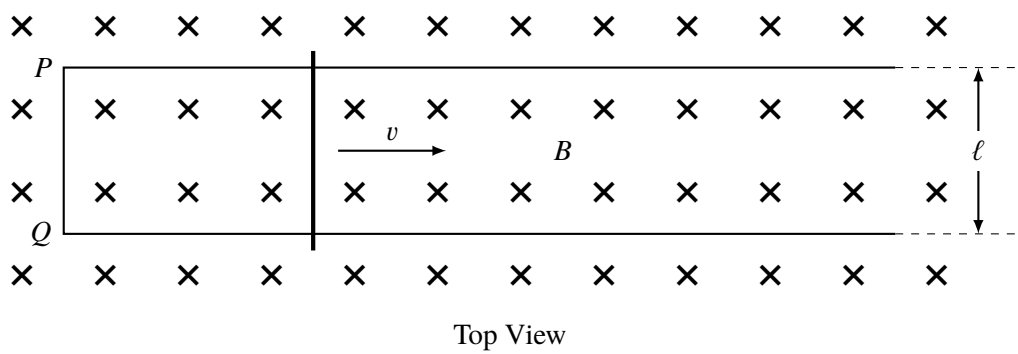
3. In the diagram above, a nichrome wire of resistance per unit length λ is bent at points P and Q to form horizontal conducting rails that are a distance ℓ apart. The wire is placed within a uniform magnetic field of magnitude B pointing into the page. A conducting rod of negligible resistance, which 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