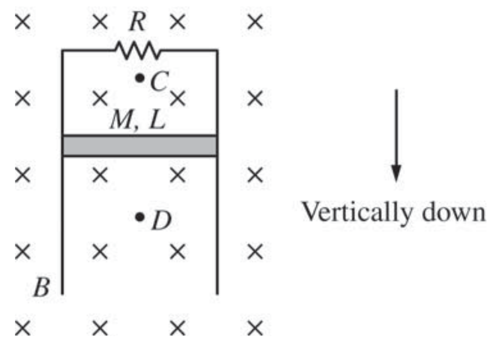

E&M.3.

A conducting bar of mass *M*, length *L,* and negligible resistance is connected to two long vertical conducting rails of negligible resistance. The two rails are connected by a resistor of resistance *R* at the top. The entire apparatus is located in a magnetic field of magnitude *B* directed into the page, as shown in the figure above. The bar is released from rest and slides without friction down the rails.

(a) What is the direction of the current in the resistor?

____ Left ____ Right

(b)

i. Is the magnitude of the net magnetic field above the bar at point *C* greater than, less than, or equal to the magnitude of the net magnetic field before the bar is released?

_____ Greater than _____ Less than _____ Equal to

Justify your answer.

ii. While the bar is above point D, is the magnitude of the net magnetic field at point *D* greater than, less than, or equal to the magnitude of the net magnetic field before the bar is released?

_____ Greater than _____ Less than _____ Equal to

Justify your answer.

Express your answers to parts (c) and (d) in terms of *M*, *L*, *R*, *B*, and physical constants, as appropriate.

(c) Write, but do NOT solve, a differential equation that could be used to determine the velocity of the falling bar as a function of time *t*.

(d) Determine an expression for the terminal velocity v_T of the bar.

Express your answers to parts (e) and (f) in terms of v_T, *M*, *L*, *R*, *B*, and physical constants, as appropriate.

(e) Derive an expression for the power dissipated in the resistor when the bar is falling at terminal velocity.

(f) Using your differential equation from part (c), derive an expression for the speed of the falling bar $v(t)$ as a function of time *t*.

STOP

END OF EXAM

Question 3

15 points total | **Distribution of points**

(a) 1 point

For selecting "Left" — 1 point

(b)

i. 2 points

For selecting "Less than" — 1 point

For a correct justification — 1 point

Example: Because as the bar falls the flux at point C is increasing, the emf generated must create a magnetic field to oppose this change. Therefore, it will create a magnetic field to decrease the flux and thus decrease the magnetic field.

No points are earned if the wrong answer is selected.

ii. 2 points

For selecting "Greater than" — 1 point

For a correct justification — 1 point

Example: The field at point C, which is above the bar, is less than the original magnetic field, and point D is on the other side of the bar. Therefore, the direction of the magnetic field from the bar at point D is the opposite of the direction at point C, so the net magnetic field at D when the bar is falling must be greater than the original magnetic field.

No points are earned if the wrong answer is selected.

(c) 4 points

For correctly applying Newton's second law to the motion of the bar — 1 point

$$F_{net} = Mg - F_M = Mg - BIL$$

$$I = \mathcal{E}/R$$

For attempting to use Faraday's law to obtain an expression for the emf in the bar — 1 point

$$\mathcal{E} = d\Phi/dt = BL(dx/dt)$$

For correctly using the expression for emf to obtain an expression for the current — 1 point

$$I = \frac{BL(dx/dt)}{R} = \frac{BLv}{R}$$

$$Ma = Mg - B\frac{BLv}{R}L$$

$$a = g - \frac{B^2L^2v}{MR}$$

For writing the acceleration as dv/dt — 1 point

$$\frac{dv}{dt} = g - \frac{B^2L^2v}{MR}$$