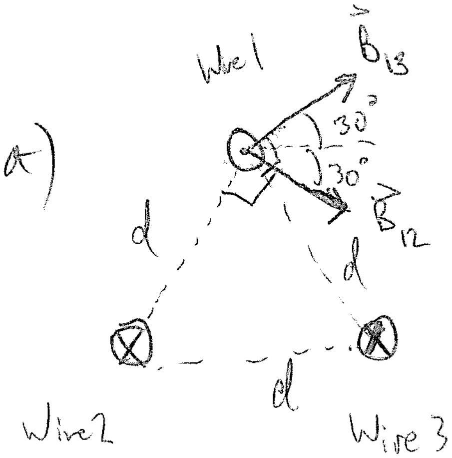
1) a)

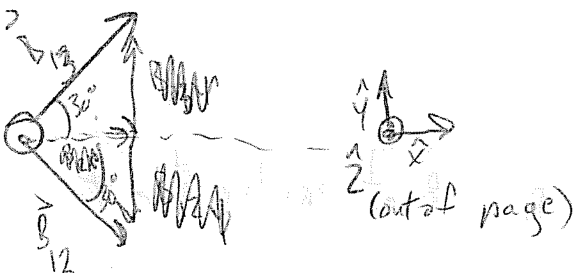


$(d = 0.04\ m)$

$\vec{B}_{13}$ is $\vec{B}$ at 1 due to 3

$\vec{B}_{12}$ is $\vec{B}$ at 1 due to 2

$$|\vec{B}_{12}| = |\vec{B}_{13}| = \frac{\mu_0 I}{2\pi d}$$



$$\vec{B}_{12} + \vec{B}_{13} = \frac{\mu_0 I}{2\pi d}\left[(\cos 30° + \cos 30°)\hat{x} + (\sin 30° - \sin 30°)\hat{y}\right]$$

$$= \frac{\mu_0 I}{2\pi d}\left[\frac{\sqrt{3}}{2} + \frac{\sqrt{3}}{2}\right]\hat{x} = \frac{\sqrt{3}\mu_0 I}{2\pi d}\hat{x}$$

$$\vec{F}_{\text{magnetic on } 1} = (\vec{I} \times \vec{B}) \cdot l = \mu_0 \frac{I^2 \sqrt{3}}{2\pi d} l \cdot (\hat{z} \times \hat{x})$$

$$= \frac{\sqrt{3}}{2\pi d}\mu_0 I^2 l\ \hat{y}$$

1)a) (cont) for wire 1 to hover

$$\vec{F}_{magnetic} = -\vec{F}_{grav} = mg\,\hat{y}$$

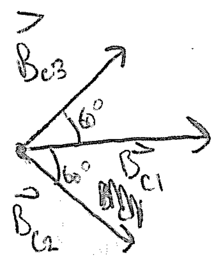
$$= \rho \cdot g \cdot l\,\hat{y}$$

$\rho = 50\ g/cm = 5\ kg/m$ $\qquad g = 9.8\ m/s^2$

So $\quad I^2 \cancel{l} \cdot \dfrac{\sqrt{3}}{2\pi d} = \rho g \cancel{l}$

$$\Rightarrow \quad I = \sqrt{\frac{2\pi \rho g d}{\sqrt{3}\,\mu_0}} = \boxed{2.38 \cdot 10^{3}\ A}$$

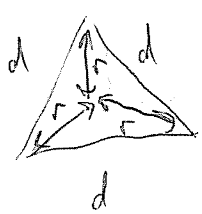
b)



$\vec{B}_{c1} = \vec{B}$ at center due to 1, etc.

$$\vec{B}_{at\ center} = \vec{B}_{c1} + \vec{B}_{c2} + \vec{B}_{c3}$$

$$|\vec{B}_{c1}| = |\vec{B}_{c2}| = |\vec{B}_{c3}| = \frac{\mu_0 I}{2\pi r}$$

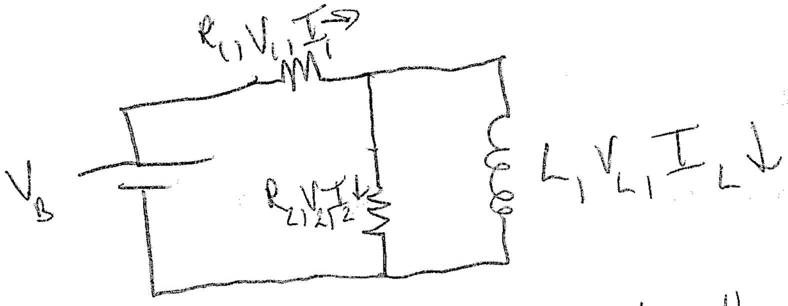


$$r = \frac{d}{\sqrt{3}}$$

$$\vec{B}_{at\ center} = \frac{\mu_0 I}{2\pi r}\left[(\cos 60° + \cos 60° + 1)\,\hat{x} + (\cancel{\sin 60°} - \cancel{\sin 60°} + 0)\,\hat{y}\right]$$

$$= \frac{\mu_0 I}{\cancel{2}\pi\left(\frac{d}{\sqrt{3}}\right)}[\cancel{2}]\,\hat{x} = \boxed{0.0412\ T\ \hat{x}}$$

2)



By kirchoff's node rule, at all times:

(1) $I_1 = I_2 + I_L$

By kirchoff's loop rule, at all times

(2) $V_B = V_1 + V_2 = I_1 R_1 + I_2 R_2$

(3) $V_B = V_1 + V_L = I_1 R_1 + L\dfrac{dI_L}{dt}$

(4) $V_L = V_2 \Rightarrow L\dfrac{dI_L}{dt} = I_2 R_2$

(Note: 2, 3, and 4 are not independent equs)

a) Immediately after switch is closed $I_L = 0$
(current through inductor is continuous)

$\Rightarrow$ by (1) $I_1 = I_2$

$\Rightarrow$ by (2) $30\,V = I_1 \cdot R_1 + I_1 \cdot R_2 \Rightarrow 30\,V = I_1 (10\Omega + 20\Omega)$

$\Rightarrow I_1 = I_2 = \boxed{1\,A}$ (downward through $20\,\Omega$ resistor)

b) After a long time $\dfrac{dI_L}{dt} = 0 \Rightarrow V_L = 0 \Rightarrow$ by (4) $V_2 = 0 \Rightarrow \boxed{I_2 = 0}$

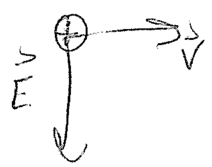
c) After a long time $V_L = 0$ (as above) $\Rightarrow$ by (3) $V_1 = V_B = 30\,V$
$\Rightarrow I_1 R_1 = 30\,V \Rightarrow I_1 = 3\,A$ (to the right) but $I_2 = 0 \Rightarrow I_1 = I_L \Rightarrow I_L = 3\,A$

2)c) (cont) But current through L is continuous

$\Rightarrow$ Immediately After re-opening $I_L = 3A$ and $I_1 = 0A$

$$\Rightarrow I_2 = -I_L = \boxed{-3A} \quad (\text{i.e. } I_2 = 3A \text{ upward})$$

3) a)



$$\vec{F}_{\text{on proton}} = q(\vec{E} + \vec{v} \times \vec{B})$$

We require $\vec{F}_{\text{on proton}} = \vec{0}$

$$\Rightarrow \vec{E} + \vec{v} \times \vec{B} = 0 \quad \Rightarrow \vec{v} \times \vec{B} = -\vec{E}$$

If we want $\vec{v} \times \vec{B}$ to point up with magnitude $|\vec{E}|$

we can make $\vec{B}$ $\boxed{\text{into the page}}$ with magnitude

$$\frac{|\vec{E}|}{|\vec{v}|} = \boxed{0.1\ T}$$

use r.h.r.

(note: We could also have given $\vec{B}$ whatever component to the left or right we wanted without affecting anything because the cross-product of $\vec{v}$ with these components is 0.

b) $\vec{E}' = \vec{E} + \vec{v} \times \vec{B} = \boxed{\vec{0}}$ (by construction of $\vec{B}$)

$$B' = \vec{B} - \frac{1}{c^2}\vec{v} \times \vec{E} = 0.1T \text{ into page} - (1.0 \cdot 10^5 \cdot 1.0 \cdot 10^6 / 9 \cdot 10^{16})\, T \text{ into the page}$$

$$= \boxed{(0.1 - 1.11 \cdot 10^{-6})\, T \text{ into the page}}$$