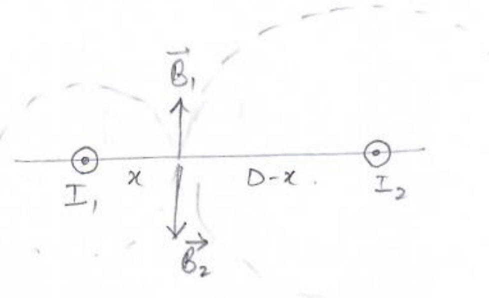
Solutions — PHYS-205B (Midterm Exam 03) Fall 2023

Problem 1



$$B_1 = B_2$$

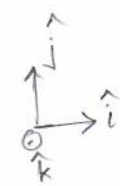
$$\frac{\mu_0}{4\pi}\frac{2I_1}{x} = \frac{\mu_0}{4\pi}\frac{2I_2}{D-x}$$

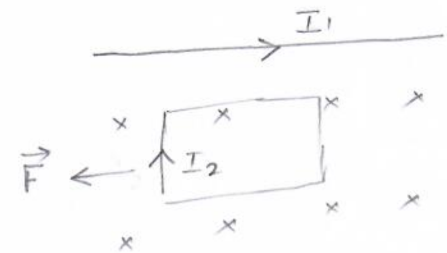
$$\frac{I_1}{x_1} = \frac{I_2}{D-x}$$

$$\frac{1.0}{x} = \frac{2.0}{D-x} \Rightarrow x = \frac{D}{3} = 3.0\text{cm} \quad (\text{from } I_1)$$

Problem 2

Towards lelf (along $-\hat{i}$)





Problem 3

Magnetic flux is not changing. Thus, there is no induced current.

Problem 4

$$\left[\frac{1}{\sqrt{\mu_0\epsilon_0}}\right] = \frac{L}{T}$$

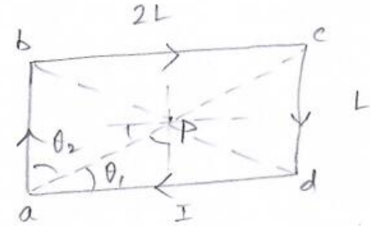
$$\frac{q^2}{4\pi\epsilon_0 r^2} = q\,v\,\frac{\mu_0 I\,2}{4\pi r}$$

$$\frac{1}{\mu_0\epsilon_0} = \frac{(\text{length})^2}{(\text{time})^2}$$

$$[F_e] = [F_b]$$

Problem 5

$\vec{B}_{tot}$ at point P is into the page.



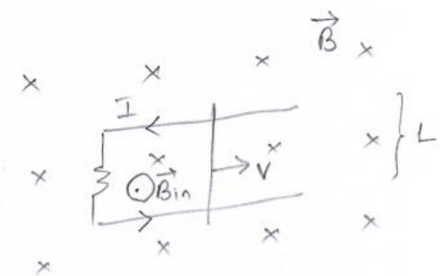
$$B_{tot} = B_{ab} + B_{bc} + B_{cd} + B_{da}$$
$$= 2\,B_{ab} + 2\,B_{bc}$$
$$= 2\,\frac{\mu_0}{4\pi}\,\frac{I}{L}\,2\sin\theta_1 + 2\,\frac{\mu_0}{4\pi}\,\frac{I}{L/2}\,2\sin\theta_2$$
$$= 4\,\frac{\mu_0 I}{4\pi L}\left[\sin\theta_1 + 2\sin\theta_2\right]$$
$$= 4\,\frac{\mu_0 I}{4\pi L}\left[\frac{1}{\sqrt{5}} + 2\,\frac{2}{\sqrt{5}}\right]$$
$$= 4\sqrt{5}\,\frac{\mu_0 I}{4\pi L}$$

$$\sin\theta_1 = \frac{L}{\sqrt{L^2+4L^2}} = \frac{1}{\sqrt{5}}$$
$$\sin\theta_2 = \frac{2L}{\sqrt{L^2+4L^2}} = \frac{2}{\sqrt{5}}$$

Problem 6

→ Flux is increasing
→ $\vec{B}_{in}$ opposite to $\vec{B}$
→ I is counterclockwise.

$$I = \frac{v l B}{R}$$
$$= \frac{(4.0)(0.050)(0.12)}{(0.30)}$$
$$= 0.080\ \text{A}$$



Problem 7

$$I = \frac{V}{R}\left(1 - e^{-\frac{t}{\tau}}\right)$$
$$\frac{1}{2}\,\frac{V}{R} = \frac{V}{R}\left(1 - e^{-\frac{t}{\tau}}\right)$$
$$\frac{1}{2} = 1 - e^{-\frac{t}{\tau}}$$
$$e^{-\frac{t}{\tau}} = 1 - \frac{1}{2}$$

$$\ln e^{-\frac{t}{\tau}} = \ln\frac{1}{2}$$
$$-\frac{t}{\tau} = -\ln 2$$
$$t = \tau \ln 2$$
$$= (1.0\times10^{-9})(0.69)$$
$$= 0.69\ \text{ns}.$$

$$\tau = \frac{L}{R}$$
$$= \frac{1.0\times10^{-3}}{1.0\times10^{6}}$$
$$= 1.0\ \text{ns}$$