MOTION OF ELECTRONS IN A MAGNETIC FIELD :

Consider an electron is to be placed in the region of magnetic filed

Case.(i) :

If the electron is placed in uniform magnetic field with a zero initial velocity (electron is at rest position)

The magnetic force f_m acting on the e^- in uniform magnetic field is given by

$$f_m = eBv\sin\phi$$

Since the initial velocity is zero then $f_m = 0$ i.e., there is no effect of force on electron due to magnetic field.

Case(ii): If the electron is moving parallel to the direction of magnetic field intensity (along magnetic field intensity). The force f_m is given by

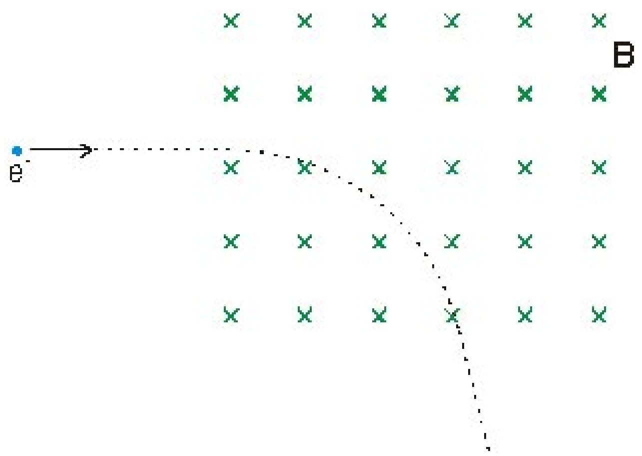
$$f_m = eBv\sin\phi$$

But $\phi = 0 \Rightarrow f_m = 0$

Again there is no effect of force on electron due to magnetic field.

Case(iii):

The electron is moving perpendicular to magnetic filed



Consider an electron enters the uniform magnetic no field region with initial vel. v_{ox}. the magnetic field is $\perp'r$ to plane of paper and it is directed outside of paper (towards reader). The resultant direction will be $\perp'r$ to both B and v. At every instant force is $\perp'r$ to v (direction of motion). Therefore there is no work done on electron. When there is no work done means kinetic energy is not changed so velocity is constant. Since (v and B are constant in magnitude and f_m is also constant magnitude and $\perp'r$ to direction of motion of electron. This type of force results an electron to move in circular path with constant speed.

The direction of magnitude force is acting towards the centre.

It is similar to stone tied to a thread move with a constant speed this force is known as centripetal force remains constant in magnitude and is always directed towards centre and is $\perp'r$ to direction of motion of mass/stone.

The magnitude force is same as centripetal force which always tries to push the electron in a circular path.

Radium of Circle :

As electron is moving in a circular path with a constant speed 'v' and force always directed towards the centre of circle.

$$centripetal\ \ force = \frac{mv^2}{R}$$

Where R is radius of circular path

$$\therefore \frac{mv^2}{R} = evB$$

$$\Rightarrow R = \frac{mv^2}{evB}$$

$$\boxed{R = \frac{mv}{eB}}$$

The angular velocity in $\frac{rad}{\sec} = \omega$

$$\omega = \frac{v}{R}$$
$$= \frac{eB}{m}$$

The time taken by an electron to complete one revolution is ‘T’

$$\omega = 2\pi n = \frac{2\pi}{T}$$
$$\Rightarrow \frac{eB}{m} = \frac{2\pi}{T}$$
$$\therefore T = \frac{2\pi m}{eB}$$

For electron $e = 1.6 \times 10^{-19}$

$$m = 9.1 \times 10^{-31}$$

$$\Rightarrow T = \frac{2\pi \times 9.1 \times 10 - 31}{1.6 \times 10^{-19} \times B}$$

$$= \frac{3.57 \times 10^{-11}}{B} \sec$$

$\therefore$ Radius of circular path is directly proportional to velocity of electron.

$$R \alpha v$$

The faster moving electrons will travels a larges circles in the same time let us slower particles moves a small circle.

Problem :

1. In a fixed CRT has a final anode voltage of 600V. The deflection plates are 3.5cm long and 0.5cm apart. The screen is at a distance of 20cm from centre of plates. A voltage of 20V is applied to the deflection plates. Calculate

(i) vel. of e- on reaching the field

(ii) acceleration due to deflection field

(iii) Deflection produced on screen

(iv) Deflection sensitivity in cm/volt

Sol. Anode potential $V_a = 600V$

Distance between plates $d = 0.8cm$

Length of plates, $l = 3.5cm$

$$L = 20cm$$

Potential difference between plates, $V_d = 20V$

(i) vel. of e^- on reaching field $v_{0x} = \sqrt{\frac{2eV_a}{m}}$

$$= \sqrt{\frac{2\times1.6\times10^{-19}\times600}{9.1\times10^{-31}}}$$

$$= 5.93\sqrt{V} \times 10^5$$
$$= 5.93 \times 24.49 \times 10^5$$
$$= 145.25 \times 10^5 \, m/s$$

(ii) $a_y = \dfrac{eV_d}{md} = \dfrac{1.6 \times 10^{-19} \times 20}{9.1 \times 10^{-31} \times 0.8}$

$$= 4.3 \times 10^{12} \, cm/\sec$$

(iii) $D = \dfrac{lLV_d}{2dV_a} = \dfrac{3.5 \times 20 \times 20}{2 \times 0.8 \times 600}$

$$= \frac{3.5}{2.4}$$
$$= 1.45 cm/\sec$$

(iv) Deflection sesitivity $S_E = \dfrac{lL}{2dV_a}$

$$= \frac{D}{V_d}$$
$$= \frac{1.45}{20}$$
$$= 0.0729 cm/volt$$

Current density (J) :

It is defined as current per unit area of conducting medium. Assuming uniform current distribution.

$$J = \frac{I}{A} \qquad - \qquad (1)$$

Where J is $\dfrac{Amp}{m^2}$

A is cross-sectional area in m^2

I is current in amp.

But $I = \frac{Ne}{T}$

Substitute $I = \frac{Ne}{T}$ in eq (1)

$$J = \frac{Ne}{AT} \qquad - \qquad (2)$$

Velocity $v = \frac{L}{T} = \frac{distance}{time}$

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

Substitute $T = \frac{1}{v}$ in eq(2)

$$J = \frac{Ne}{A}\frac{v}{L}$$

$$= \frac{Nev}{AL}$$

Where LA is volume of conductor

Electrons concentration $= n = \frac{N}{LA}$ (electrons/m^3)

$$J = Nev$$

Volume charge density $e_v = ne$ (coulomb/m^3)

$$J = e_v v$$