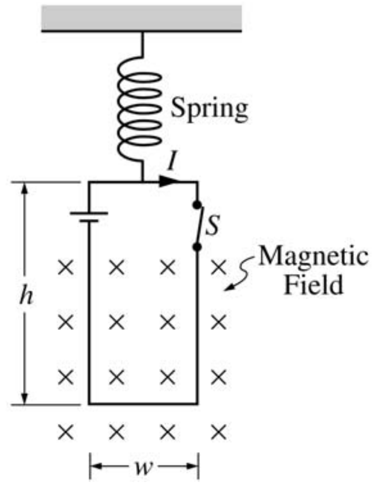
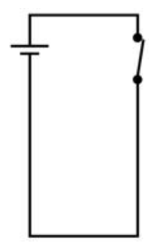


E&M 3.

A loop of wire of width w and height h contains a switch and a battery and is connected to a spring of force constant k, as shown above. The loop carries a current I in a clockwise direction, and its bottom is in a constant, uniform magnetic field directed into the plane of the page.

(a) On the diagram of the loop below, indicate the directions of the magnetic forces, if any, that act on each side of the loop.

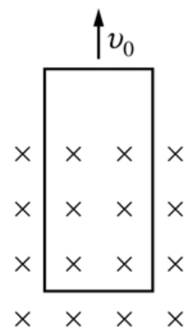


(b) The switch S is opened, and the loop eventually comes to rest at a new equilibrium position that is a distance x from its former position. Derive an expression for the magnitude B_0 of the uniform magnetic field in terms of the given quantities and fundamental constants.

The spring and loop are replaced with a loop of the same dimensions and resistance R but without the battery and switch. The new loop is pulled upward, out of the magnetic field, at constant speed v_0. Express algebraic answers to the following questions in terms of B_0, v_0, R, and the dimensions of the loop.

(c)

i. On the diagram of the new loop below, indicate the direction of the induced current in the loop as the loop moves upward.



ii. Derive an expression for the magnitude of this current.

(d) Derive an expression for the power dissipated in the loop as the loop is pulled at constant speed out of the field.

(e) Suppose the magnitude of the magnetic field is increased. Does the external force required to pull the loop at speed v_0 increase, decrease, or remain the same?

_____ Increases   _____ Decreases   _____ Remains the same

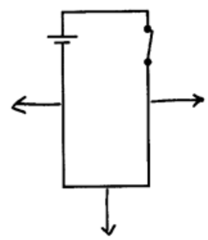
Justify your answer.

END OF EXAM

Question 3

15 points total | **Distribution of points**

(a) 2 points



For indicating at least one of the magnetic forces shown, perpendicular to any of the three lower arms and in the plane of the loop, and no forces on the upper arm — 1 point

For correctly indicating all three forces shown — 1 point

(b) 3 points

For recognizing the equilibrium condition with the upward spring force balancing the downward magnetic force and NO inclusion of the gravitational force on the loop — 1 point

$F_S = F_M$ or $kx = I\ell B$

For explicitly solving for the initial magnetic field strength B_0, using the correct expressions for F_S and F_M — 1 point

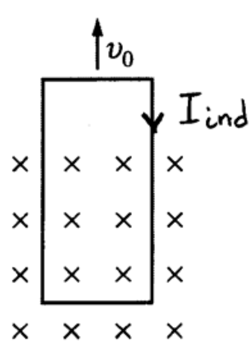
$$B_0 = \frac{kx}{I\ell}$$

For substituting the width w of the loop bottom for the length ℓ in the magnetic force — 1 point

$$B_0 = \frac{kx}{Iw}$$

(c)

(i) 2 points



For indicating the clockwise induced current direction in the loop — 2 points

Question 3 (continued)

Distribution of points

(e) 3 points

For choosing "Increases"	1 point
For a clear and complete justification indicating that the magnetic field affects the force directly through the relationship $F_M = B_0 I_{ind} \ell$ and also through the induced current $I_{ind} = B_0 w v_0 / R$	2 points

Example:

An increased magnetic field causes the magnetic force on the loop bottom to be larger for a given current and wire length. The larger field also increases the size of the induced current. Thus, the motion must be balanced by a larger applied force to keep the loop moving at the same constant speed v_0 through a larger field with a larger induced current.

<u>Note</u>: *A partially complete or unclear justification was awarded 1 point.*