Homework #7 Solutions

Q 28.7 We used the magnetic field only from one conductor in calculating the force on the second conductor since a wire can not accelerate itself.

8.6 a) Both charges produce a magnetic field into the page at P.

$$B_{tot} = B_q + B_{q'} = \frac{\mu_0}{4\pi}\left(\frac{qv}{r^2} + \frac{q'v'}{r'^2}\right)$$

where

$q = 8\,\mu C$ $\qquad q' = 3\,\mu C$

$v = 4.5\times10^6\,m/s$ $\qquad v = 9\times10^6\,m/s$

$r = 0.12\,m$ $\qquad r' = 0.12\,m$

$$B_{tot} = 10^{-7}\frac{Tm}{A}\,\frac{1}{(0.12)^2 m^2}\left(8\,\mu C\;4.5\times10^6\frac{m}{s} + 3\,\mu C\;9\times10^6\frac{m}{s}\right)$$

$$= \frac{10^2}{1.44}\left(0.8(4.5) + 2.7\right)\mu T$$

$$= 437.5\,\mu T$$

b) Magnetic and electric forces are repulsive.

B_q = magnetic field at q' due to q.

$$B_q = \frac{\mu_0}{4\pi}\frac{qv}{4d^2}, \quad F_{q'} = q'v'B_q$$

$$F_{q'} = \frac{\mu_0}{4\pi}\frac{qq'vv'}{4d^2} = 10^{-7}\frac{Tm}{A}\,\frac{24\,10^{-12}\,C^2}{4(1.44)\,10^{-2}\,m^2} \otimes 4.5(9)\times10^{12}\frac{m^2}{s^2}$$

$$F_{q'} = \frac{6(4.5)(8)}{1.44} \times 10^{-5} \; \frac{N}{Am} \; \frac{m}{A} \; \frac{C^2}{s^2}$$

$$= 1.69 \times 10^{-3} \, N \quad = \text{magnetic force}$$

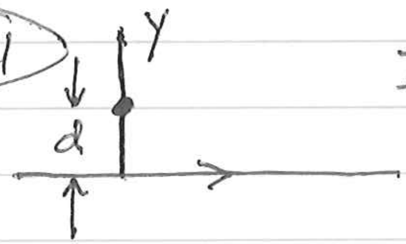
$$F_{q'} = F_q$$

$$F_E = \frac{q q'}{4\pi\epsilon_0 \, 4d^2} = 9\times10^{9} \, \frac{N\cancel{m^2}}{\cancel{C^2}} \; \frac{24 \times 10^{-12} \cancel{C^2}}{4(1.44)\,10^{-2} \cancel{m^2}}$$

$$= \frac{54}{1.44} \times 10^{-1} \, N = 3.75 \, N$$

c) Magnitude of magnetic force is the same but now attractive.

(28.14)



$x \rightarrow$

F

$I = 60\,A$, $m = 3\times10^{-6}\,kg$

$q = 8\times10^{-3}\,C$

$$B_z = \frac{\mu_0 I}{2\pi d}$$

$d = 0.08\,m$

$$m\underline{a} = q\, \underline{v} \times \underline{B} \qquad a_x = -5\times10^{3}\, m/s^2, \; a_y = 9\times10^{3}\, \frac{m}{s^2}$$

$$m a_x = q\, v_y B_z \Rightarrow v_y = \frac{m a_x}{q B_z}$$

$$m a_y = -q\, v_x B_z \qquad v_x = \frac{-m a_y}{q B_z}$$

$$B_z = 10^{-7} \frac{T\cancel{m}}{\cancel{A}} \; \frac{2(60)\cancel{A}}{0.08\, \cancel{m}} = \frac{1.2}{0.8} \times 10^{-4}\, T$$

$$= 1.5 \times 10^{-4}\, T$$

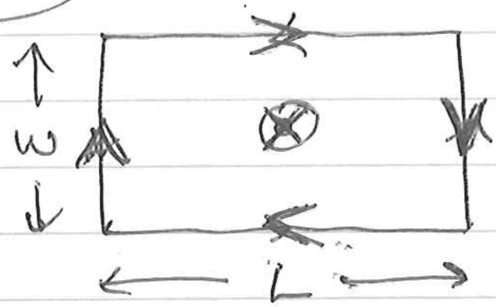
$$v_y = -\frac{3\times10^{-6} \cancel{kg} \; 5\times10^{3} \frac{m}{\cancel{s^2}}}{8\times10^{-3} C \;\; 1.5\times10^{-4}} \; \frac{Am}{\cancel{N}} = -\frac{10}{8}\times10^{4}\, \frac{m}{s}$$

$$= -1.25\times10^{4}\, m/s$$

$$V_x = -\frac{3\times10^{-6}\,kg\; 9\times10^{3}\,\frac{m}{s^2}}{8\times10^{-3}\,C\; 1.5\times10^{-4}}\frac{Am}{N} = -\frac{27}{12}\times10^{4}\,\frac{m}{s}$$

$$= -2.25\times10^{4}\,\frac{m}{s}$$

28.22



$w = 0.042\,m$

$L = 0.095\,m$

$B = 5.5\times10^{-5}\,T$

B is ~~out~~ in so current is ~~counter~~ clockwise.

For a segment of length ℓ at a distance x from the midpoint

$$B = \frac{\mu_0 I}{4\pi}\frac{\ell}{x\left(x^2+\frac{\ell^2}{4}\right)^{1/2}}$$

$$B = \frac{\mu_0}{4\pi}\,2I\left(\frac{w}{\frac{L}{2}\left(\frac{L^2}{4}+\frac{w^2}{4}\right)^{1/2}} + \frac{L}{\frac{W}{2}\left(\frac{w^2}{4}+\frac{L^2}{4}\right)^{1/2}}\right)$$

$$= \frac{\mu_0}{4\pi}\,8I\left(\frac{w}{L}+\frac{L}{w}\right)\frac{1}{(w^2+L^2)^{\frac{1}{2}}}$$

$$\cancel{5.5\times10^{-5}T = 10^{-7}\frac{Tm}{A}\,8I\left(\left(\frac{4.2}{9.5}\right)+\left(\frac{9.5}{4.2}\right)\right)\frac{10^{2}}{10.4}}$$

$$5.5\times10^{-5}\,T = \frac{\mu_0}{4\pi}\,8I\,\frac{(w^2+L^2)^{1/2}}{wL} = 10^{-7}\,\frac{Tm}{A}\,8I\,\frac{10.4\times10^{-2}\,m}{9.5(4.2)10^{-4}\,m^2}$$

$$\frac{5.5(9.5)(4.2)}{8(10.4)}\,A = I = 2.6\,A$$

28.28 ~~Force between~~

Force/length between two wires is

$$F = \frac{\mu_0}{2\pi r} I_1 I_2$$

with r the separation. Parallel currents attract and opposite currents repell.

Force on top current

$$F = \frac{\mu_0}{2\pi} I^2 \left(\frac{1}{d} - \frac{1}{2d} \right) = \frac{\mu_0}{4\pi} \frac{I^2}{d}$$

upward

Force on bottom current is same magnitude but downward.

No force on middle wire

28.38 $\underset{\text{in}}{I_1 = 4A}, \underset{\text{out}}{I_2 = 6A}, \underset{\text{out}}{I_3 = 2A}$

paths are counterclockwise so $\underset{\sim}{A}$ is out.

path (a) $\Rightarrow \oint \underline{B} \cdot d\underline{l} = 0$

path (b) $\Rightarrow \oint \underline{B} \cdot d\underline{l} = -\mu_0 4A$

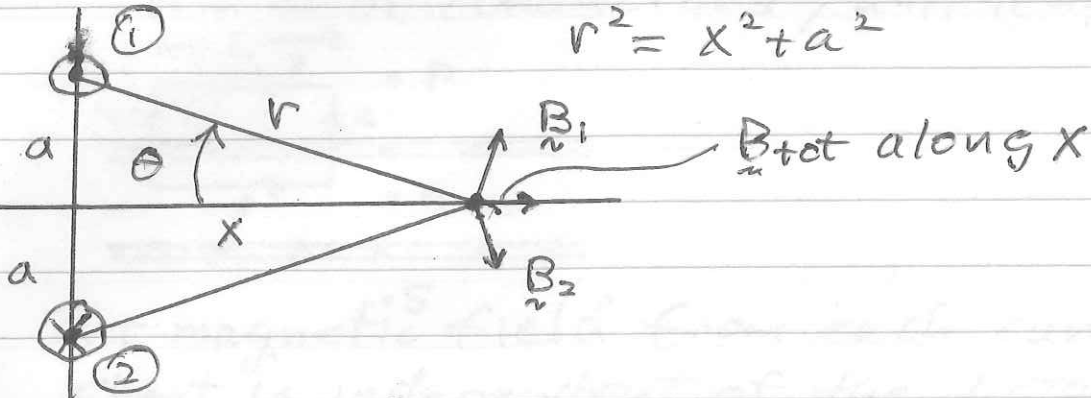
$= -16\pi \times 10^{-7}$ Tm

path (c) $\Rightarrow \oint \underline{B} \cdot d\underline{l} = \mu_0 2A = 8\pi \times 10^{-7}$ Tm

path (d) $\Rightarrow \oint \underline{B} \cdot d\underline{l} = \mu_0 4A = 16\pi \times 10^{-7}$ Tm

28.58

$r^2 = x^2 + a^2$

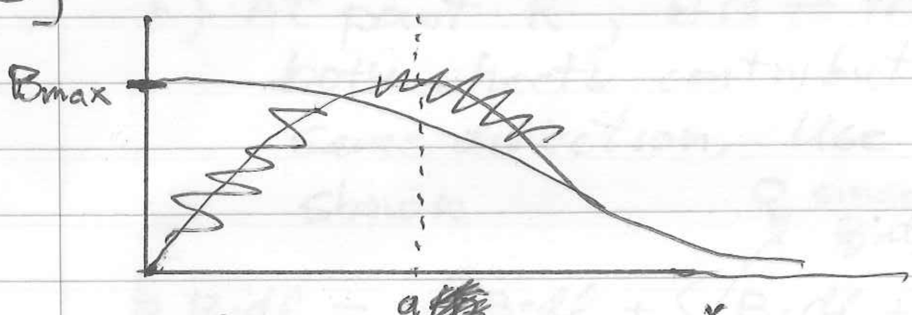


b) $B_1 = B_2 = \frac{\mu_0 I}{2\pi r} = B$

$B_x = 2B\cos\theta = 2B\frac{a}{r}$

$B_x = \frac{\mu_0 I a}{\pi(x^2+a^2)} \Rightarrow B_x > 0$

c)



d) Find ~~max~~ value x where B_x has its max value at $x=0$.

$\cancel{\frac{d}{dx}\left(\frac{x}{(x^2+a^2)}\right) = \left(\frac{1}{(\;)} - \frac{x(2x)}{(\;)^{3/2}}\right) = 0}$

$\cancel{x^2+a^2 - 2x^2 = 0}$

$\cancel{x = a}$

For $x \gg a$,

$\cancel{B_{max} = \frac{\mu_0 I}{2\pi a}}$

$B_x \simeq \frac{\mu_0 I a}{\pi x^2}$

28.70

n = # of conductors / unit length

The magnetic field from each current sheet is independent of the distance from the sheet.

a) At P the magnetic field from the top sheet is to the left and from bottom sheet is to the right. The two cancel so $B=0$.

b) At point R, B is to the right since both sheets contribute in the same direction. Use Amperian loop shown

$$\oint \underline{B}\cdot d\underline{l} = \int_1 \underline{B}\cdot d\underline{l} + \underbrace{\int_2 \underline{B}\cdot d\underline{l}}_{0 \text{ since } \underline{B}\cdot d\underline{l}=0} + \underbrace{\int_3 \underline{B}\cdot d\underline{l}}_{0 \text{ since } \underline{B}=0} + \underbrace{\int_4 \underline{B}\cdot d\underline{l}}_{0 \text{ since } \underline{B}\cdot d\underline{l}=0}$$

$$= \int_1 \underline{B}\cdot d\underline{l} = BL$$

$$= \mu_0 n I L$$

$$B = \mu_0 n I$$

c) $B=0$ below since B from each sheet cancels.