CURRENT:

- Flow of charges constitutes an Electric current
- It can be measured by measuring how many charges are passing thro' a specified surface or a point in a material per second.
- It is rate of flow of charge at a specified point or across a specified surface per unit time is called an <u>Electric current</u>.
- It is measured in Ampere, which is coulombs/sec (c/s).

i.e. $\boxed{I = \frac{dQ}{dt} \text{ c/s i.e Amps}}$.

A current of 1 Amp is said to be flowing across the surface when a charge of <u>one</u> <u>coulomb</u> is passing across the surface in <u>one</u> <u>second</u>.

<u>CURRENT</u> <u>DENSITY</u>:

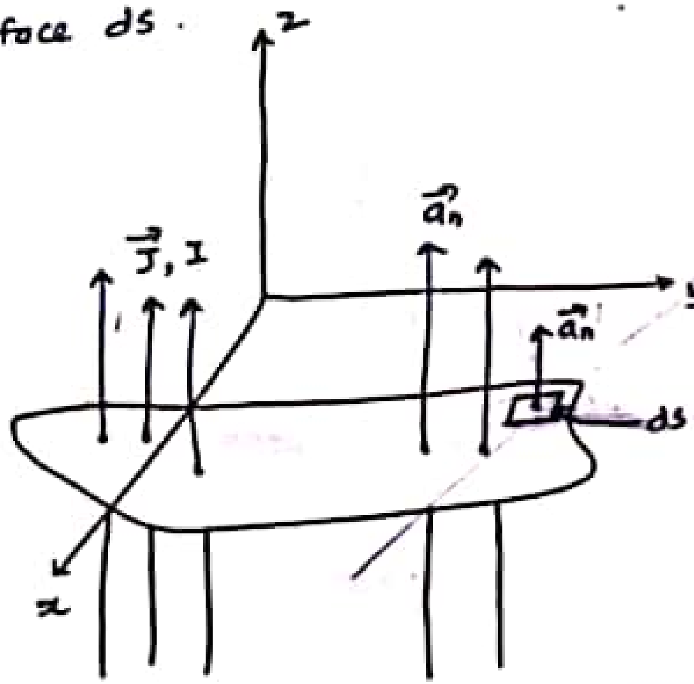
It is defined as the current passing thro' the unit surface area, when the surface is held normal to direction of the current.

- It is a vector quantity and denoted as $\vec{J}$.
- It is measured in Amperes per sq.meters (A/m^2).

<u>RELATIONSHIP</u> <u>BETWEEN</u> <u>I AND J</u>:

consider a surface S and I is the current passing thro' the surface. The direction of current is normal to the surface S and hence direction of $\vec{J}$ is also normal to the surface S.

Consider an incremental area ds as shown in fig below and $\vec{a_n}$ is the unit vector normal to the incremental surface ds.



$A/m^2 \quad m^2$

$I = J \times S$

$$\vec{ds} = ds\,\vec{a_n}$$

$$dI = \vec{J} \cdot \vec{ds}$$

$$\vec{J} = J\,\vec{a_n}$$

Then the differential current dI passing thro' the differential surface ds is given by the dot product of the current density vector $\vec{J}$ and $\vec{ds}$

$\therefore \quad dI = \vec{J} \cdot \vec{ds}$ [dot Product]

when $\vec{J}$ and $\vec{ds}$ are at right angles ($\theta = 0°$) then

$$dI = \vec{J} \cdot \vec{ds} = |\vec{J}|\,|\vec{ds}| \cos 0°$$

$$\boxed{dI = J\,ds}$$

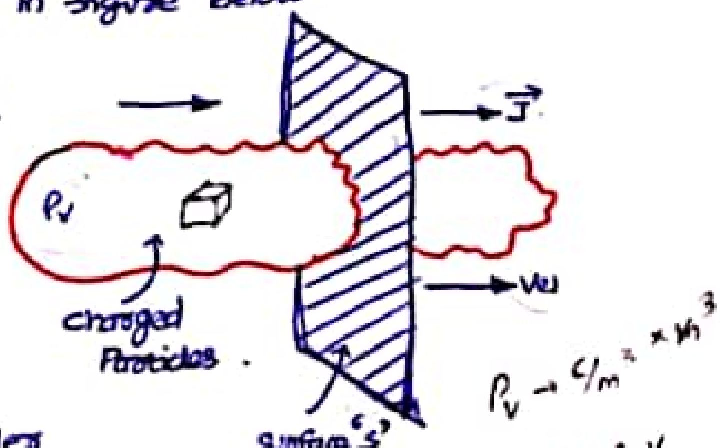
and $I = \oint_S J \cdot ds$. $\quad J \rightarrow$ current density in A/m^2

But if $\vec{J}$ is not normal to $\vec{ds}$ then the total current is obtained by integrating $\vec{J} \cdot \vec{ds}$

$$\boxed{I = \oint_S \vec{J} \cdot \vec{ds}}$$

RELATION BETWEEN $\vec{J}$ & ρ_v

The set of charged Particles give rise to a charge density ρ_v in a volume V. The current density $\vec{J}$ can be related to the velocity with the volume charge density. i.e charged particles in volume V. crosses the surface S at a Point. This is shown in figure below



The velocity with which the charge is getting transferred is $\vec{v}$ m/s. This is a vector quantity.

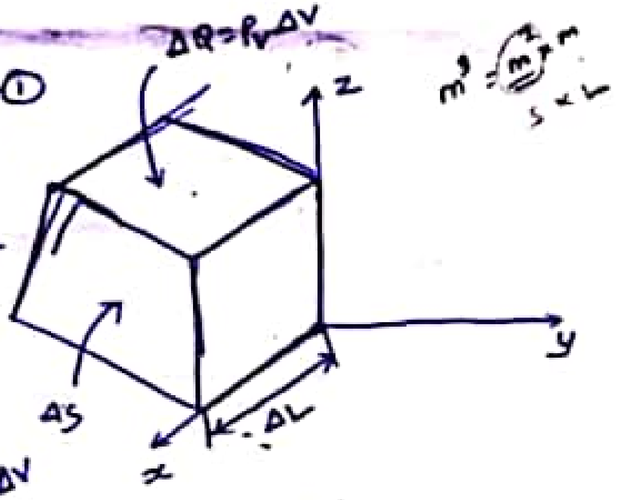
$\rho_v \to C/m^3 \times m^3$

To derive the relation between $\vec{J}$ and ρ_v, consider differential volume Δv having charge density ρ_v as show in figure below. The elementary charge that volume carries is,

$Q = \rho_v V$

$\Delta Q = \rho_v \Delta V$

$$\boxed{\Delta Q = \rho_v \Delta V} \quad --- (1)$$



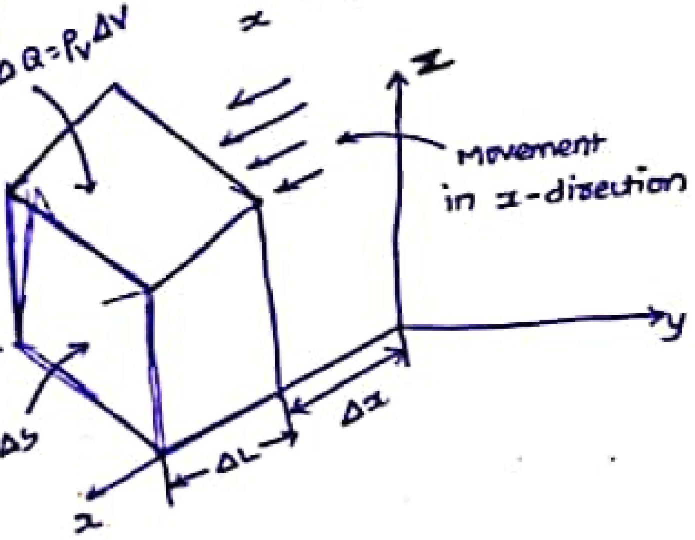
$m^3 = m^2 \times m$

Let ΔL is the incremental length while ΔS is the incremental surface area & incremental volume is,

$$\boxed{\Delta V = \Delta S \Delta L} \quad --- (2)$$

∴ sub (2) in (1) we get

$$\boxed{\Delta Q = \rho_v \Delta S \Delta L} \quad --- (3) \quad \Delta Q = \rho_v \Delta V$$



Let the charge is moving in x-direction with velocity $\vec{v}$ and thus velocity has only x component v_x.

In the time interval Δt the element of charge has moved through distance Δx, in x direction. The direction is normal to the surface ΔS and hence the resultant current can be expressed as,

$$\boxed{\Delta I = \frac{\Delta Q}{\Delta t}} \quad \text{---} \; (4)$$

But now, $\Delta Q = \rho_v \Delta S \Delta x$ as the charge corresponding the length Δx is moved and responsible for the current.

$$\therefore \quad \Delta I = \rho_v \Delta S \frac{\Delta x}{\Delta t} \quad \text{----} \; (5)$$

But $\frac{\Delta x}{\Delta t}$ = Velocity in x-direction i.e. v_x

$$\therefore \quad \Delta I = \rho_v \Delta S \, v_x \quad \text{---} \; (6)$$

v_x → X component of velocity $\vec{v}$

But $\Delta I = \vec{J} \Delta S$ when $\vec{J}$ and ΔS are normal. --- (7)

Here $\vec{J}$ and ΔS are normal to each other hence comparing (7) and (6) we get

$$J_x = \rho_v v_x = x \text{ component of } \vec{J} \quad \text{------} \; (8)$$

In general, the relation ship between $\vec{J}$ and ρ_v be expressed as

$$\boxed{\vec{J} = \rho_v \vec{v}}$$

where $\vec{v}$ is the velocity vector.

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