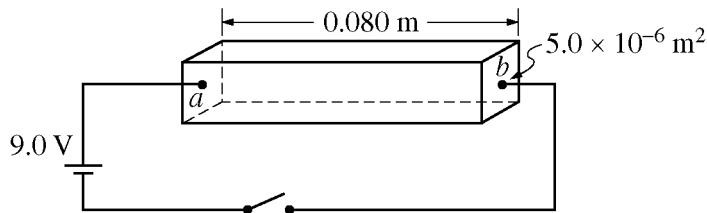


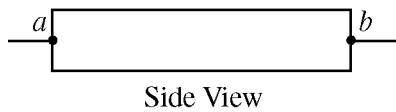
2009 AP® PHYSICS C: ELECTRICITY AND MAGNETISM FREE-RESPONSE QUESTIONS



E&M. 2.

A 9.0 V battery is connected to a rectangular bar of length 0.080 m, uniform cross-sectional area $5.0 \times 10^{-6} \text{ m}^2$, and resistivity $4.5 \times 10^{-4} \Omega \cdot \text{m}$, 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 $t = 0$.

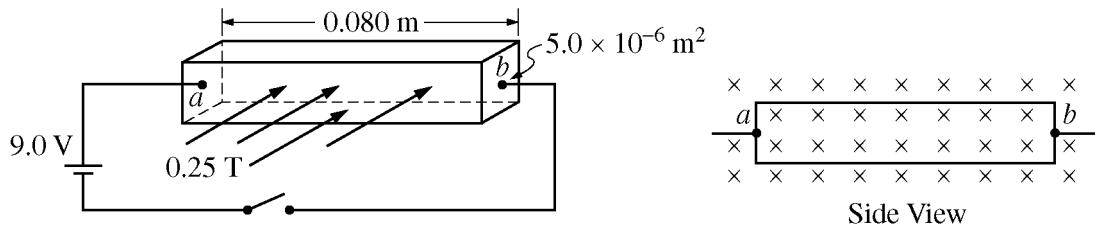
- Calculate the power delivered to the circuit by the battery.
- On the diagram below, indicate the direction of the electric field in the bar.



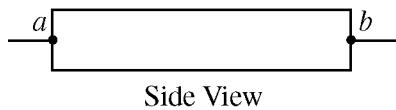
Explain your answer.

- 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.

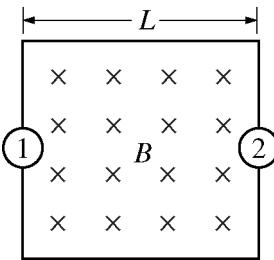


- Calculate the magnetic force on the bar.
- The electrons moving through the bar are initially deflected by the external magnetic field. On the diagram below, indicate the direction of the additional electric field that is created in the bar by the deflected electrons.



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

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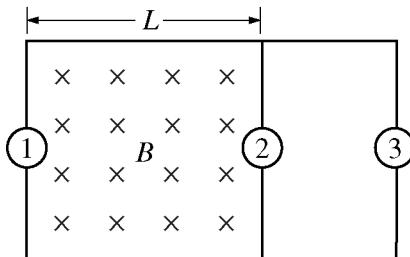


E&M. 3.

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?

Brighter Dimmer The same

Justify your answer.

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Question 2

15 points total

Distribution of points

(a) 3 points

For correctly substituting the given values into the expression for resistance 1 point

$$R = \rho\ell/A$$

$$R = (4.5 \times 10^{-4} \Omega \cdot \text{m})(0.080 \text{ m}) / (5.0 \times 10^{-6} \text{ m}^2) = 7.2 \Omega$$

For correctly combining $V = IR$ and $P = IV$ to get an expression for power in terms 1 point
of voltage and resistance

$$P = V^2/R$$

$$P = (9.0 \text{ V})^2 / 7.2 \Omega$$

For the correct answer 1 point

$$P = 11 \text{ W}$$

Alternate solution:

Alternate Points

For correctly substituting the given values into the expression for resistance 1 point

$$R = \rho\ell/A$$

$$R = (4.5 \times 10^{-4} \Omega \cdot \text{m})(0.080 \text{ m}) / (5.0 \times 10^{-6} \text{ m}^2) = 7.2 \Omega$$

For correctly combining $V = IR$ and $P = IV$ to get an expression for power in terms 1 point
of current and resistance

$$P = I^2R$$

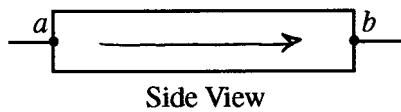
$$I = 9.0 \text{ V} / 7.2 \Omega = 1.25 \text{ A}$$

$$P = (1.25 \text{ A})^2(7.2 \Omega)$$

For the correct answer 1 point

$$P = 11 \text{ W}$$

(b) 3 points



For an arrow directed from *a* to *b* 1 point

For correctly indicating that the conventional current is from *a* to *b* OR that the electron 1 point
current is from *b* to *a*

For correctly indicating that the electric field is in the same direction as the conventional 1 point
current OR in the opposite direction to the electron current

Alternate solution: *Alternate Points*

For an arrow directed from *a* to *b* 1 point

For stating that point *a* is at a higher potential than point *b* 1 point

For stating that electric field points from higher to lower potential 1 point

Note: The third point could be earned for an incorrect field direction consistent with an
incorrect current or potential drop direction.

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Question 2 (continued)

Distribution of points

(f) 3 points

For recognizing that when there is no longer deflection, the electric force is equal and opposite to the magnetic force 1 point

$$F_E = F_B$$

For the correct expressions for the electric force and the magnetic force 1 point

$$F_E = qE$$

$$F_B = qvB$$

$$qE = qvB$$

$$E = vB$$

For correctly substituting values 1 point

$$E = (3.5 \times 10^{-3} \text{ m/s})(0.25 \text{ T})$$

$$E = 8.8 \times 10^{-4} \text{ V/m}$$

Units point

For the correct units on at least two numerical answers 1 point