

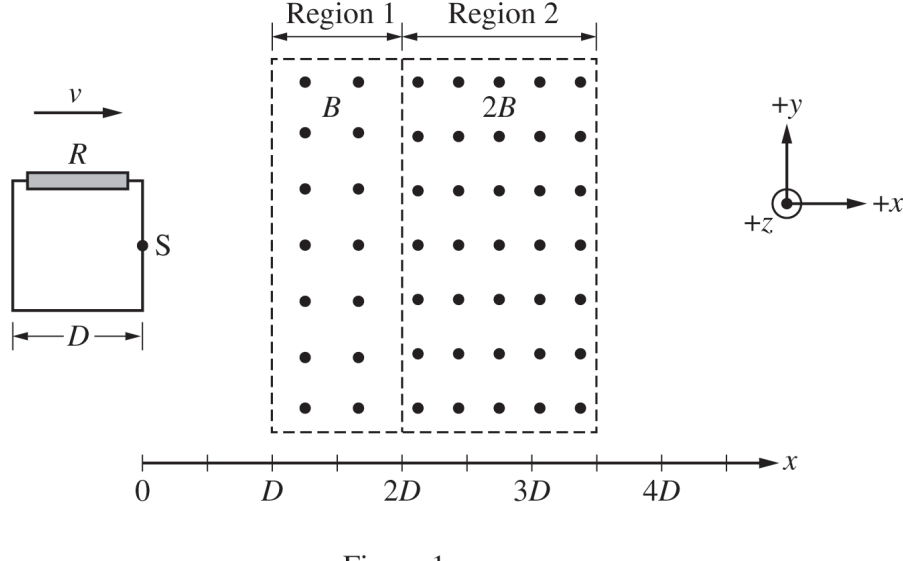


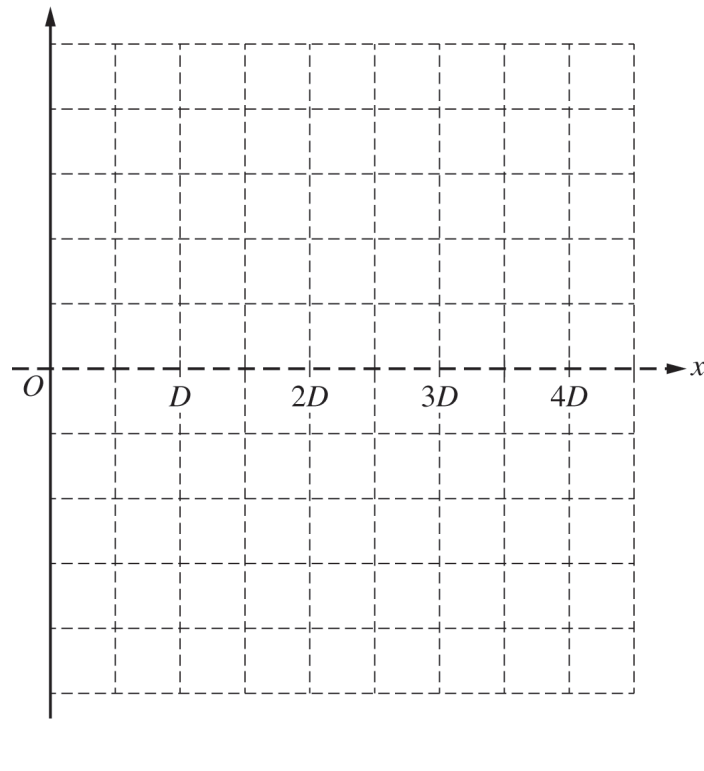
Figure 1

3. A wire is connected to a resistor of resistance R to form a rigid square loop of side length D . An external force is exerted on the loop so that the loop always moves with constant speed v in the $+x$ direction, as shown in Figure 1. The loop then enters Region 1 of external uniform magnetic field of magnitude B that is directed in the $+z$ -direction. Region 1 has boundaries $x = D$ and $x = 2D$. The loop later enters Region 2 of external uniform magnetic field of magnitude $2B$ that is directed in the $+z$ -direction. Region 2 has boundaries $x = 2D$ and $x = 3.5D$. Point S is the midpoint of the leading edge of the loop.

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Continue your response to **QUESTION 3** on this page.

- (a) On the following axes, **sketch** a graph of the magnetic flux Φ through the square loop as a function of the position x of Point S from $x = 0$ to $x = 4.5D$. The $+z$ -direction indicated in Figure 1 corresponds to $+\Phi$.



- (b) Consider the instant when Point S reaches $x = 1.5D$.
- i. **Indicate** whether the current I_S that is induced in the square loop when Point S reaches $x = 1.5D$ is clockwise, counterclockwise, or zero.
- _____ Clockwise _____ Counterclockwise _____ Zero
- Briefly **justify** your answer.

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- ii. **Derive** an expression for I_S when Point S reaches $x = 1.5D$. If $I_S = 0$, indicate how the derived expression shows that $I_S = 0$. Express your answer in terms of R , D , v , B , and physical constants, as appropriate.

- iii. **Derive** an expression for the power P dissipated by the resistor when Point S reaches $x = 1.5D$. Express your answer in terms of R , D , v , B , and physical constants, as appropriate.

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The total energy dissipated by the resistor in the square loop as Point S moves from $x = 0$ to $x = 4.5D$ is E_{original} .

The vertical boundary between regions 1 and 2 is now shifted to $x = 2.5D$. After the boundary is shifted, the square loop again moves with speed v in the $+x$ -direction, as shown in Figure 2. The total energy dissipated by the resistor as Point S moves from $x = 0$ to $x = 4.5D$ is E_{new} .

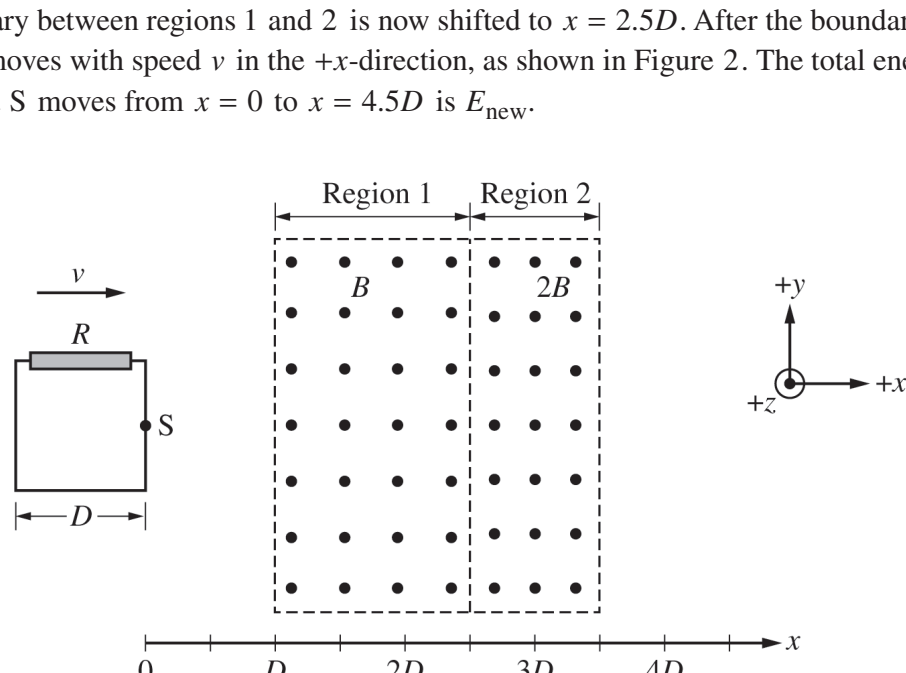


Figure 2

- (c) **Indicate** whether E_{new} is greater than, less than, or equal to E_{original} .
- _____ $E_{\text{new}} > E_{\text{original}}$ _____ $E_{\text{new}} < E_{\text{original}}$ _____ $E_{\text{new}} = E_{\text{original}}$
- Briefly **justify** your answer.

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The original magnetic fields are modified so that the region $D < x < 3.5D$ contains an external uniform magnetic field of magnitude B that is directed in the $+z$ -direction.

A new wire is connected to a resistor of resistance R to form a rigid triangular loop with base length D and height D . An external force is exerted on the loop so that the loop always moves with speed v in the $+x$ -direction, as shown in Figure 3. Point S represents the upper-leading corner of the loop.

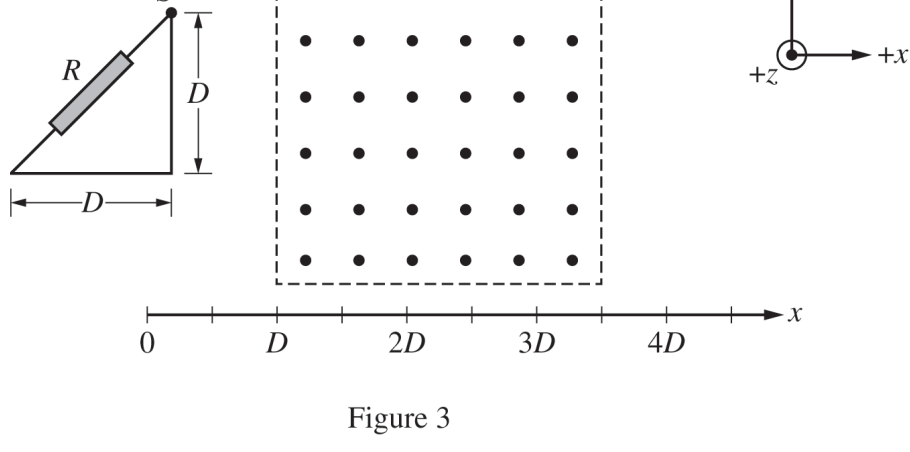
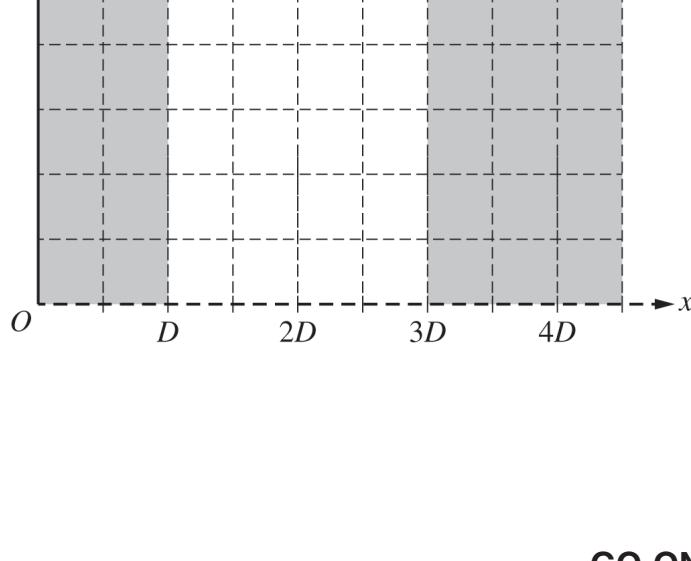


Figure 3

- (d) On the following axes, **sketch** a graph of the induced current I_T in the loop as Point S moves from $x = D$ to $x = 3D$.



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END OF EXAM