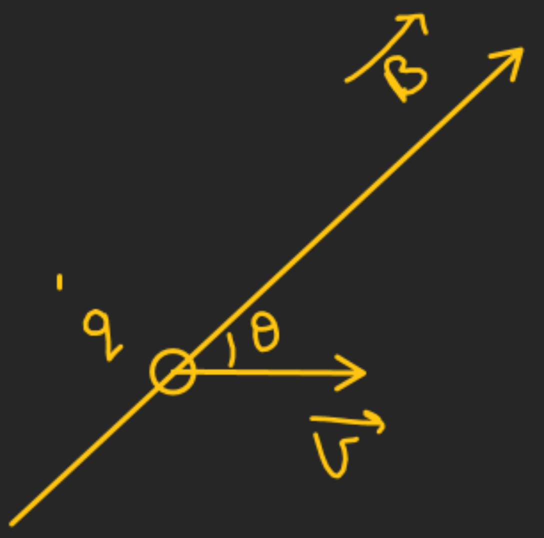
Nishant Jindal

MAGNETIC FIELD

Motion of charge particle in a magnetic field

(A) Force acting on a Charge particle place in a Uniform Magnetic field :-

$$\boxed{\vec{F} = q(\vec{v} \times \vec{B})}$$ **



$$|\vec{F}| = [qvB\sin\theta]$$

θ = Angle b/w ($\vec{B}$ & $\vec{v}$)

Direction of $\vec{F}$:- Always perpendicular to the plane Containing both $\vec{v}$ & $\vec{B}$.

Note.

For e⁻.

$$\vec{F} = -q(\vec{v} \times \vec{B})$$

Direction of Magnetic force is opposite w.r.t +ve Charge direction

Magnetic field.

↳ Influence of a moving Charge.

+q → v = c → Electric field; Magnetic field.

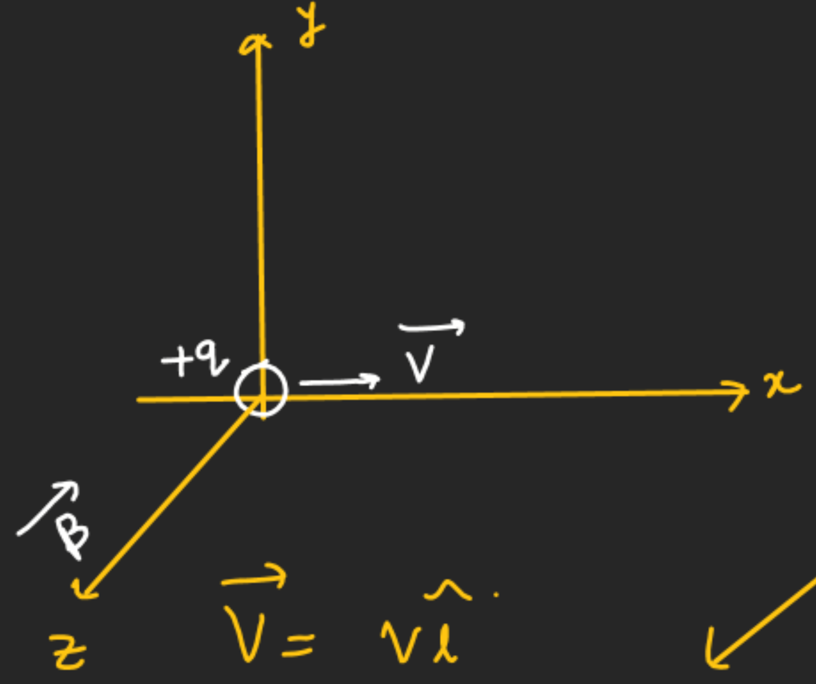
+q → a = c → Electric field.; Magnetic field.; Electromagnetic radiation

--→ Constant

Nishant Jindal

MAGNETIC FIELD

Motion of charge particle in a magnetic field



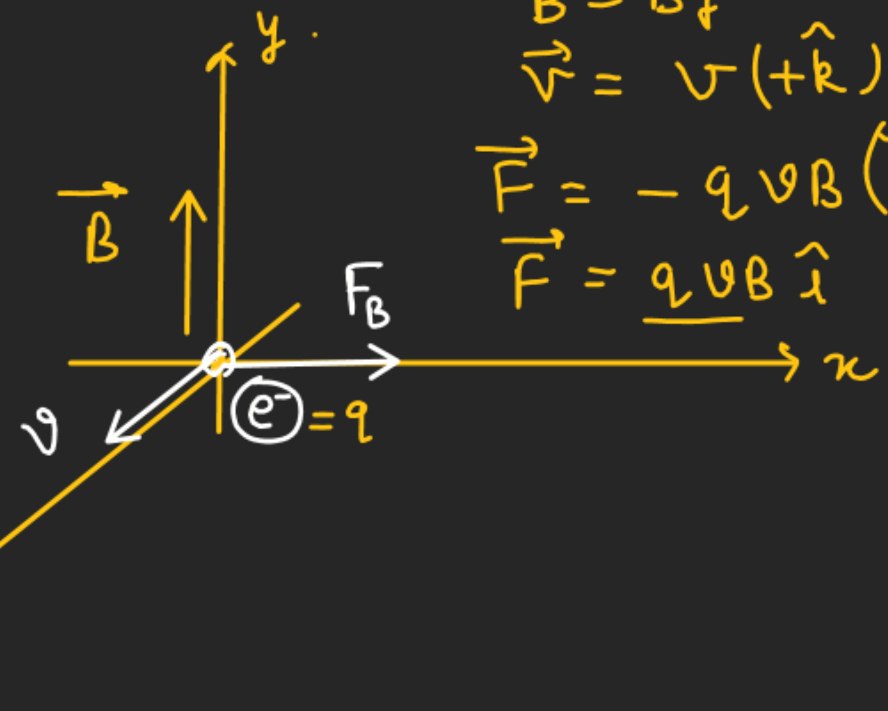
$$\vec{V} = v\hat{i}$$

$$\vec{B} = B\hat{k}$$

$$\vec{F} = q(\vec{v} \times \vec{B})$$

$$= qvB(\hat{i} \times \hat{k})$$

$$\vec{F} = (qvB)(-\hat{j})$$



$$\vec{B} = B\hat{j}$$

$$\vec{v} = v(+\hat{k})$$

$$\vec{F} = -qvB(\underbrace{\hat{k} \times \hat{j}}_{(-\hat{i})})$$

$$\vec{F} = qvB\,\hat{i}$$

Cross product

$$\vec{A} \times \vec{B} = [AB\sin\theta]\,\hat{n}$$

$\theta \rightarrow$ Angle b/w $\vec{A}$ & $\vec{B}$.

$$|\vec{A} \times \vec{B}| = \underbrace{AB\sin\theta}_{\text{Magnitude of } (\vec{A} \times \vec{B})}$$

$\hat{n}$ = Unit vector $\perp$ to the plane containing both $\vec{A}$ & $\vec{B}$.

Nishant Jindal

MAGNETIC FIELD

Motion of charge particle in a magnetic field

Ex:- $\vec{F} = 2\hat{i} + 3\hat{j} + 4\hat{k}$

$\vec{v} = -\hat{i} + \hat{j} + \hat{k}$

$\vec{F}$ is acting on a charge particle having magnitude 2C in a Uniform magnetic field. find $|\vec{B}| = ?$

Sol^n:→ let, $\vec{B} = B_x\hat{i} + B_y\hat{j} + B_z\hat{k}$

$$\vec{v}\times\vec{B} = \begin{array}{ccc} + & - & + \end{array}$$

$$\vec{v}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -1 & 1 & 1 \\ B_x & B_y & B_z \end{vmatrix}$$

$\vec{F} = q(\vec{v}\times\vec{B})$

$\vec{v}\times\vec{B} = \hat{i}(B_z - B_y) - \hat{j}(-B_z - B_x) + \hat{k}(-B_y - B_x)$

$2\hat{i} + 3\hat{j} + 4\hat{k} = \vec{F} = 2(B_z - B_y)\hat{i} + 2(B_z + B_x)\hat{j} - 2(B_y + B_x)\hat{k}$

$2(B_z - B_y) = 2 \Rightarrow B_z - B_y = 1$ — (1)

$2(B_z + B_x) = 3 \Rightarrow B_z + B_x = \frac{3}{2}$ — (2)

$-2(B_y + B_x) = 4$

$B_y + B_x = -2$ — (3)

$$\left\{\begin{array}{l} B_x = \\ B_y = \\ B_z = \end{array}\right\}$$

Nishant Jindal

MAGNETIC FIELD

Motion of charge particle in a magnetic field

4. Magnetic force

↳ It change the direction of charge particle not the speed of the charge particle.

as it always acts perpendicular to $\vec{v}$ so it doesn't perform any work. So kinetic energy of charge particle remain same.

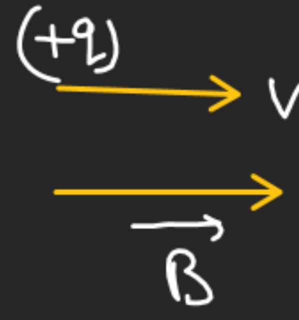
$(F_B)_{max} = ??$

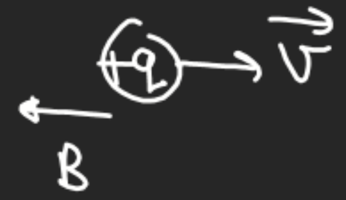
$\vec{v} \perp \vec{B}$

$F_B = qvB\sin\theta$

$\boxed{(F_B)_{max} = qvB}$ $\theta = 90^\circ$

$(F_B)_{min} = 0$ or $(\vec{v} \parallel \vec{B})$, $(\vec{v} \uparrow\downarrow \vec{B})$





↳ Undeviated.

Nishant Jindal

MAGNETIC FIELD

Motion of charge particle in a magnetic field

**

Case-1 $[\vec{v} \perp \vec{B}]$

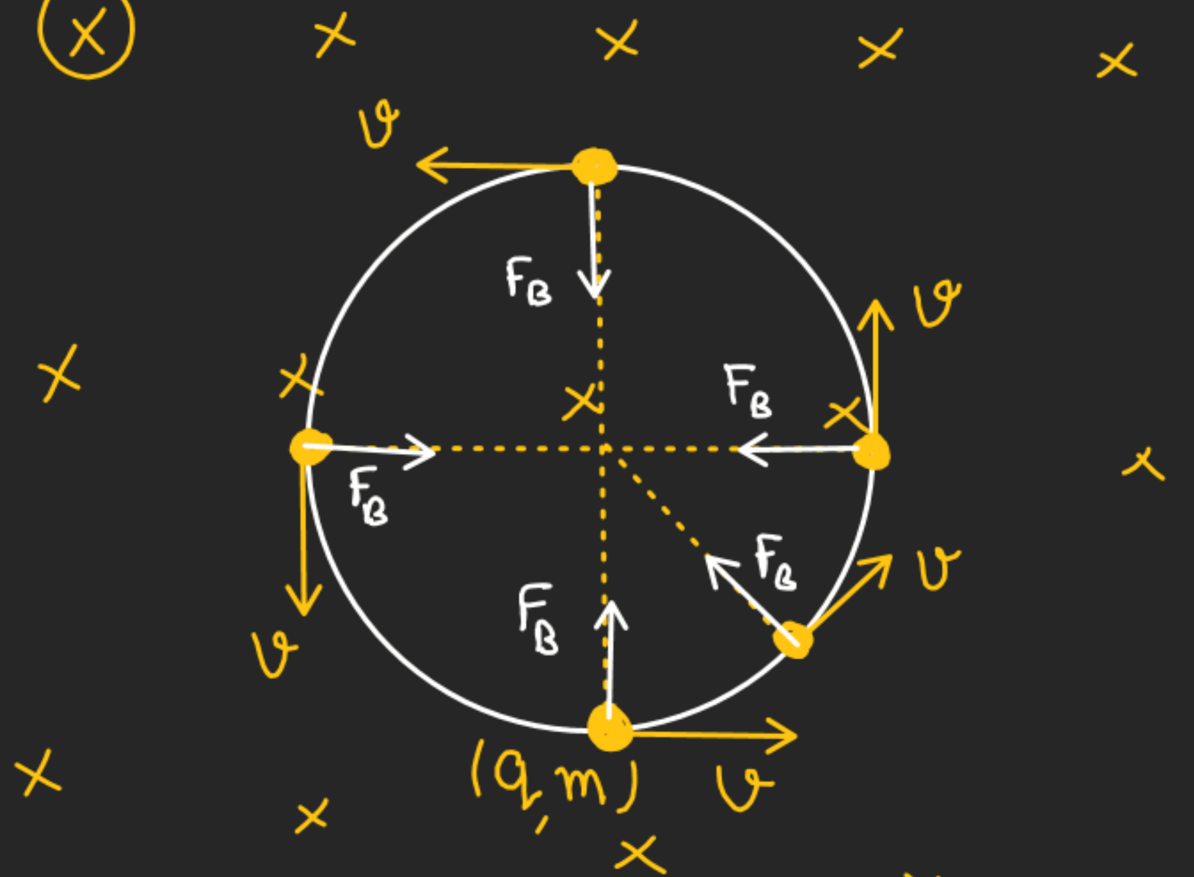
↳ Locus is a uniform Circular Motion.

ⓧ → ⊥ to plane and inward.

⊙ → ⊥ to plane and outward

$B \Rightarrow$ Uniform

ⓧ



$\Rightarrow$ F_B acts as a Centripetal force.

$$F_B = \frac{mv^2}{R} \qquad \left(\begin{matrix}\vec{v} \perp \vec{B} \\ \theta = 90°\end{matrix}\right)$$

$$\Downarrow$$

$$qvB = \frac{mv^2}{R} \Rightarrow \boxed{R = \frac{mv}{qB}} \quad **$$

$$T = \frac{2\pi R}{v}$$

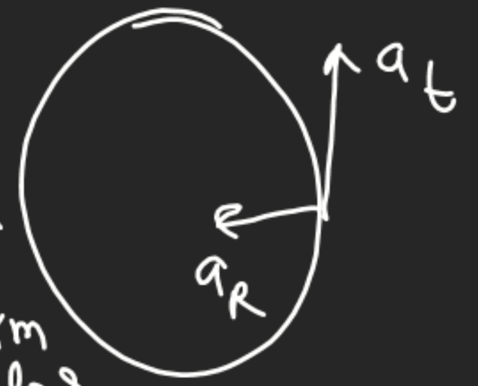
$$T = \frac{2\pi}{v} \times \frac{mv}{qB} \Rightarrow \boxed{T = \frac{2\pi m}{qB}} \quad **$$

$$a_t = \frac{d|v|}{dt}$$

$$a_R = \frac{v^2}{R} = \omega^2 R$$

If $a_t = 0$

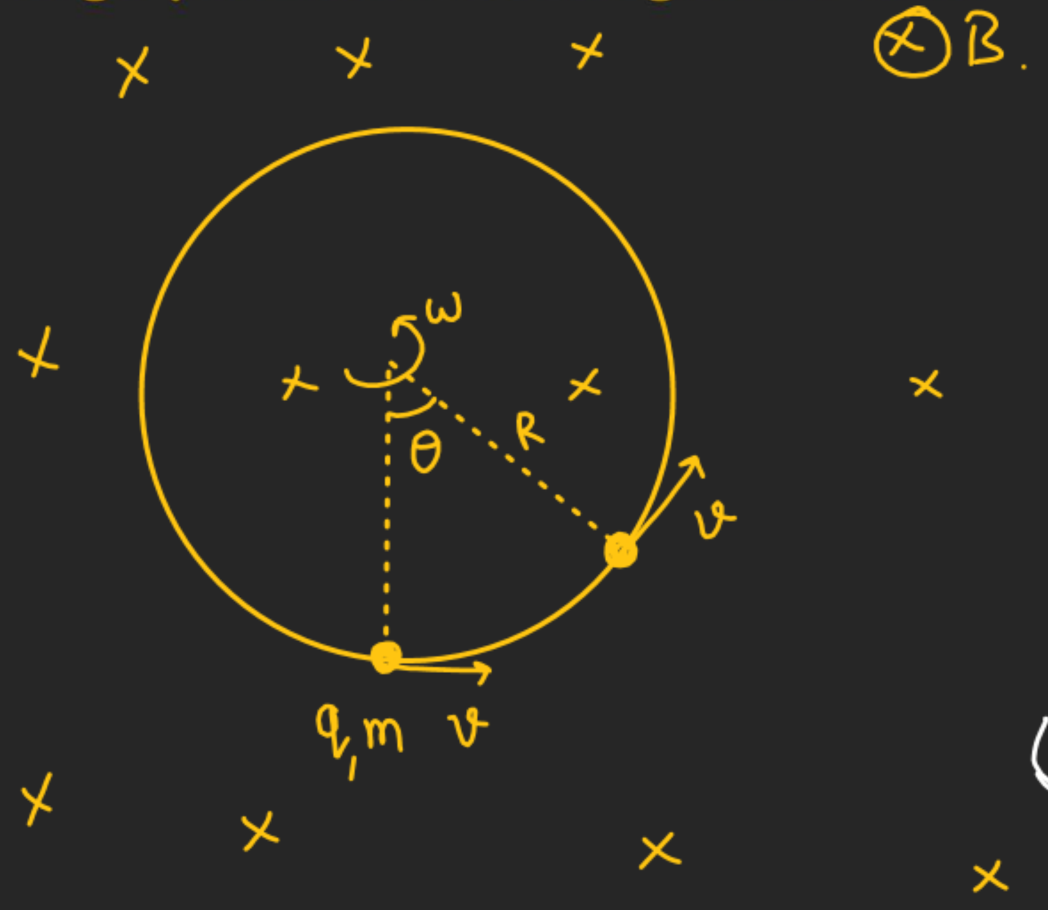
$a_R = \frac{v^2}{R} \Rightarrow$ Uniform circular Motion



Nishant Jindal

MAGNETIC FIELD

Motion of charge particle in a magnetic field



$$v = R\omega$$

$$\omega = \left(\frac{v}{R}\right)$$

$$\omega = \frac{2\pi}{T} = 2\pi f$$

$$f = \frac{1}{T}$$

⇓

(frequency)

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{\left(\frac{2\pi m}{qB}\right)}$$

⇓

$$\boxed{\omega = \frac{qB}{m}}$$

$$\theta = \omega t$$

$$\boxed{\theta = \frac{qB}{m}t}$$

Nishant Jindal

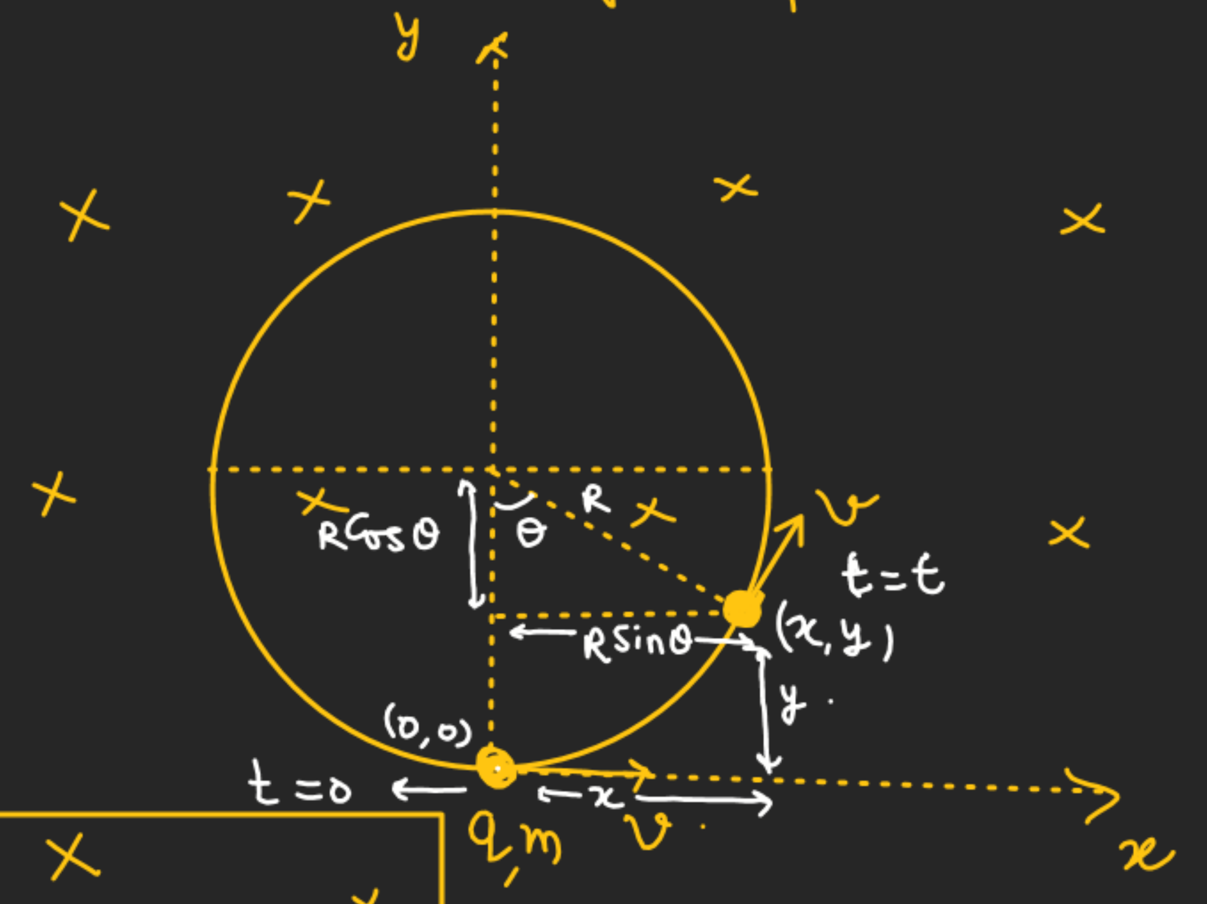
MAGNETIC FIELD

Motion of charge particle in a magnetic field

(*) general velocity vector and position vector of the charged particle when $\vec{v} \perp \vec{B}$.

$$R = \left(\frac{mv}{qB}\right)$$

$$\theta = \omega t = \left(\frac{qB}{m}t\right)$$



$$x = R\sin\theta$$

$$x = \frac{mv}{qB}\sin\omega t$$

$$x = \frac{mv}{qB}\sin\left(\frac{qB}{m}t\right)$$

$$Y = R(1-\cos\theta) = \frac{mv}{qB}\left[1-\cos\left(\frac{qB}{m}\right)t\right]$$

$$\boxed{\vec{r} = x\hat{i} + Y\hat{j} = \frac{mv}{qB}\left[\sin\left(\frac{qB}{m}t\right)\hat{i} + \left(1-\cos\frac{qB}{m}t\right)\hat{j}\right]}$$

Nishant Jindal

general velocity vector

$\theta = \omega t$

$\theta = \frac{qB}{m} t$

$$\vec{v} = v\cos\theta\,\hat{i} + v\sin\theta\,\hat{j}$$

$$\vec{v} = v\cos\left(\frac{qB}{m}t\right)\hat{i} + v\sin\left(\frac{qB}{m}t\right)\hat{j}$$

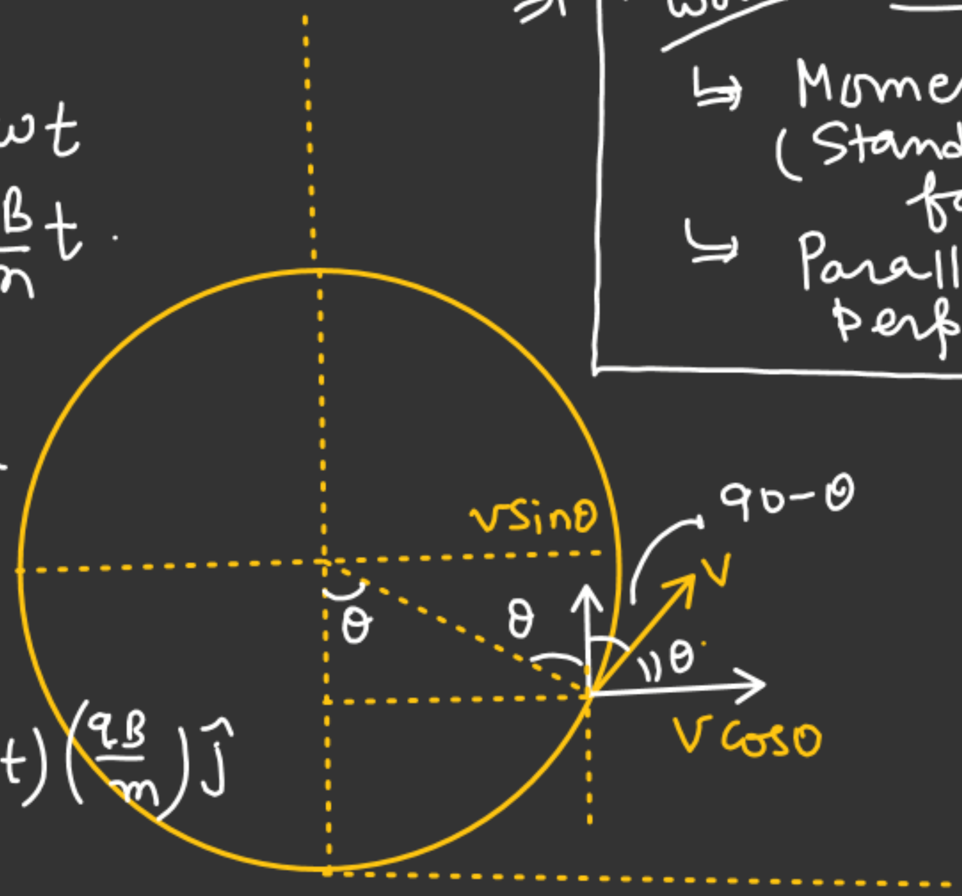
$$\vec{a} = \frac{d\vec{v}}{dt} = -v\sin\left(\frac{qB}{m}t\right)\left(\frac{qB}{m}\right)\hat{i} + v\cos\left(\frac{qB}{m}t\right)\left(\frac{qB}{m}\right)\hat{j}$$

$\omega = v/R$

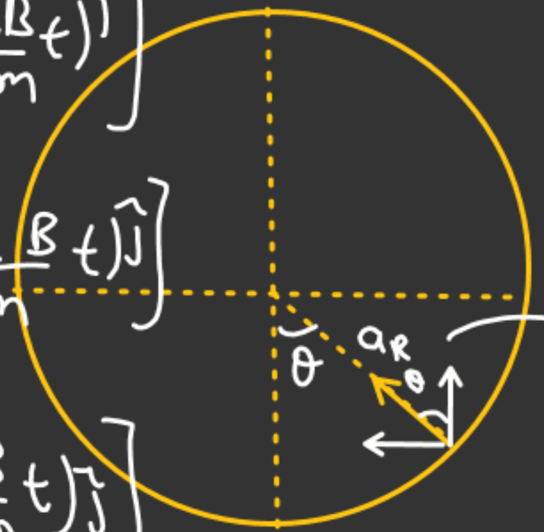
$$\vec{a} = \left(v\times\left(\frac{qB}{m}\right)\right)\left[-\sin\left(\frac{qB}{m}t\right)\hat{i} + \cos\left(\frac{qB}{m}t\right)\hat{j}\right]$$

$$\vec{a} = v\times\frac{v}{R}\left[-\sin\left(\frac{qB}{m}t\right)\hat{i} + \cos\left(\frac{qB}{m}t\right)\hat{j}\right]$$

$$\vec{a} = \left(\frac{v^2}{R}\right)\left[-\sin\left(\frac{qB}{m}t\right)\hat{i} + \cos\left(\frac{qB}{m}t\right)\hat{j}\right]$$



→ Home work
↳ Torque
↳ Moment of Inertia (Standard body formula)
↳ Parallel axis and perpendicula axis



$a_R = a_{net} = \omega^2 R = v^2/R$

$a_R = -a_R\sin\theta\,\hat{i} + a_R\cos\theta\,\hat{j}$

$$a_R = \frac{v^2}{R}\left[-\sin\left(\frac{qB}{m}t\right)\hat{i} + \cos\left(\frac{qB}{m}t\right)\hat{j}\right]$$