Tutorial - 1

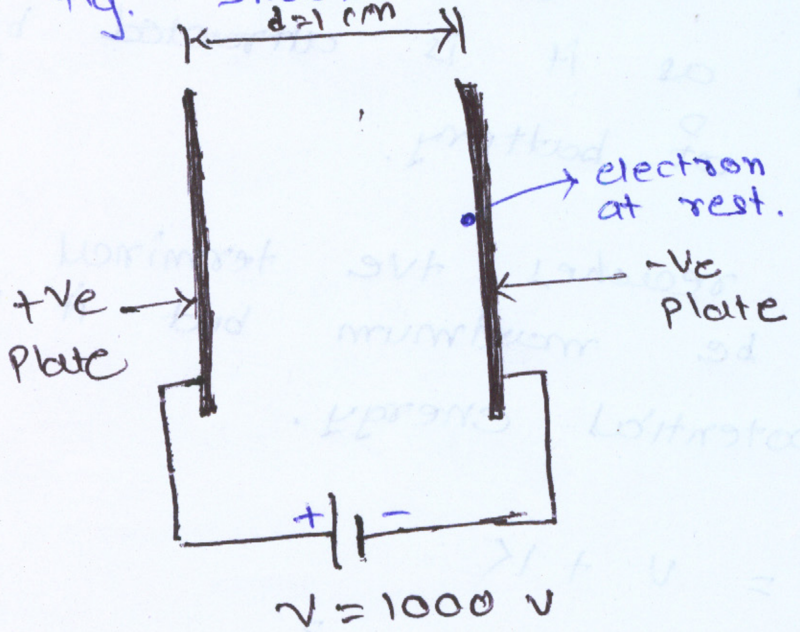
CH - 1 - Energy Bands in Solids.

1)
(a) The distance between the plates of a plane-parallel capacitor is 1 cm. An electron starts at rest at the negative plate. If a direct voltage of 1000 V is applied, How long it will take the electron to reach the opposite plate?

(b) What is the magnitude of force, which is exerted on the electron at the begining and at the end of its path?

(c) What is its final velocity?

Ans-)
→ The fig. shows the scenario.



→ As per given data, electron is at rest on negative plate so its initial speed $V_0 = 0$ and Potential energy is maximum

→ Hence, total energy at -ve plate

$$W = U + K \quad \text{—— (1)}$$

Here

$U = -qV$

$K = \frac{1}{2} m v_0^2 = 0$, bcz electron is at rest.

m = mass of electron.

→ So eq (1) reduces to

$$\therefore W = -qV \quad \text{—— (2)}$$

where

q = charge of e^-

V = Potential Applied

→ Now, after the application of 1000 V electron starts its a journey to +ve plate and Hence correspondingly it looses the potential energy and its speed will be increased as it is attracted by +ve charge of battery.

→ When it reaches +ve terminal its speed will be maximum but it looses all its potential energy.

$$\therefore W = U + K$$

$$\therefore W = K = \frac{1}{2} m v^2 \quad \text{—— (3)}$$

where

$U = 0$ (potential energy = 0)

v = Speed at +ve plate.

→ Total Energy Always remains constant. Hence equating eq 2 and 3.

$$\therefore -qV = \frac{1}{2} m v^2 \quad \text{———— (4)}$$

→ $$\therefore v^2 = \frac{-2qV}{m} \quad \text{———— (5)}$$

→ But velocity can't be -ve, but it indicates electron is travelling to the opposite direction ~~of~~ to the direction of applied field (field direction +ve to -re).

→ So eq 5 becomes

$$v = \sqrt{\frac{2qV}{m}}$$

$$\therefore v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 1000}{9.109 \times 10^{-31}}}$$

$$v = 18.74 \times 10^{6} \text{ m/s}$$

Ans-c $$\boxed{v = 1.874 \times 10^{9} \text{ cm/s}}$$ ———— (6)

→ Eq 6 is the Ans of prob c

→ Now

$$v = \frac{\text{distance}}{\text{time}}$$

$$\therefore t = \frac{\text{distance}}{v}$$

$$= \frac{1 \text{ cm}}{1.874 \times 10^{9} \text{ cm/s}}$$

Ans-a) $\boxed{t = 5.33 \times 10^{-10} \text{ s.}}$

Ans-b) → We know that

$$\vec{F} = q\vec{\mathcal{E}} = m\frac{d\vec{v}}{dt} \quad \text{——— (7)}$$

[Note:
→ We can't use $\vec{F} = m\frac{d\vec{v}}{dt}$ bcz, $\frac{d\vec{v}}{dt}$ gives change of velocity at particular instant.]

th.

$$F = q.\vec{\mathcal{E}}$$

→ Now $\mathcal{E} = \frac{V}{d} = \frac{1000 \text{ V}}{1 \text{ cm}} = 1000 \text{ V/cm.}$

at the possitive plate.

→

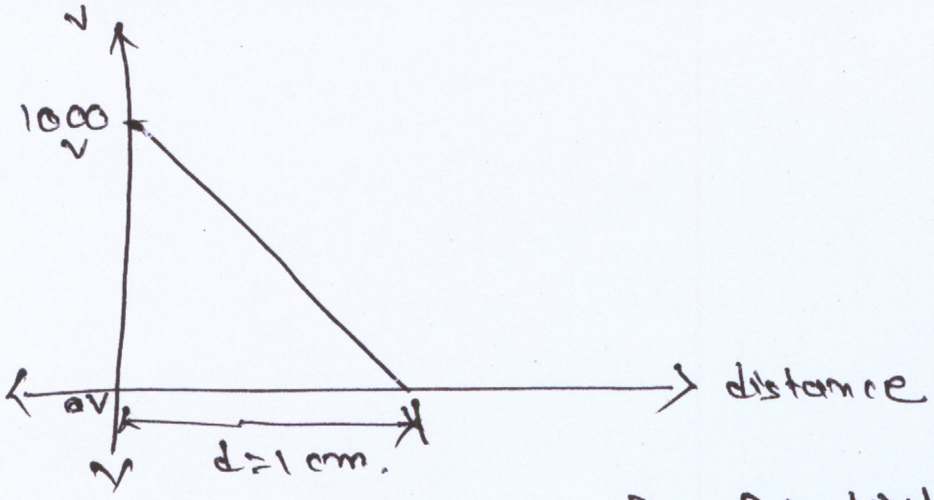


Fig : Variation of Potential V → x.

→ Now

At possitive plate $\mathcal{E} = 1000$ V/cm

and at negative plate $\mathcal{E} = 0$ V/cm ($\because$ from Fig).

→ So force at begining i.e at -ve plate.

$$\boxed{F = q \cdot \mathcal{E} = 0}$$

→ Force at End i.e. at +ve plate

$$F = q \cdot \mathcal{E}$$

$$= 1.6 \times 10^{-19} \times 1000 \text{ V/cm}$$

$$\boxed{F = 1.6 \times 10^{-16} \text{ N.}}$$

Note: Don't use $F = \frac{q^2}{4\pi\varepsilon_0 r^2}$ equation because this force is bet nucleus and electron at Distance r.

Best of Luck.