part 2

Motion of a charged particle in a Uniform Magnetic Field

when a charged particle of charge q and mass m enters a region of magnetic field force is perpendicular to both the velocity and the magnetic field The charge moves in a circular path.

The magnetic force $\vec{F_B}$ acting on the charge is always directed toward the center of the circle

when the velocity of a charged particle is perpendicular to a uniform magnetic field the particle moves in a circular path in a plane perpendicular to $\vec{B}$.

Applying Newton's second law:

$$\sum F_c = F_B$$

$$m a_c = \sum F$$

$$\rightarrow m a_c = \sum F_B$$

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

$$r = \frac{mv}{qB}$$

$$\omega = \frac{v}{r}$$

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

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

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

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

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

$$f = \frac{qB}{2\pi m}$$

F_c : centerpetal force (N)
a_c : centerpetal acceleration m/s^2
m : mass (kg)
q : charge (C)
v : speed (m/s)
B : magnetic field (T)
r : radius of the circular path (m)
ω : angular speed (rad/sec)
T : period of circular path (sec)

Ex (29.2) A proton is moving in a circular orbit of radius 14 cm in a Uniform 0.35 T magnetic field perpendicular to the velocity of the proton.

(a) Find the speed of the proton

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

$$= \frac{1.6\times10^{-19}\times0.35\times0.14}{1.67\times10^{-27}}$$

$$= 4.7\times10^{6}\ m/s$$

(b) Find the angular frequency (ω)

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

$$= \frac{1.6\times10^{-19}\times0.35}{1.67\times10^{-27}}$$

$$= 33.5\times10^{6}\ rad/sec$$

(c) magnetic Force

$$F_B = qvB\sin\theta$$

$$= 1.6\times10^{-19}\times4.7\times10^{6}\times0.35\times1$$

$$= 2.63\times10^{-13}\ N$$

(d) frequency (f)

$$f = \frac{qB}{2\pi m}$$

$$= \frac{1.6 \times 10^{-19} \times 0.35}{2 \times 3.14 \times 1.67 \times 10^{-27}}$$

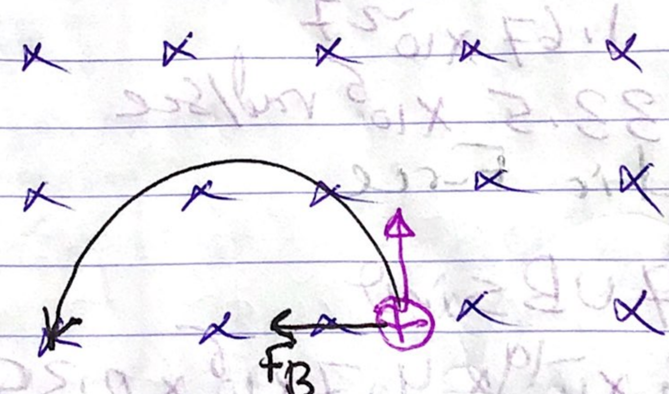
$$= 5.34 \times 10^{6} \text{ Hz}$$

(e) Period (T)

$$T = \frac{1}{f} = \frac{1}{5.34 \times 10^{6}}$$

$$= 1.87 \times 10^{-7} \text{ sec}$$

(f) Draw the direction of motion of q



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EXP (29.3) Bending an Electron Beam

In an experiment designed to measure the magnitude of a uniform magnetic field, electrons are accelerated from rest through a potential difference of 350 volt and then enter a uniform magnetic field that is perpendicular to the velocity vector of the electrons. The electrons travel along a curved path because of the magnetic force exerted on them and the radius of the path is measured to be 7.5 cm

(a) what is the magnitude of the magnetic field?

$\Delta K + \Delta U = 0$

$\left(\frac{1}{2} m v^2 - 0\right) + q \Delta V = 0$

$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 - 1.6 \times 10^{-19} \times 350 = 0$

$v = 1.11 \times 10^{7}$ m/s

$r = \frac{mv}{qB}$

$B = \frac{mv}{qr} = \frac{9.11 \times 10^{-31} \times 1.11 \times 10^{7}}{1.6 \times 10^{-19} \times 0.075}$

$= 8.4 \times 10^{-4}$ T

(B) what is the angular speed

$$\omega = \frac{v}{r}$$

$$= \frac{1.11 \times 10^{7}}{0.075}$$

$$= 148 \times 10^{6} \text{ rad/sec}$$

(C) frequency

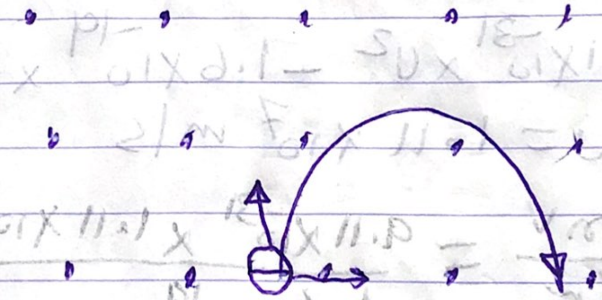
$$f = \frac{qB}{2\pi m}$$

$$= \frac{1.6 \times 10^{-19} \times 8.4 \times 10^{-4}}{2 \times 3.14 \times 9.11 \times 10^{-31}}$$

$$= 23.5 \times 10^{6} \text{ Hz}$$

(d)

draw the path of the electron



29.3 Applications Involving Charged Particles Moving in a Magnetic Field

A charge is moving with velocity v in space where an Electric Field E and a Magnetic Field B exist. The charge particle will experience two forces:

1- Electric Force given by

$$F_E = qE$$

2- Magnetic Force given by

$$F_B = qvB$$

The net force acting on the charge is called Lorentz Force

$$\vec{F_L} = \vec{F_E} + \vec{F_B}$$

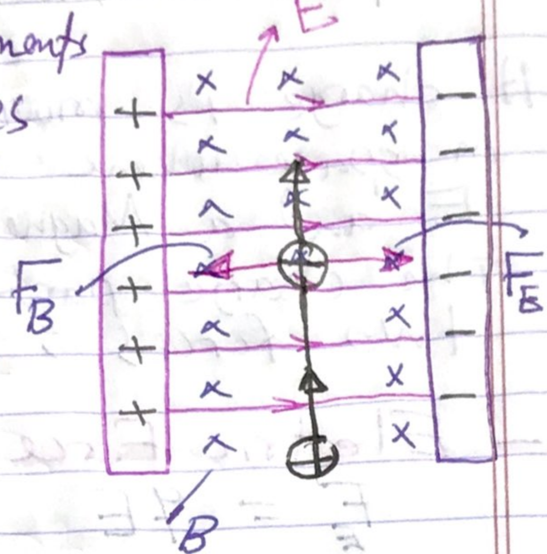
$$= q\vec{E} + q\vec{V} \times \vec{B}$$

$$\vec{F_L} = q(\vec{E} + \vec{v} \times \vec{B})$$

Applications → 1- Velocity Selector
2- The mass spectrometer
3- The cyclotron

1- Velocity selector

In some experiments charged particles are required to move with the same velocity



$|F_E| = |F_B|$

$qE = qVB$

or

$$V = \frac{E}{B}$$

A velocity selector when a positively charged particle is moving with velocity v in the presence of Electric field E and magnetic field B

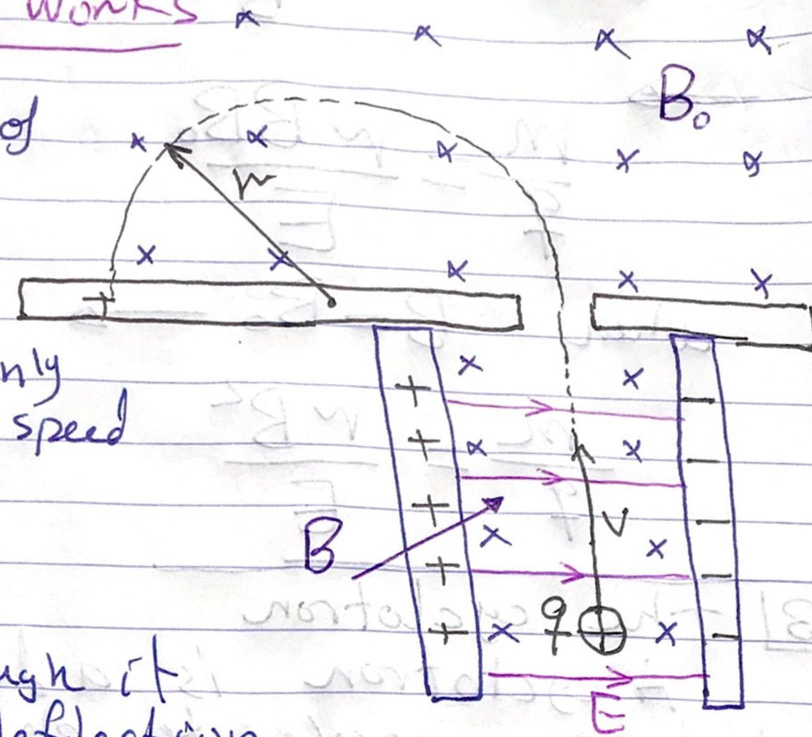
$\vec{F_E} = q\vec{E}$

$F_B = q\vec{V} \times \vec{B}$

2- The mass spectrometer

A mass spectrometer seperates ions According to their mass-to-charge ratio.

How it works



1- A beam of ion passes first through a velocity selector only ions with speed

$$V = \frac{E}{B}$$

passes through it without deflection

2- ions passes straight forward from the selector enters a region where magnetic field (B_0) that has the same direction as the field in the selector exists

3- since the ions enters B_0 they are moving in circular path

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

but $v = \frac{E}{B}$

$\longrightarrow$

$$\frac{m}{q} = \frac{rBB_o}{E}$$

when $B = B_o \longrightarrow$

$$\frac{m}{q} = \frac{rB^2}{E}$$

3] The cyclotron

A cyclotron is a device that can accelerate charged particles to very high speeds used to bombard atomic nuclei to produce nuclear reactions.

Kinetic Energy of accelerated particles

$K = \frac{1}{2}mv^2$, $v = \frac{qBr}{m}$

$$K = \frac{q^2B^2r^2}{2m}$$