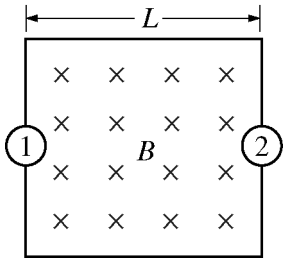


E&M. 3.

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.

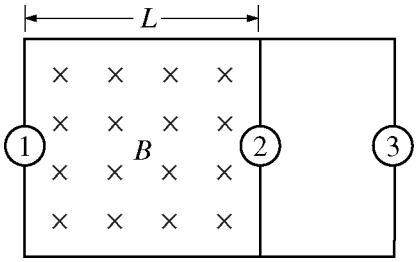
(a) Derive an expression for the magnitude of the emf generated in the loop.

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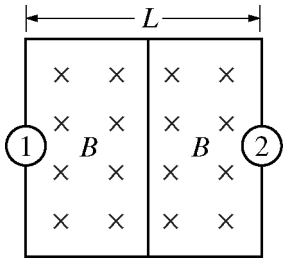
Now the portion of the circuit containing bulb 3 is removed, and a wire is added to connect the midpoints of the top and bottom of the original loop, as shown below.



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

____ Brighter ____ Dimmer ____ The same

Justify your answer.

END OF EXAM

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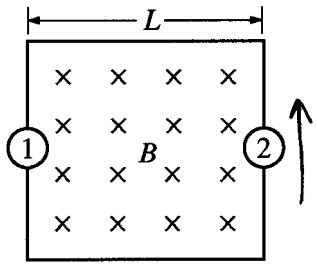
AP® PHYSICS C: ELECTRICITY AND MAGNETISM
2009 SCORING GUIDELINES

Question 3 (continued)

Distribution of points

(b) (continued)

(ii) 1 point



For indicating that current flows upward in bulb 2 or counterclockwise around the loop 1 point

(c) 2 points

$P_1 = I_1V_1 = I_1^2R_1 = V_1^2/R_1$

For substituting one correct value into one of the above expressions 1 point

For substituting a second correct value in the chosen expression 1 point

$P = \left(\frac{aL^2}{2R_0}\right)\left(\frac{aL^2}{2}\right)$ OR $P = \left(\frac{aL^2}{2R_0}\right)^2 R_0$ OR $P = \left(\frac{aL^2}{2}\right)^2 \Big/ R_0$

$P = a^2L^4/4R_0$

(d) 4 points

For indicating that bulb 1 is brighter 1 point

For any indication that the emf is the same as in the original circuit (since there is no flux through the added loop) 1 point

For stating that adding a bulb in parallel with bulb 2 decreases the overall resistance of the circuit 1 point

For stating that decreasing the overall resistance increases the overall current, which is equal to the current in bulb 1 1 point

(e) 2 points

For indicating that bulb 1 is the same brightness as in the original circuit 1 point

For a complete and correct justification 1 point

Examples:

Since each loop has half the area, each has half the original emf. But each also has half the resistance. This means the current and thus the power in bulb 1 is the same.

The two loops are essentially identical. Separately, the flux through each loop would create an emf that is counterclockwise. Since these emfs are in opposite directions in the central wire, the net effect is that there is no emf in that wire. Therefore the situation is equivalent to the original one.

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