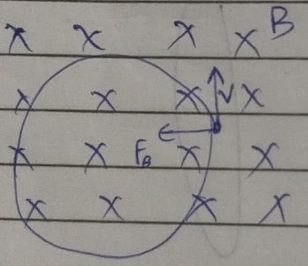
Stationary charges → E
Moving charges → B & E

$F_{mag} = Q(\vec{V} \times \vec{B})$

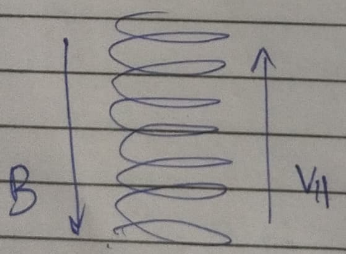
↳ magnetic force on charge Q moving with velocity in Field B

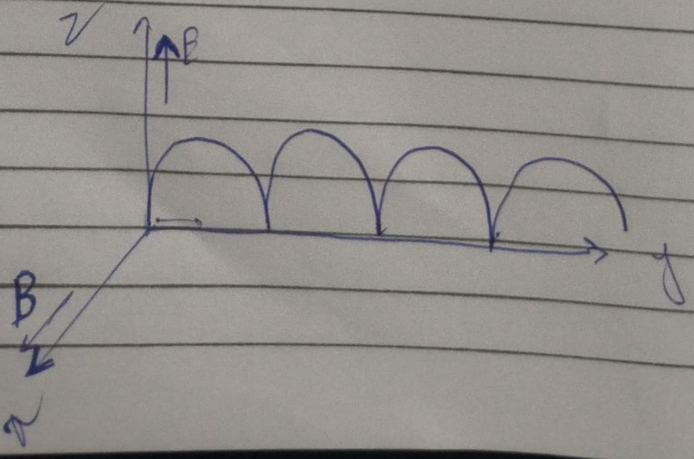
$$\boxed{F_{net} = Q(\vec{E} + \vec{V} \times \vec{B})}$$



$$QVB = \frac{mv^2}{R}$$

$$R = \frac{mV}{QB}$$



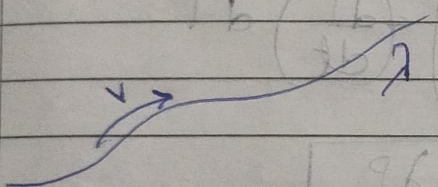


$$dW_{mag} = F_{mag} \cdot dl$$
$$= Q(\vec{v} \times \vec{B}) \cdot \vec{v}\, dt$$
$$= 0$$

$$\therefore \boxed{W_{mag} = 0}$$

Current

Charge per unit time passing at given point.



$$I = \lambda v$$

$$F_{mag} = \int (\vec{v} \times \vec{B})\, dq = \int (\vec{dl} \times \vec{B}) \frac{dq}{dt}$$

$$\boxed{F_{mag} = \int i\, (\vec{dl} \times \vec{B})}$$

$\bar{i}, \vec{dl}$ point in the same direct^n

When charge flows over a surface, we describe it by the surface current density K.

$$K = \frac{di}{dl_\perp}$$

$k \rightarrow$ current per unit width

$$\boxed{K = \sigma V}$$

$$F_{mag} = \int (V \times B)\, \sigma\, da$$

$$\therefore \boxed{F_{mag} = \int (K \times B)\, da}$$

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Date ______ Page ______

Volume current density

$J = \frac{di}{da_\perp}$

curr / Area

$\boxed{J = \rho V}$

$J = \int (\rho \times B)\, d\tau$

$I = \int_S J \cdot da = \int (\nabla \cdot J)\, d\tau$

$\int (\nabla \cdot J)\, d\tau = -\frac{d}{dt} \int \rho\, d\tau$

$= -\int \left(\frac{d\rho}{dt}\right) d\tau$

$\therefore \boxed{\nabla \cdot J = -\frac{\partial \rho}{\partial t}}$

$\rho \rightarrow$ Charge $\overset{\text{volm}}{\cdot}$ density

Dictionary

$\sum_{i=1}^{n} (\ ) q_i v_i \approx \int_{\text{line}} (\ ) I\, dl \approx \int_{\text{surface}} (\ ) K\, da \approx \int_{\text{volm}} (\ ) J\, d\tau$

Steady currents $\longrightarrow$ constant magnetic fields (magnetostatics

$$\therefore \frac{\partial \rho}{\partial t} = 0 \quad \& \quad \frac{\partial J}{\partial t} = 0$$

$\boxed{\nabla \cdot J = 0}$ for steady currents

$$\boxed{B(r) = \frac{\mu_0}{4\pi} i \int \frac{dl \times \hat{r}}{r^2}}$$

$dl \rightarrow$ along wire in direct^n of current

unit Tesla (T)

$\vec{r} \rightarrow$ point at which we want B

$$\boxed{B_\infty = \frac{\mu_0 i}{2\pi s}} \rightarrow$$ Due to ∞ length wire

$$f = \frac{\mu_0 i_1 i_2}{2\pi d}$$

force per unit length b/w two ∞ current carrying wires

$$B(r) = \frac{\mu_0}{4\pi} \int \frac{K \times \hat{r}}{r^2} da = \frac{\mu_0}{4\pi} \int \frac{J \times \hat{r}}{r^2} d\tau$$

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Date ______ Page ______

Divergence & curl of B

$$\boxed{\oint \vec{B}\cdot d\vec{l} = \mu_0 i_{encl}}$$

$$\boxed{i_{encl} = \int J \, da}$$

$$\oint B \cdot dl = \int (\nabla \times B) \, da = \mu_0 \int J \cdot da$$

$$\therefore \boxed{\nabla \times B = \mu_0 J}$$

$$\boxed{\nabla \cdot B = 0}$$

Magnetic vector potential

$$\boxed{B = \nabla \times A}$$

$A \rightarrow$ vector potential

$$\boxed{\nabla \cdot A = 0}$$

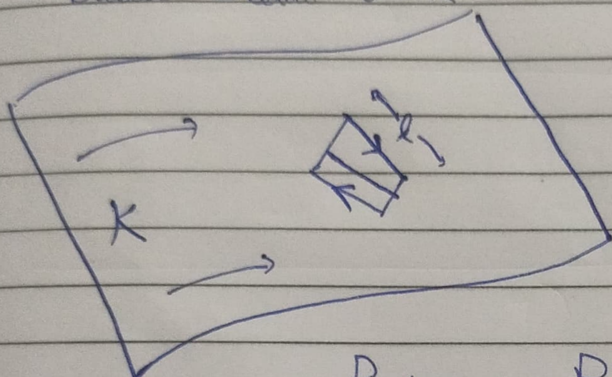
$$\boxed{\nabla^2 A = -\mu_0 J}$$

$$A(r) = \frac{\mu_0}{4\pi}\int \frac{J(r')}{r}\, d\tau' = \frac{\mu_0}{4\pi}\int \frac{K}{r}\, da'$$

$$= \frac{\mu_0 i}{4\pi}\int \frac{dl'}{r}$$

$$\oint B\cdot dl = \left(B^{\parallel}_{above} - B^{\parallel}_{below}\right) l = \mu_0 \underbrace{K l}_{I_{enc}}$$

$$\therefore B^{\parallel}_{above} - B^{\parallel}_{below} = \mu_0 K$$



since $B_{\perp}$ a $\oint B\cdot da = 0$

$$B^{\perp}_{above} = B^{\perp}_{below}$$

$$B_{above} - B_{below} = \mu_0 (K \times \hat{n})$$

$$A_{above} = A_{below}$$

$$\boxed{A_{dip}(r) = \frac{\mu_0}{4\pi}\frac{m \times \hat{r}}{r^2}}$$

$$\boxed{m = I\int da = Ia}$$

Magnetic dipole moment