An electron emitted by a heated cathode and accelerated through a potential difference of 2.0 kV, enters a region with uniform magnetic field of 0.15 T. Determine the trajectory of the electron if the field (a) is transverse to its initial velocity, (b) makes an angle of 30° with the initial velocity.

Magnetic field strength, B = 0.15 T

Charge on the electron, $e = 1.6 \times 10^{-19}$ C

Mass of the electron, $m = 9.1 \times 10^{-31}$ kg

Potential difference, $V = 2.0\ \text{kV} = 2 \times 10^3$ V

Thus, kinetic energy of the electron = eV

$$\Rightarrow eV = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2eV}{m}} \quad \text{... (1)}$$

Where,

v = velocity of the electron

(a) Magnetic force on the electron provides the required centripetal force of the electron.

Hence, the electr a circular path of radius r.

Magnetic force ron is given by the relation,

B ev

Centripetal force $= \frac{mv^2}{r}$

$$\therefore Bev = \frac{mv^2}{r}$$

$$r = \frac{mv}{Be} \quad \text{... (2)}$$

From equations (1) and (2), we get

$$r = \frac{m}{Be}\left[\frac{2eV}{m}\right]^{\frac{1}{2}}$$

$$= \frac{9.1 \times 10^{-31}}{0.15 \times 1.6 \times 10^{-19}} \times \left(\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^3}{9.1 \times 10^{-31}}\right)^{\frac{1}{2}}$$

$$= 100.55 \times 10^{-5}$$

$$= 1.01 \times 10^{-3}\ \text{m}$$

$$= 1\ \text{mm}$$

Hence, the electron has a circular trajectory of radius 1.0 mm normal to the magnetic field.

(b) When the field makes an angle θ of 30° with initial velocity, the initial velocity will be,

$$v_1 = v \sin\theta$$

From equation (2), we can write the expression for new radius as:

$$r_1 = \frac{mv_1}{Be}$$

$$= \frac{mv\sin\theta}{Be}$$

$$= \frac{9.1 \times 10^{-31}}{0.15 \times 1.6 \times 10^{-19}} \times \left[\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^3}{9 \times 10^{-31}}\right]^{\frac{1}{2}} \times \sin 30°$$

$$= 0.5 \times 10^{-3}\ \text{m}$$

$$= 0.5\ \text{mm}$$