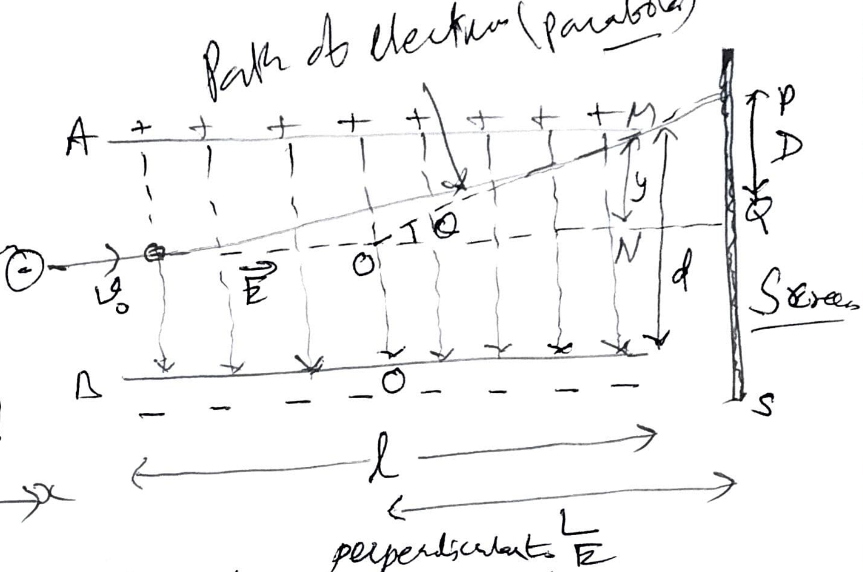
Electron motion in transverse uniform electric field

If size of plate is large in comparison to distance 'd' between them



The electric field (E) will be uniform

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

An electron with horizontal velocity v_{0x} enters along x-axis. The acting forces on the electron will be

$$\left.\begin{aligned} F_z &= m a_z = 0 \\ F_y &= m a_y \\ F_x &= m a_x = 0 \end{aligned}\right\} \quad \text{—— (1)}$$

The acting force will be only along (+) y direction and horizontal velocity v_0 is constant

$$v_x = v_0 \text{ (constant)}$$

The acceleration due to force in y-direction

$$a_y = \frac{F_y}{m} = \frac{eE}{m}$$

In 't' time, the velocity of electron in y-direction

$$v_y = a_y t \qquad \text{(initial velocity is zero)}$$

$$= \frac{F}{m} t$$

$$= \frac{eE}{m} t$$

In time interval (t) two kind of motion in electron will take place

(i) velocity v_0 in x direction

(ii) velocity v_y in y direction

After time 't' (i) displacement in x-direction

$$x = v_0 t \quad ---(i)$$

(ii) displacement in y direction

$$y = \frac{1}{2} a_y t^2$$

$$= \frac{1}{2} \frac{eE}{m} t^2 \quad ---(ii)$$

eliminating 't' from (i) & (ii)

$$y = \frac{eE}{2mv_0^2} x^2 \quad ---(2)$$

or $y = kx^2$ ---(2a)

here $k = \frac{2E}{2mv_0^2}$ = constant

Eqn (2a) represents a 'parabola'. If particle is positively charged the direction of y will be negative but path will be again parabola

velocity $v = \sqrt{v_x^2 + v_y^2}$ ---(3)

If we put a screen(s) on distance L from mid point O, electron hits on point P with flourscent.

PO line is tangent on the electron exit parabola path

$$\tan\theta = \frac{MN}{ON} = \frac{y}{ON}$$

$$\tan\theta = \frac{dy}{dx} = \frac{2eE}{2mv_0^2} x = \frac{eE}{mv_0^2} x \quad ---(4)$$

(on differentiating eqn (2))

$x = l$

$$\tan\theta = \frac{eEl}{mv_0^2} \quad ---(4a)$$

$ON = l/2$

From figure

$$PQ = QO \tan\alpha$$

or $D = L \tan\alpha$

from eq^n (4)

$$D = \frac{L e E l}{m v_0^2} \quad \text{---} (5)$$

If initially electron accelerates by potential V_a is E

$$\frac{1}{2} m v_0^2 = e V_a$$

$$\text{or} \quad v_0^2 = \frac{2 e V_a}{m}$$

in eq^n (5) v_0^2 and $E = \frac{V}{d}$

$$D = \frac{L l V}{2 d V_A} \quad \text{---} (6)$$

$$\text{or} \quad \frac{D}{V} = S = \frac{L l}{2 d V_A} \quad \text{---} (7)$$

here $\frac{D}{V} \rightarrow$ deflection sensitivity, represents deflection per unit volt on screen.

$$G = \frac{1}{S} = \frac{2 d V_A}{L l} \quad \text{---} (8)$$

deflection component

Motion of electron in Uniform Magnetic field

(8)

If an electron at rest in a magnetic field there is no force.
If electron moves in a magnetic field, there will be Lorentz force (F_L)

$$\vec{F}_L = (-)e(\vec{v} \times \vec{B}) \quad \text{---(1)}$$

$$|\vec{F}_L| = |evB \sin\theta| \quad \text{---(1a)}$$

direction of $\vec{F}_L$ is perpendicular to $\vec{v}$ and $\vec{B}$ plane. Lorentz force is always perpendicular to electron displacement → work done is zero

$$W = \vec{F} \cdot \vec{ds} = |F||ds| \cos\theta$$

here $\theta = 90^\circ$

This force does not change velocity of electron but only changes its direction.

Motion of electron in Longitudinal Magnetic field

If motion of electron, parallel to magnetic field

$\theta = 0^\circ$, or 180°

from eq^n (1a) Lorentz force

$$F_L = evB \sin 0^\circ = 0$$

or $$F_L = evB \sin 180^\circ = 0$$

Electron motion in a Transverse Uniform Magnetic field

force on electron

$$\vec{F}_L = (-)e(\vec{v} \times \vec{B}) \quad \text{---(2)}$$

$$|\vec{F}_L| = evB \quad \text{---(2a)}$$

angle between v and B is 90°