



## **AP<sup>®</sup> Physics C: Electricity and Magnetism 2004 Sample Student Responses**

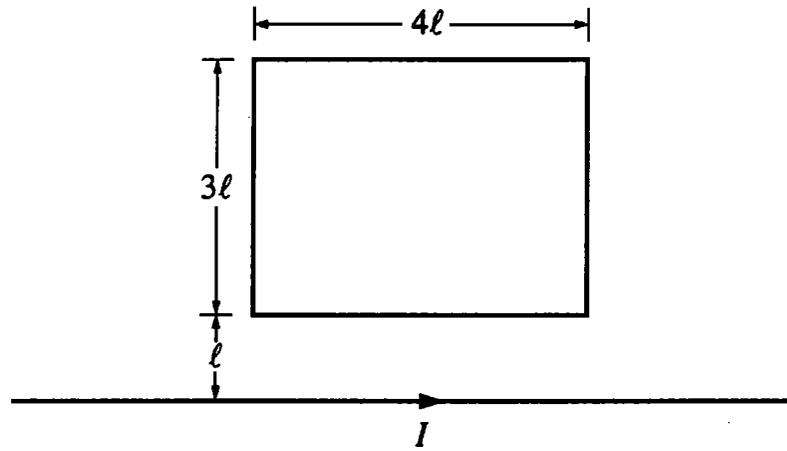
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E&M. 3.

A rectangular loop of dimensions  $3l$  and  $4l$  lies in the plane of the page as shown above. A long straight wire also in the plane of the page carries a current  $I$ .

(a) Calculate the magnetic flux through the rectangular loop in terms of  $I$ ,  $l$ , and fundamental constants.

$\Phi_B = \int B \cdot dA$        $\oint B \cdot ds = \mu_0 I$   
 $B 2\pi r = \mu_0 I$

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 $\oint B \cdot ds = \mu_0 I$   
 $B 2\pi r = \mu_0 I$   
 $B = \frac{\mu_0 I}{2\pi r}$

$\Phi_B = \int \frac{\mu_0 I}{2\pi r} \cdot dA$   
 $\Phi_B = \int_l^{4l} \frac{\mu_0 I}{2\pi r} 4l dr$   
 $\Phi_B = \frac{2\mu_0 I l}{\pi} (\ln(4l) - \ln(l))$   
 $\Phi_B = \frac{2\mu_0 I l}{\pi} \ln(4)$   
 $\Phi_B = \frac{4\mu_0 I l}{\pi} \ln(2)$

$A = 4l \cdot r$   
 $dA = 4l dr$

Starting at time  $t = 0$ , the current in the long straight wire is given as a function of time  $t$  by

$I(t) = I_0 e^{-kt}$ , where  $I_0$  and  $k$  are constants.

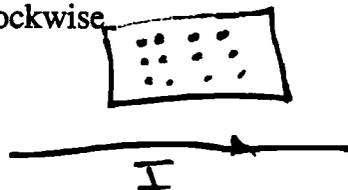
(b) The current induced in the loop is in which direction?

Clockwise       Counterclockwise

Justify your answer.

$I(t) = I_0 e^{-kt}$

function starts at  $I_0$  and decreases from there



$\therefore$  B field is decreasing out of the loop.



according to Lenz's law: B field created by induced current must be in same direction as decreasing B field thus..



GO ON TO THE NEXT PAGE.

The loop has a resistance  $R$ . Calculate each of the following in terms of  $R$ ,  $I_0$ ,  $k$ ,  $\ell$ , and fundamental constants.

(c) The current in the loop as a function of time  $t$

$$\Phi_B = \frac{4\ell\mu_0 I_0 e^{-kt} \ln(2)}{\pi}$$

$$\mathcal{E} = -\frac{d\Phi_B}{dt}$$

$$I = \frac{1}{R} \frac{d\Phi_B}{dt}$$

$$I = -\frac{1}{R} \cdot \left( \frac{4\ell\mu_0 I_0 \ln(2) e^{-kt}}{\pi} \right)$$

$$I = \frac{4\ell\mu_0 I_0 \ln(2) k e^{-kt}}{R\pi}$$

(d) The total energy dissipated in the loop from  $t = 0$  to  $t = \infty$

$$P = \frac{dW}{dt}$$

$$\int_0^{\infty} P dt = W$$

~~$P = IV$~~ 

$$P = IV$$

$$V = IR$$

$$P = I^2 R$$

$$\int_0^{\infty} I^2 R dt = W$$

$$\int_0^{\infty} \frac{16\ell^2 \mu_0^2 I_0^2 \ln^2(2) k^2 e^{-2kt}}{R^2 \pi^2} R dt = W$$

$$\frac{16\ell^2 \mu_0^2 I_0^2 \ln^2(2) k^2}{R\pi^2} \left( \frac{-e^{-2kt}}{2k} \right) \Big|_0^{\infty}$$

$$\left( \frac{-1}{2k e^{2k\infty}} - \frac{-1}{2k e^0} \right)$$

$$0 + \frac{1}{2k}$$

$$\frac{8\ell^2 \mu_0^2 I_0^2 \ln^2(2) k}{R\pi^2} = W$$



