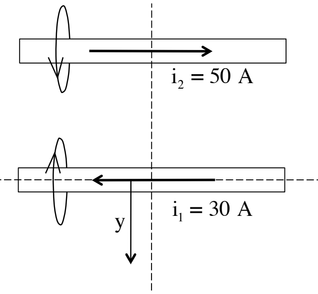
Problem 30.12



a.) The sense of the each magnetic field is shown in the sketch (I used the "right-thumb" rule to determine this).

--In between the wires, the fields will never add to zero as both fields are into the page in that region.

--Above the 50 amp wire, the fields are opposite in direction (one into, one out of the page) but the wire with the larger current will always be closer to the point of interest, so nowhere will the two add to zero in that region.

--Below the wire is the choice. Assuming the magnitude of the distance below the 30 amp wire is defined as "y,", we can write:

$$\vec{B}_{net} = 0 = B_1\left(+\hat{k}\right) + B_2\left(-\hat{k}\right)$$

$$\Rightarrow \quad 0 = \frac{\mu_o i_1}{2\pi r_1} - \frac{\mu_o i_2}{2\pi r_2}$$

$$\Rightarrow \quad \frac{\cancel{\mu_o} i_1}{\cancel{2\pi} y} = \frac{\cancel{\mu_o} i_2}{\cancel{2\pi}(y + .28)}$$

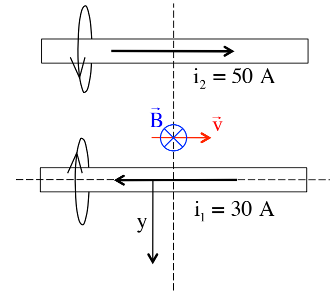
$$\Rightarrow \quad (y + .28)i_1 = i_2 y$$

$$\Rightarrow \quad y = \left(\frac{.28 i_1}{i_2 - i_1}\right)$$

$$= \left(\frac{(.28\text{ m})(30\text{ A})}{(50\text{ A}) - (30\text{ A})}\right)$$

$$= .42\text{ m} \quad \text{(again, this is below the 30 amp wire)}$$

b.) At y = .1 meters, the net B-fld is:



$$\vec{B}_{net} = B_1\left(-\hat{k}\right) + B_2\left(-\hat{k}\right)$$

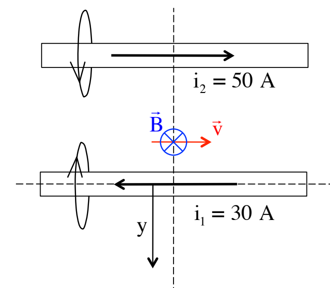
$$= \left(\frac{\mu_o i_1}{2\pi r_1} + \frac{\mu_o i_2}{2\pi r_2}\right)\left(-\hat{k}\right)$$

$$= \frac{\mu_o}{2\pi}\left(\frac{i_1}{r_1} + \frac{i_2}{r_2}\right)\left(-\hat{k}\right)$$

$$= \frac{\left(4\pi x10^{-7}\ \text{T}\bullet\text{m / A}\right)}{2\pi}\left(\frac{(30\text{ A})}{(.1\text{ m})} + \frac{(50\text{ A})}{(.128\text{ m})}\right)\left(-\hat{k}\right)$$

$$\Rightarrow \quad \vec{B}_{net} = \left(1.16x10^{-4}\text{ T}\right)\left(-\hat{k}\right)$$

Noting that crossing a vector in the $\hat{i}$ direction (i.e., the velocity vector) into a vector in the $-\hat{k}$ direction (i.e., the B-fld) yields, using the right-hand rule on the cross product, a vector in the $+\hat{j}$ direction. That would be the direction of the force if the charge feeling the effect was positive. As our charge is negative, the direction of force on it is $-\hat{j}$ and we can write:

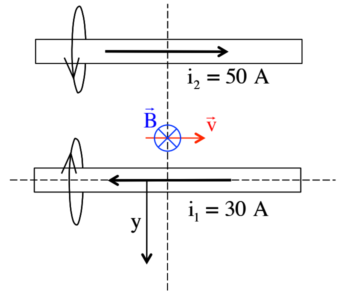


$$\vec{F} = q \qquad \vec{v} \qquad x \qquad \vec{B}$$

$$= \left(-2x10^{-6}\text{ C}\right)\left[\left(1.5x10^{8}\text{ m/s}\right)\left(\hat{i}\right)x\left(\left(1.16x10^{-4}\text{ T}\right)\left(-\hat{k}\right)\right)\right]$$

$$= \left(3.47x10^{-2}\text{ N}\right)\left(-\hat{j}\right)$$

c.) How large an electric field would be required to allow the charge to pass undeflected through the region?



It seems kind of obvious that the force due to the magnetic field (determined in the previous section) would have to be equal and opposite the force on the charge due to the electric field. That is:

$$\vec{F}_{net} = 0 = \vec{F}_B + \vec{F}_E$$

$$\Rightarrow \quad 0 = q\vec{v}x\vec{B} + q\vec{E}$$

$$\Rightarrow \quad q\vec{v}x\vec{B} = -q\vec{E}$$

$$\Rightarrow \quad \left(3.47x10^{-2}\ N\right)\left(-\hat{j}\right) = -\left(-2x10^{-6}\ C\right)\vec{E}$$

$$\Rightarrow \quad \vec{E} = \left(1.73x10^{4}\ N/C\right)\left(-\hat{j}\right)$$