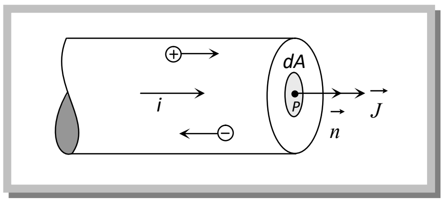
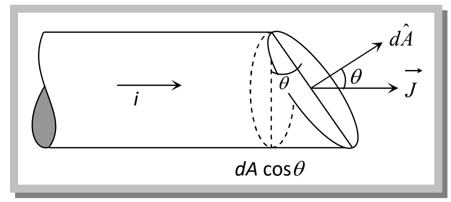
## Current density (J).

In case of flow of charge through a cross-section, current density is defined as a vector having magnitude equal to current per unit area surrounding that point. Remember area is normal to the direction of charge flow (or current passes) through that point. Current density at point P is given by $\vec{J} = \frac{di}{dA}\vec{n}$




If the cross-sectional area is not normal to the current, the cross-sectional area normal to current in accordance with following figure will be dA cosθ and so in this situation:

$J = \frac{di}{dA\cos\theta}$ i.e. $di = JdA\cos\theta$ or $di = \vec{J}.\vec{dA} \Rightarrow i = \int \vec{J}\cdot\vec{dA}$

i.e., in terms of current density, current is the flux of current density.

Note: If current density $\vec{J}$ is uniform for a normal cross-section $\vec{A}$ then: $i = \int \vec{J}\cdot\vec{ds} = \vec{J}\cdot\int\vec{ds}$ [as $\vec{J}$ = constant]

or $i = \vec{J}\cdot\vec{A} = JA\cos 0 = JA \Rightarrow \boldsymbol{J} = \frac{\boldsymbol{i}}{\boldsymbol{A}}$ [as $\int \vec{dA} = \vec{A}$ andθ = 0o]

(1) Unit and dimension: Current density $\vec{J}$ is a vector quantity having S.I. unit Amp/m2 and dimension. [L–2A]

(2) Current density in terms of velocity of charge: In case of uniform flow of charge through a cross-section normal to it as $i = nqvA$ so, $\vec{J} = \frac{i}{A}\vec{n} = (nqv)\vec{n}$ or $\vec{J} = nq\vec{v} = \vec{v}\,(\rho)$ [With $\rho = \frac{\text{charge}}{\text{volume}} = nq$ ]

i.e., current density at a point is equal to the product of volume charge density with velocity of charge distribution at that point.

(3) Current density in terms of electric field: Current density relates with electric field as

$$J = \sigma E = \frac{E}{\rho}$$ ; where σ = conductivity and ρ = resistivity or specific resistance of substance.

(i) Direction of current density $\vec{J}$ is same as that of electric field $\vec{E}$.

(ii) If electric field is uniform (i.e. $\vec{E} = \text{constant}$) current density will be constant [as σ = constant]

(iii) If electric field is zero (as in electrostatics inside a conductor), current density and hence current will be zero.