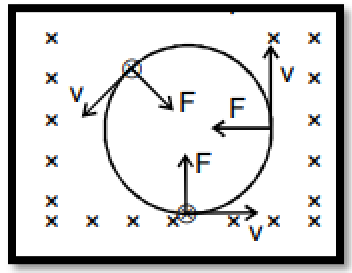
MOVING CHARGES AND MAGNETISM

MOTION IN A MAGNETIC FIELD

MOTION OF A CHARGED PARTICLE IN A UNIFORM MAGNETIC FIELD.

WHEN THE CHARGED PARTICLE IS GIVEN VELOCITY PERPENDICULAR TO THE FIELD



Let a particle of charged q and mass m is moving with a velocity v and enters at right angles to a uniform magnetic field $\vec{B}$ as shown in figure.

The force on the particle is qvB and this force will always act in a direction perpendicular to v. Hence, the particle will move on a circular path. If the radius of the path is r then

$$\frac{mv^2}{r} = Bqv \text{ or } r\frac{mv}{qB}$$

Thus, radius of the path is proportional to the momentum mv of the particle and inversely proportional to the magnitude of magnetic field.

Time period: The time period is the time taken by the charged particle to complete one rotation of the circular path which is given by,

$$T = \frac{2\pi r}{v} = \frac{2\pi m}{qB}$$

The time period is independent of the speed v.

Frequency: The frequency is number of revolutions of charged particle in one second, which is given by,

$$v = \frac{1}{T} = \frac{qB}{2\pi m}$$

And angular frequency $= \omega = 2\pi\nu$

Ex. A proton (p), α - particle and deuteron (D) are moving in circular paths with same kinetic energies in the same magnetic field. Find the ratio of their radii and time periods. (Neglect interaction between particles).

Sol.

$$R = \frac{\sqrt{2mk}}{qB}$$

$$R_p : R_a : R_D = \frac{\sqrt{2mk}}{qB} : \frac{\sqrt{2.4mk}}{qB} : \frac{\sqrt{2.2mk}}{qB}$$

$$1 : 1 : \sqrt{2}$$

$$T = 2\pi m / qB$$

$$T_p : T_a : T_D = \frac{2\pi m}{qB} : \frac{2\pi 4m}{2qB} : \frac{2\pi 2m}{qB}$$

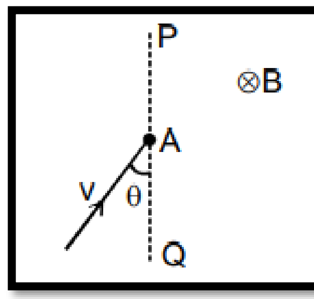
$$= 1 : 2 : 2 \text{ Ans}$$

Ex. A positive charge particle of charge q, mass m enters into a uniform magnetic field with velocity v as shown in the figure. There is no magnetic field to the left of PQ. Find

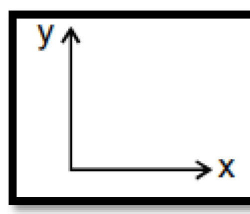
(i) time spent,

(ii) distance travelled in the magnetic field

(iii) Impulse of magnetic force.



Sol. The particle will move in the field as shown. Angle subtended by the arc at the center $= 2\theta$

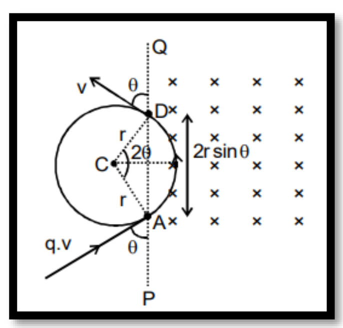


(i) Time spent by the charge in magnetic field

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

(ii) Distance travelled by the charge in magnetic field :

$$r(2\theta) = \frac{mv}{qB} \cdot 2\theta$$

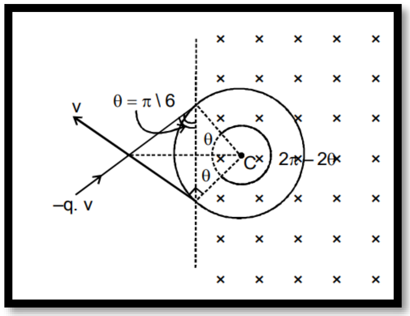


(iii) Impulse = change in momentum of the charge

$$(-mv\sin\theta \hat{i} + mv\cos\theta \hat{j})$$

$$-(mv\sin\theta \hat{i} + mv\cos\theta \vec{j}) = -2mv\sin\theta \hat{i}$$

Ex. Repeat above question if the charge is -ve and the angle made by the boundary with the velocity is $\frac{\pi}{6}$



Sol. (i) $2\pi - 2\theta = 2\pi - 2\cdot\frac{\pi}{6} = 2\pi - \frac{\pi}{3} = \frac{5\pi}{3}$

$$\omega t = \frac{qBt}{m} \Rightarrow t = \frac{5\pi m}{3qB}$$

(ii) Distance travelled $s = r(2\pi - 2\theta) = \frac{5\pi r}{3}$

(iii) Impulse = charge in linear momentum

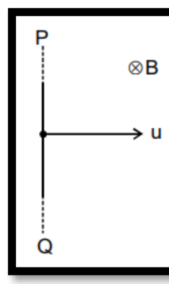
$$= m(-v\sin\theta\hat{i} + v\cos\theta\hat{j})$$

$$-m(v\sin\theta\hat{i} + v\cos\theta\hat{j})$$

$$-2mv\sin\theta\hat{i} = -2mv\sin\frac{\pi}{6}\hat{i} = -mv\hat{i}$$

Ex. In the figure shown the magnetic field on the left on PQ is zero and on the right of PQ it is uniform.

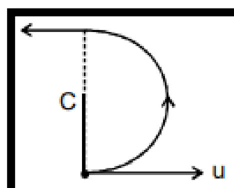
Find the time spent in the magnetic field.



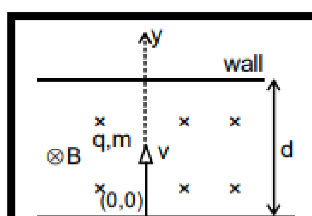
Sol. The path will be semicircular

Time spent

$$= T/2 = \pi m/qB$$

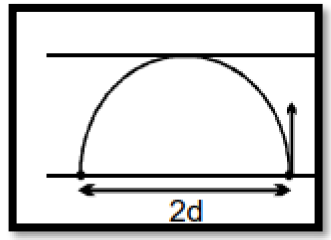


Ex. What should be the speed of charged particle so that it canít collide with the upper wall? Also find the coordinate of the point where the particle strikes the lower plate in the limiting case of velocity.



Sol. (i) The path of the particle will be circular larger the velocity, larger will be the radius.

For particle not to s strike R < d



$$\frac{mu}{qB} \leq d$$

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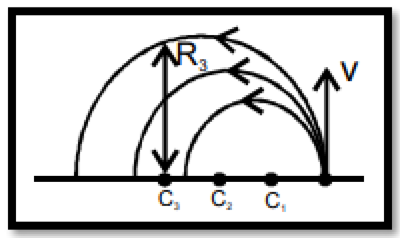
$$v \leq \frac{qBd}{m}$$

(ii) For limiting case



$$v = \frac{qBd}{m}$$

R = d

Coordinate = (-2d, 0, 0)