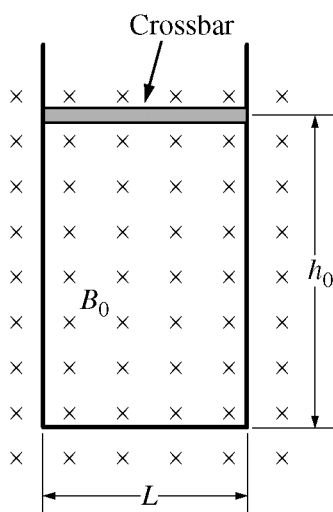


2012 AP[®] PHYSICS C: ELECTRICITY AND MAGNETISM FREE-RESPONSE QUESTIONS



E&M. 3.

A closed loop is made of a U-shaped metal wire of negligible resistance and a movable metal crossbar of resistance R . The crossbar has mass m and length L . It is initially located a distance h_0 from the other end of the loop. The loop is placed vertically in a uniform horizontal magnetic field of magnitude B_0 in the direction shown in the figure above. Express all algebraic answers to the questions below in terms of B_0 , L , m , h_0 , R , and fundamental constants, as appropriate.

- (a) Determine the magnitude of the magnetic flux through the loop when the crossbar is in the position shown.

The crossbar is released from rest and slides with negligible friction down the U-shaped wire without losing electrical contact.

- (b) On the figure below, indicate the direction of the current in the crossbar as it falls.



Justify your answer.

- (c) Calculate the magnitude of the current in the crossbar as it falls as a function of the crossbar's speed v .
- (d) Derive, but do NOT solve, the differential equation that could be used to determine the speed v of the crossbar as a function of time t .
- (e) Determine the terminal speed v_T of the crossbar.
- (f) If the resistance R of the crossbar is increased, does the terminal speed increase, decrease, or remain the same?

_____ Increases _____ Decreases _____ Remains the same

Give a physical justification for your answer in terms of the forces on the crossbar.

STOP

END OF EXAM

AP[®] PHYSICS C: ELECTRICITY AND MAGNETISM
2012 SCORING GUIDELINES

Question 3 (continued)

	Distribution of points
(d) 4 points	
For a correct net force equation showing opposite directions for the gravitational and magnetic forces, F_g and F_M	1 point
$\sum F = ma = F_g - F_M = mg - F_M$ $a = g - \frac{F_M}{m}$	
For using an appropriate equation to find F_M	1 point
$F_M = \int I d\ell \times \mathbf{B} = ILB_0$	
For substituting the current from part (c)	1 point
$F_M = \left(\frac{B_0 L v}{R} \right) LB_0 = \frac{B_0^2 L^2 v}{R}$	
For expressing acceleration a as dv/dt	1 point
$\frac{dv}{dt} = g - \frac{B_0^2 L^2 v}{mR}$	
(e) 2 points	
For setting the gravitational force equal to the magnetic force $a = 0$; therefore $F_M = F_g$	1 point
For correct substitution of expressions for the forces	1 point
$mg = ILB_0 = B_0^2 L^2 v_T / R$ $v_T = \frac{mgR}{B_0^2 L^2}$	
<u>Note:</u> If the correct expression for v_T is stated without support, 2 points are awarded.	