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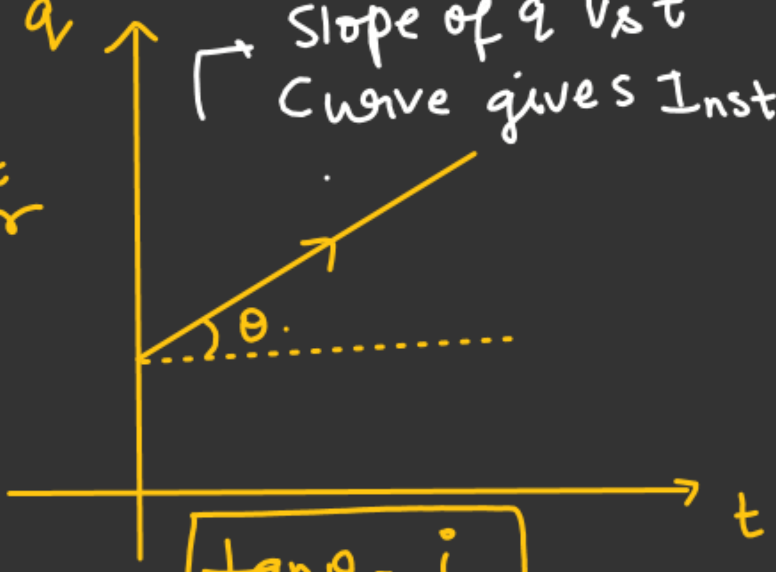
Current Electricity

Current : → (Scalar quantity)

→ [Although it has direction but it doesn't follow Δ-Law of vector addition].

Avg Current :-

$$\boxed{I_{avg} = \left(\frac{\Delta q}{\Delta t}\right)}$$



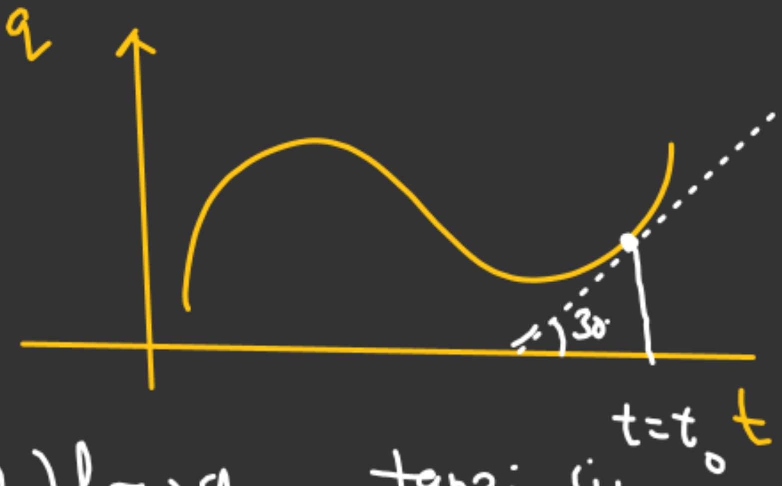
Slope of q vs t Curve gives Inst.

$$\boxed{\tan\theta = i}$$

Instantaneous Current

$$i_{nst} = \lim_{\Delta t \to 0}\left(\frac{\Delta q}{\Delta t}\right) = \left(\frac{dq}{dt}\right)$$

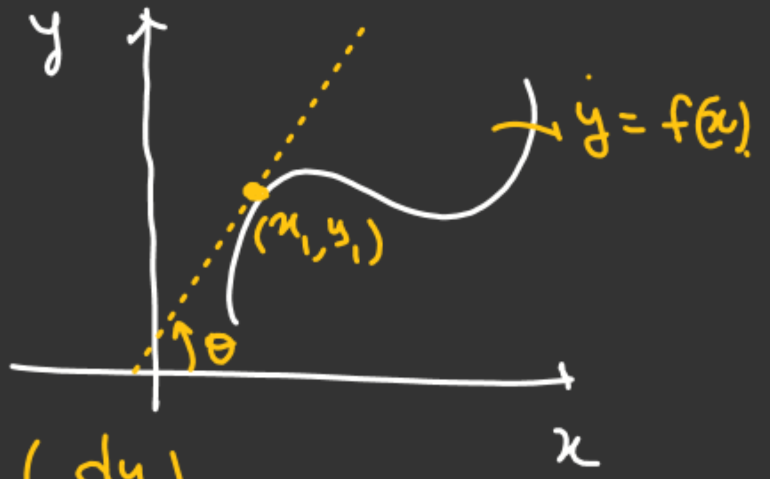
$$i_{inst} = \frac{dq}{dt}$$ ⇒ Rate of flow of Charge per unit time.



$\tan 30° = (i)_{t=t_0}$

$$\boxed{\frac{1}{\sqrt{3}}\text{ Amp} = i}$$

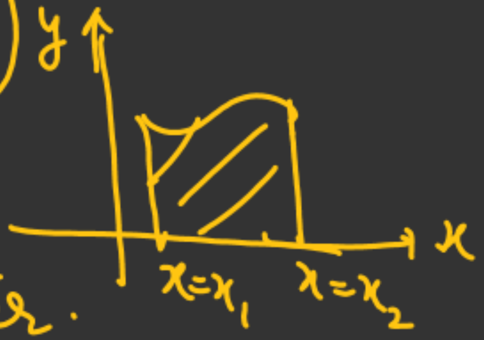
$$\boxed{\frac{dy}{dx} = \lim_{\Delta x \to 0}\left(\frac{\Delta y}{\Delta x}\right)}$$



$$\left(\frac{dy}{dx}\right)_{x=x_1} = \tan\theta$$

$$\int_{x_1}^{x_2} y \cdot dx$$ ⇒ Definite Integration

→ Area under the curve.



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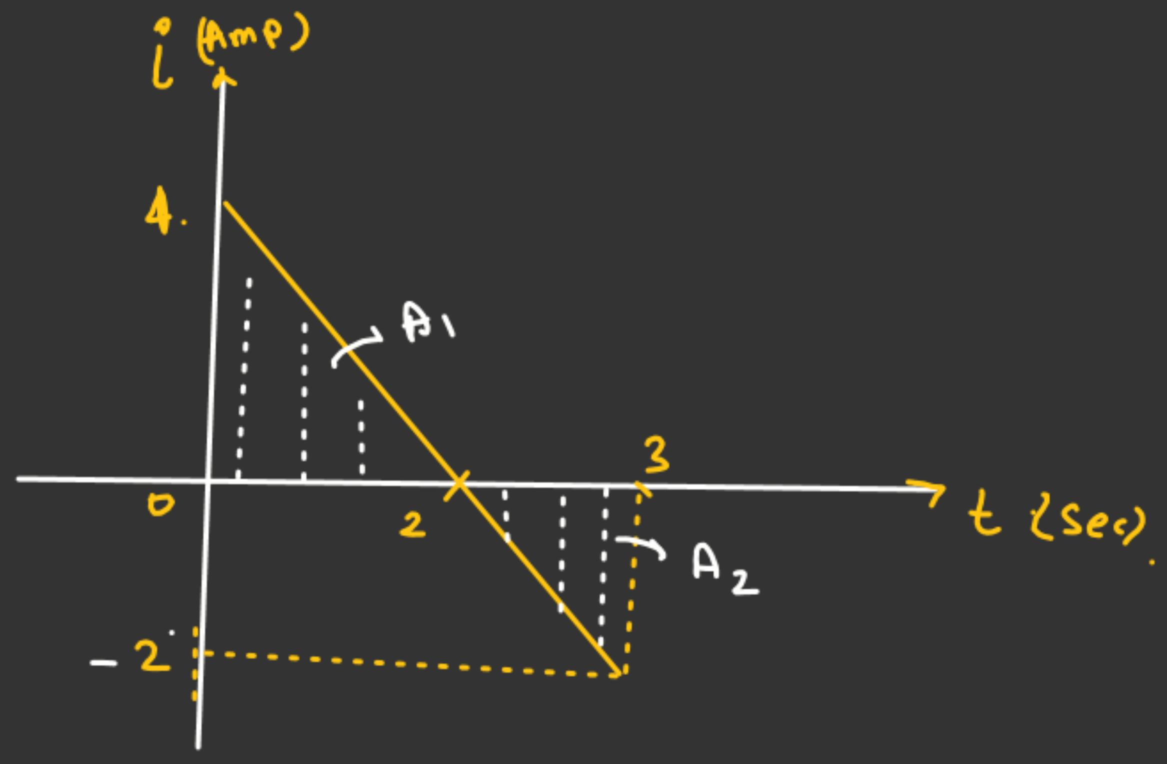
$$i = \frac{dq}{dt}$$

$$\int_0^q dq = \int_{t_1}^{t_2} i\,dt \quad \Downarrow$$

$$\underline{q} = \left(\begin{array}{l}\text{Area under}\\ i \text{ Vs } t \text{ Curve}\end{array}\right)$$

$\Downarrow$

Net Charge flow in the interval $(t_2 - t_1)$



Find total Charge flow from $\underline{t = 0 \text{ to } t = 3\text{sec}}$.

$$\Delta q = (A_1 + A_2)$$

$$= \left(\frac{1}{2} \times 2 \times 4\right) + \left(\frac{1}{2} \times 1 \times (-2)\right)$$

$$= 4 - 1$$

$$\Delta q = \underline{3C} \checkmark$$

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Current density :-

↳ (A vectorquanity).

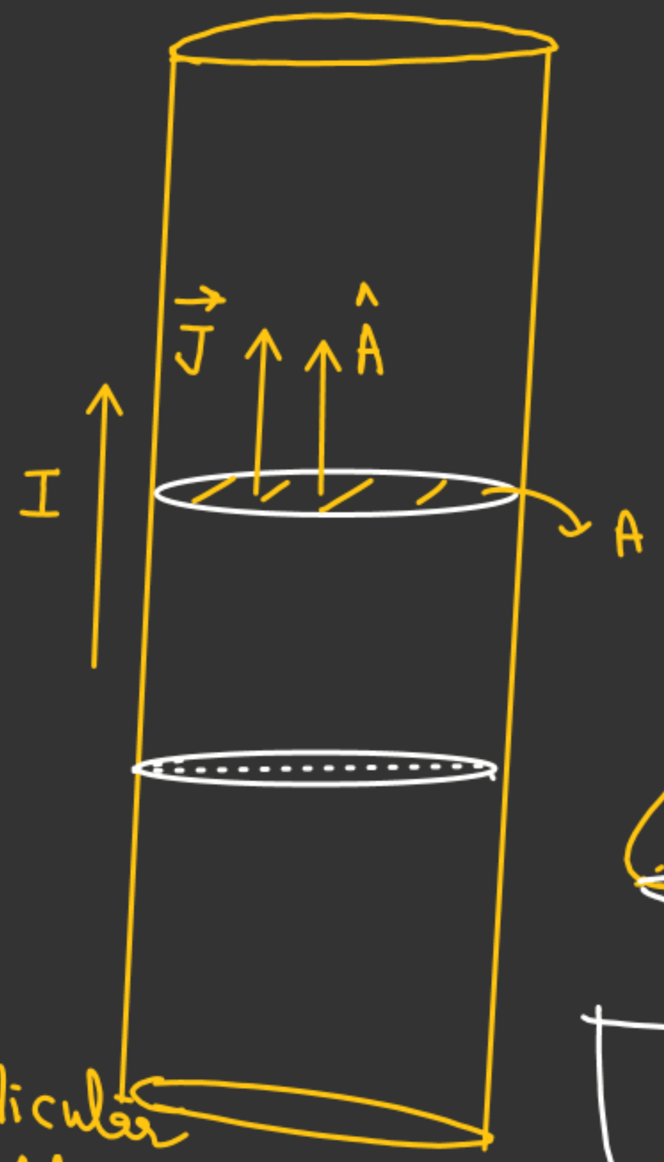
$$J = \left(\frac{\text{Current}}{\text{Area}}\right)$$

$$\boxed{J = \left(\frac{I}{A}\right)}$$

$$\vec{J} = \left(\frac{I}{A}\right)\hat{A}$$

(Magnitude)

(A) → Always perpendicular to current flow.

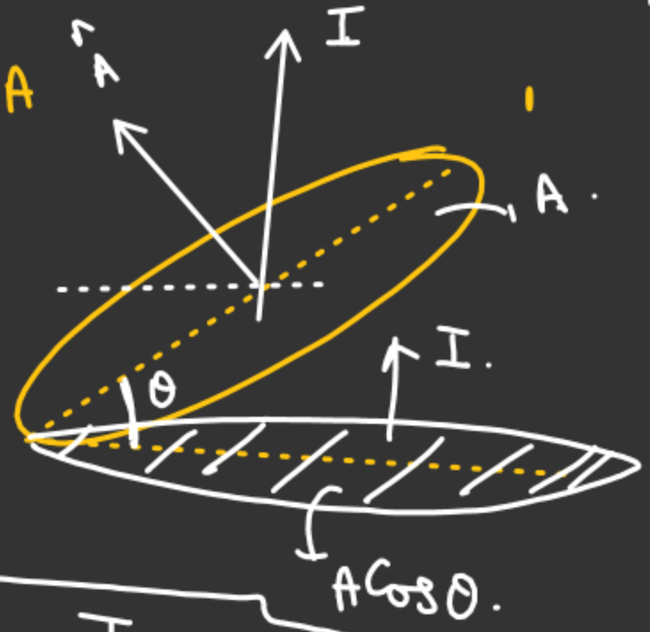


$$\boxed{I = \vec{J}\cdot\vec{A}}$$

$$I = J A\cos\theta$$

⇓

[projected Area perpendicular to I.]



$$\boxed{J = \frac{I}{A\cos\theta}}$$

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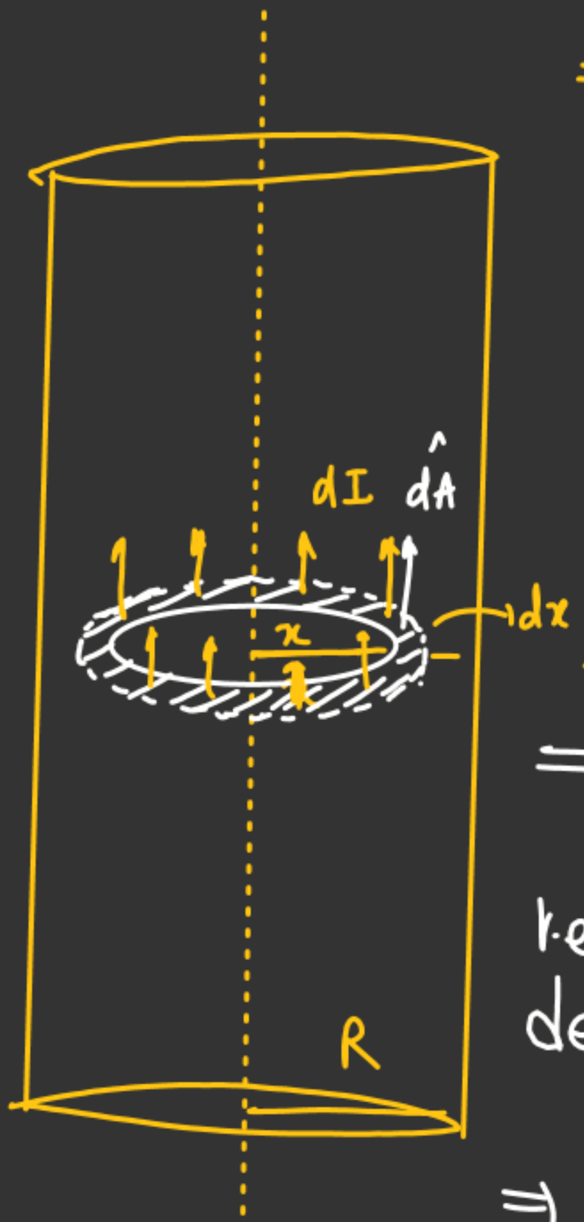
Case of Variable Current density.



$J = ax$ ✓

a is a Constant and x is the radial distance from axis.

Find Current flow = ??

$$\boxed{I = \int \vec{J} \cdot \vec{dA}}$$

$\Rightarrow$ $J_x = J_{(x+dx)}$

as dx is very small

i.e for 'dx' thickness current density is assumed to be Constant.

$\Rightarrow$ $dA = (2\pi x)dx$

$$\int_0^I dI = \int_0^R J_x \cdot dA$$

$$\int_0^I dI = a\int_0^R x\,(2\pi x\,dx)$$

$$I = 2\pi a \int_0^R x^2 dx$$

$$\boxed{I = \frac{2\pi a R^3}{3}}$$

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Concept of drift velocity and Relaxation time (τ) :→

Drift velocity :→

[Avg velocity of all the free electrons in a Conductor].

$$\vec{V}_{avg} = \left[\frac{\vec{V}_1 + \vec{V}_2 - - - -}{N_0}\right]$$

Relaxation time (τ).

↳ (Time interval b/w any two Successive collision)

For Isolated Conductor

Δq A

⇒ For isolated Conductor Since Δq Charge density is very high so net flow of charge through any crossectional area is zero. So no net current in Isolated current

u_i = i^{th} free electron velocity.

⇓

(Due to thermal energy)

$$\boxed{\sum_{i=1}^{N_0} \vec{u}_i = 0}$$

N_0 → Total no of free electrons

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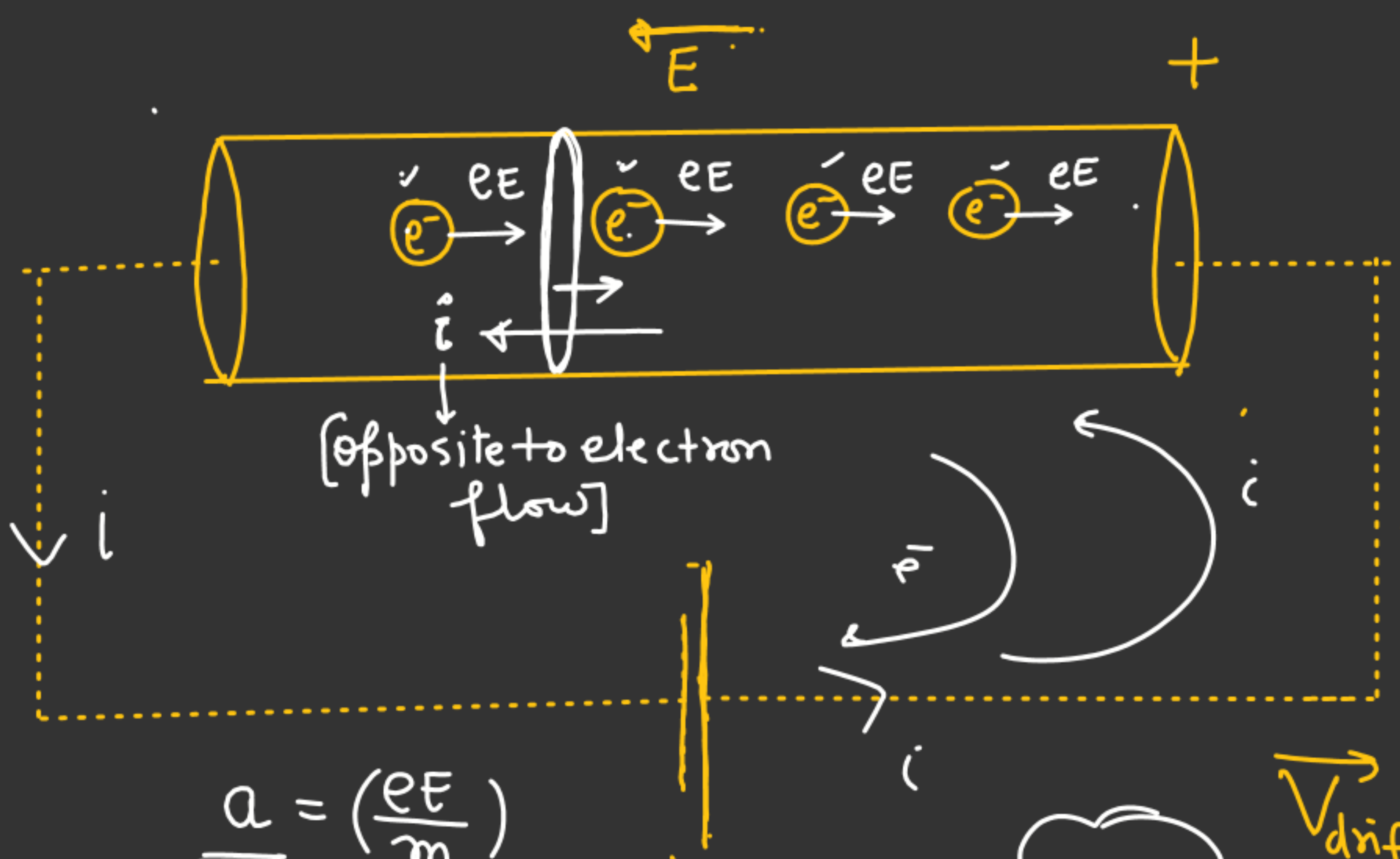
(*)

Conductor with potential source :→



$\vec{V}_1 = \underbrace{\vec{u}_1}_{\text{Due to random motion}} + \underbrace{\left(-\frac{e\vec{E}}{m}\right)t_1}_{\text{due to applied potential}}$

$\vec{V}_2 = \vec{u}_2 + \left(-\frac{e\vec{E}}{m}\right)t_2$

⋮

$\vec{V}_{n^{th}} = \vec{u}_n + \left(-\frac{e\vec{E}}{m}\right)t_n$

$\vec{V}_{\text{drif velocity}} = \left(\frac{\vec{V}_1 + \vec{V}_2 \cdots + \vec{V}_{n^{th}}}{n}\right)$

$\vec{V}_{\text{drif velocity}} = \underbrace{\left(\frac{\vec{u}_1 + \vec{u}_2 \cdots + \vec{u}_n}{n}\right)}_{\text{zero}} + \left(-\frac{e\vec{E}}{m}\right)\underbrace{\left(\frac{t_1 + t_2 \cdots + t_n}{n}\right)}_{\text{Relaxation time } (\tau)}$

$a = \left(\frac{eE}{m}\right)$

$\Rightarrow \underbrace{\vec{a}}_{\text{(accleration)}} = \left(-\frac{e\vec{E}}{\underbrace{m}_{\text{mass of electron}}}\right)$

$\sum_{i=1}^{n} u_i = 0$ ↳ Due to thermal energy

**

$$\boxed{V_{\text{drift velocity}} = \left(\frac{eE}{m}\right)\tau}$$

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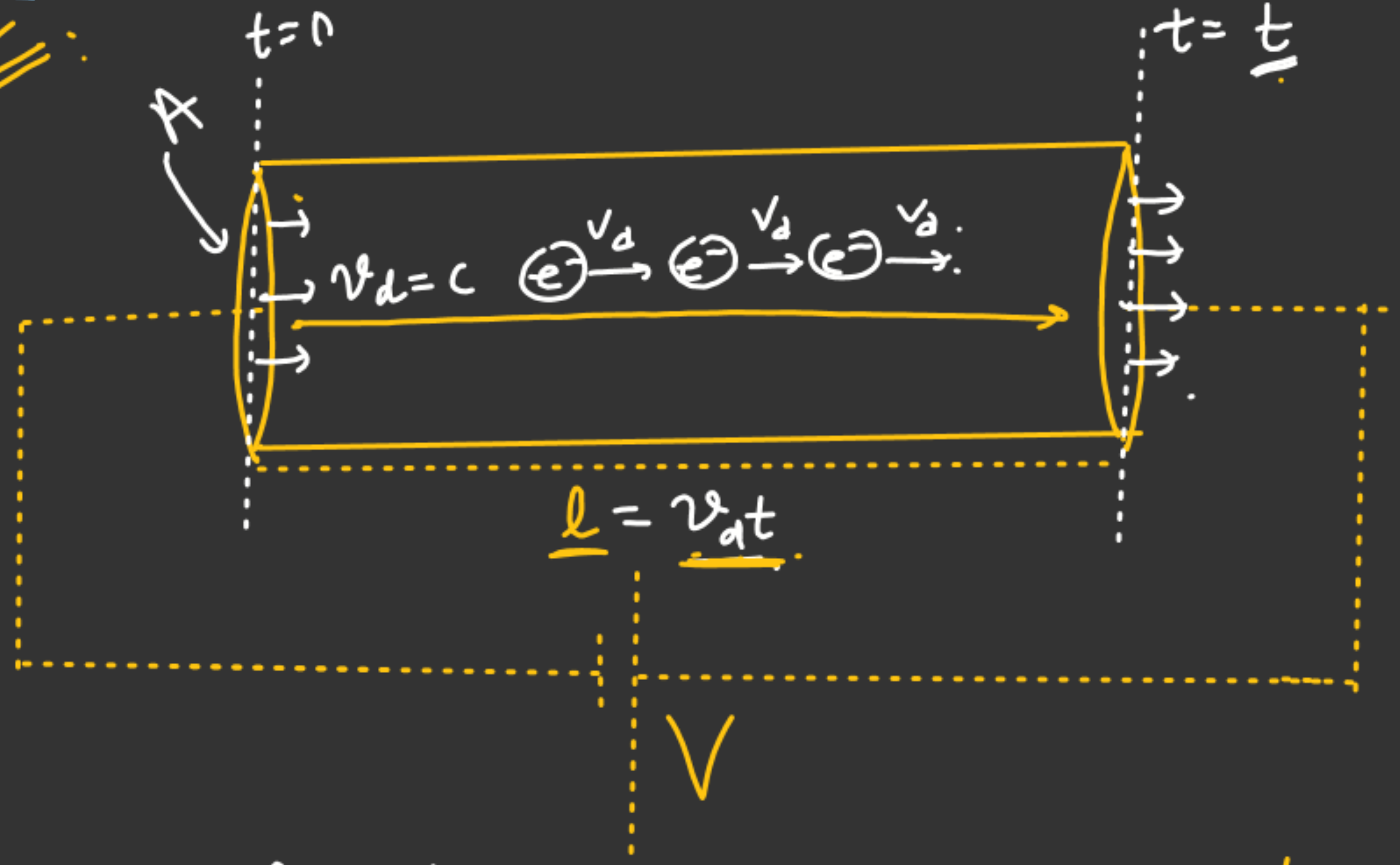

$$v_d = \left(\frac{eE}{m}\tau\right)$$

n = No of electrons per unit Volume.

Total no of electrons.

$$= n \times (\text{Volume})$$
$$= n \times A \times l.$$
$$= (n \times A \times v_d \times t)$$

Total Charge flow in 't' time $= (nAv_d t)e$.

$$\Downarrow$$

$$Q = (neAv_d t)$$

**

$$I = \frac{Q}{t} = \underline{neAv_d}$$

$$\frac{I}{A} = nev_d.$$

$$\Downarrow$$

$$\boxed{J = nev_d}$$ **

n = No of electrons per unit Volume
A = crossectional area.
v_d = drift Velocity