1. *A charge of* 2·0 μC *moves with a speed of* $2{\cdot}0 \times 10^{6}$ m s^{-1} *along the positive x-axis. A magnetic field* $\vec{B}$ *of strength* $(0{\cdot}20\,\vec{j} + 0{\cdot}40\,\vec{k})$T *exists in space. Find the magnetic force acting on the charge.*

$q = 2\times10^{-6}\,C$

$\vec{v} = 2\times10^{6}\,m/s\ \hat{i}$

$\vec{B} = (0.2\,\hat{j} + 0.4\,\hat{k})\,T$

$\vec{F_m} = \_\_\_\_$

$\vec{F_m} = q\,\bar{v}\times\bar{B}$

$$\bar{v}\times\bar{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2\times10^{6} & 0 & 0 \\ 0 & 0.2 & 0.4 \end{vmatrix}$$

$\bar{v}\times\vec{B} = \hat{i}\,(0-0) - \hat{j}\,(0.4\times2\times10^{6}) + \hat{k}\,(2\times10^{6}\times0.2-0)$

$\vec{v}\times\vec{B} = 0 + 0.8\times10^{6}(-\hat{j}) + (0.4\times10^{6})\,\hat{k}$

$\vec{F_m} = 2\times10^{-6}\left(0.8\times10^{6}(-\hat{j}) + 0.4\times10^{6}\,\hat{k}\right)$

$\vec{F_m} = \left(1.6\,(-\hat{j}) + 0.8\,\hat{k}\right)$ N. $\underline{\text{Ans}}$

$|\vec{F_m}| = \sqrt{(-1.6)^2 + (0.8)^2}$

$= \_\_\_\_\_\_\_\_$

$\vec{F_m} = q\,\vec{v}\times\vec{B}$

$\vec{F_m} = i\,\vec{l}\times\vec{B}$

$\vec{\tau} = \vec{\mu}\times\vec{B}$

$\vec{\mu} = N\,i\,\vec{A}$

2. *A wire is bent in the form of an equilateral triangle PQR of side* 10 cm *and carries a current of* 5·0 A. *It is placed in a magnetic field B of magnitude* 2·0 T *directed perpendicularly to the plane of the loop. Find the forces on the three sides of the triangle.*

Solution :

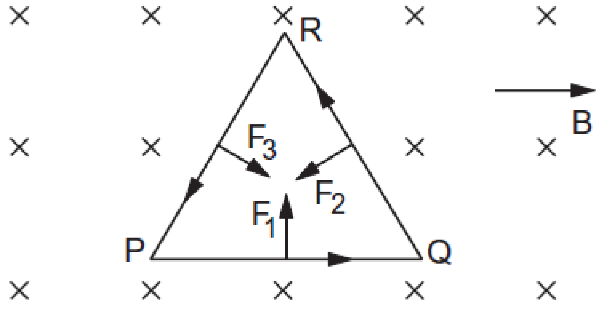


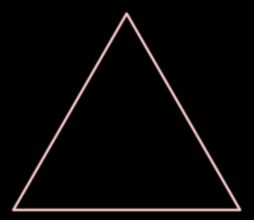
Figure 34-W1

$l = 10$ cm.

$i = 5$ A.

$B = 2.0$ T.

Forces on the sides:



$$\vec{F}_m = q\,\vec{v}\times\vec{B}$$

$$\vec{F}_m = i\,\vec{l}\times\vec{B}$$

$$\vec{\tau} = \vec{\mu}\times\vec{B}$$

$$\vec{\mu} = Ni\vec{A}.$$

$l_{eff} = 0$

$$\vec{F}_m = i\,\vec{l}\times\vec{B}$$

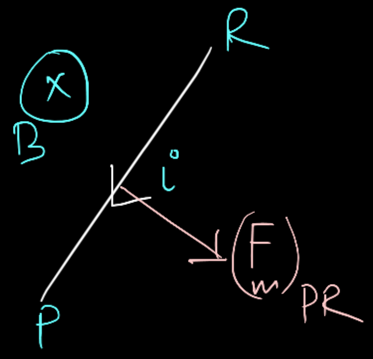
$$\vec{F}_m = i\,\vec{l}_{eff}\times\vec{B} = 0$$

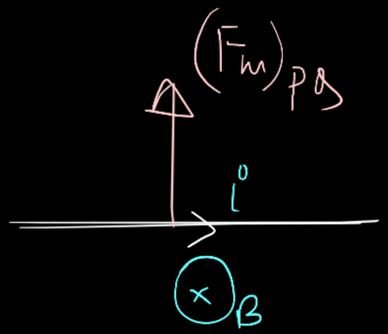
$\vec{l}_{eff} \to 0$

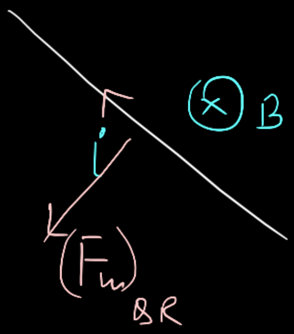
$$F_m = \cancel{(5)}\cancel{\left(\frac{1}{10}\right)}\cancel{(2)}\sin 90^\circ$$

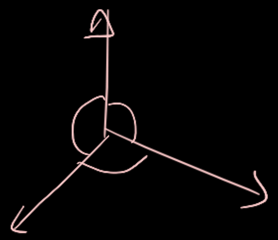
(F_m) acting on each segment

$= 1$ N.



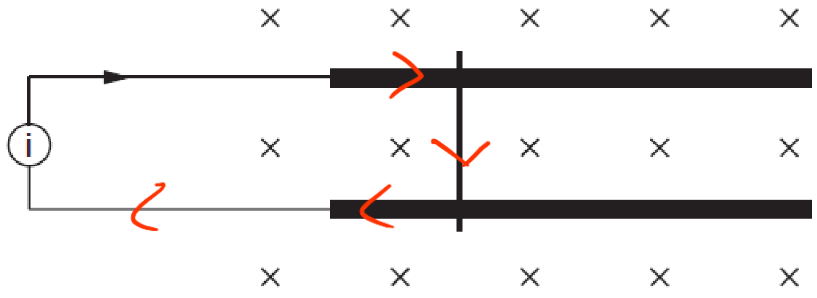




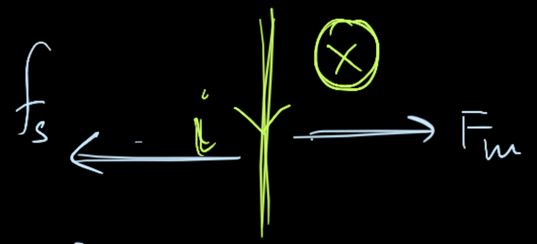


$\vec{F}_{net} = 0$

3. *Figure (34-W2) shows two long metal rails placed horizontally and parallel to each other at a separation l. A uniform magnetic field B exists in the vertically downward direction. A wire of mass m can slide on the rails. The rails are connected to a constant current source which drives a current i in the circuit. The friction coefficient between the rails and the wire is μ. (a) What should be the minimum value of μ which can prevent the wire from sliding on the rails? (b) Describe the motion of the wire if the value of μ is half the value found in the previous part.*



$$\vec{F}_m = q\,\vec{v}\times\vec{B}$$
$$\vec{F}_m = i\,\vec{l}\times\vec{B}$$
$$\vec{\tau} = \vec{\mu}\times\vec{B}$$
$$\vec{\mu} = N i \vec{A}$$



$$\vec{F}_m = i\,l(-\hat{j})\times B(-\hat{k})$$
$$= ilB\,(\hat{j}\times\hat{k})$$
$$= ilB\,(\hat{i})$$

$F_m = f_s$ for syst to be in eqb.

$$f_s = ilB$$
$$f_s \le (f_s)_{max}$$
$$ilB \le \mu mg$$
$$\frac{ilB}{mg} = \mu_{min}$$

(b)

$$F_m - f_k = ma$$
$$F_m - \frac{\mu_{min}}{2} mg = ma$$
$$ilB - \frac{ilB}{\cancel{mg}}\frac{\cancel{mg}}{2} = ma$$
$$\frac{ilB}{2} = ma$$
$$\boxed{a = \frac{ilB}{2m}}$$

4. *A proton, a deuteron and an alpha particle moving with equal kinetic energies enter perpendicularly into a magnetic field. If r_p, r_d and r_a are the respective radii of the circular paths, find the ratios r_p/r_d and r_p/r_a.*

Proton $\longrightarrow q_p, m_p$

deutron $\longrightarrow q_p, 2m_p$

α particle $\longrightarrow 2q \quad 4m_p$

$KE_p = KE_d = KE_\alpha = K_0$.

$r = \dfrac{(mv)}{qB}$

$r = \dfrac{P}{qB}$

$r = \dfrac{\sqrt{2mK}}{qB}$

$K = \dfrac{P^2}{2m}$

$\sqrt{2mK} = P$.

$\dfrac{r_p}{r_d} = \_\_\_\_$

$\dfrac{r_p}{r_\alpha} = \_\_\_\_$

$\dfrac{q_\alpha^2 r_\alpha^2}{m_\alpha} = \dfrac{q_p^2 r_p^2}{m_p}$

$\dfrac{\cancel{(2q_p)^2}(r_\alpha)^2}{\cancel{4m_p}} = \dfrac{\cancel{q_p^2} r_p^2}{\cancel{m_p}}$

$r_\alpha^2 = r_p^2 \Rightarrow \dfrac{r_p}{r_\alpha} = 1$ ✓

$r \propto \dfrac{\sqrt{m}}{q}$

$\dfrac{r_p q_p}{\sqrt{m_p}} = \dfrac{r_d q_d}{\sqrt{m_d}}$

$\dfrac{r_p \cancel{q_p}}{\sqrt{\cancel{m_p}}} = \dfrac{r_d \cdot \cancel{q_p}}{\sqrt{2\cancel{m_p}}}$

$r_p = \dfrac{r_d}{\sqrt{2}}$

$\dfrac{r_p}{r_d} = \dfrac{1}{\sqrt{2}}$

$K = \frac{1}{2}mv^2$

$K = \frac{1}{2}m\left(\dfrac{qBr}{m}\right)^2$

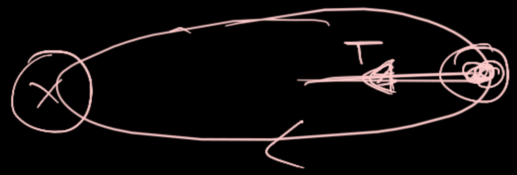
$K = \dfrac{q^2B^2r^2}{m^{\cancel{2}}} \times \dfrac{\cancel{m}}{2}$

$\text{const} = \dfrac{q^2 r^2}{m}$

$\dfrac{\cancel{q_p^2} r_p^2}{m_p} = \dfrac{\cancel{q_d^2} r_d^2}{m_d}$

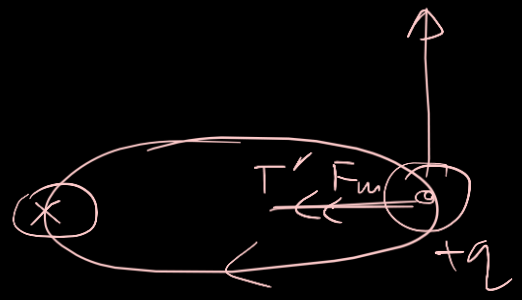
$\left(\dfrac{r_p}{r_d}\right)^2 = \dfrac{\cancel{m_p}}{2\cancel{m_p}}$

$\dfrac{r_p}{r_d} = \dfrac{1}{\sqrt{2}}$



x2 B=0

$T = \frac{mv^2}{r}$



x2

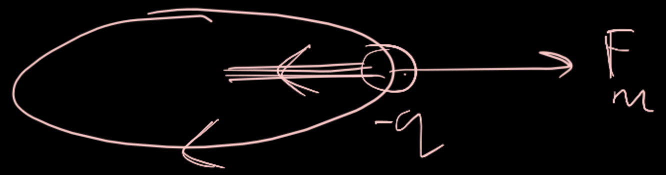
$T' + F_m = \frac{mv^2}{R}$

$T' = \frac{mv^2}{R} - F_m$

decre

$\bar{v} \times \bar{B} = v\hat{k} \times B\hat{j}$

$F_m = qvB(-\hat{i})$



q : negch

T: increases

$T - F_m = \frac{mv^2}{R}$

$T = \frac{mv^2}{R} + F_m$