

ELECTRICITY 2

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Electric Current

SECTION 1

Current and Current Density

Electric charge in motion constitutes an electric current. In the steady flow of charge in a wire of cross-sectional area A , the total charge passing through this area in unit time is defined to be the electric current I at this place. If a total charge q flows through this area in time t , the current I is given by:

$$I = \frac{q}{t}. \quad (1.1)$$

where I is measured in Ampere. Sometimes it is also convenient to look at the density of the current we're observing over a certain area A called *current density*

$$J = \frac{I}{A}. \quad (1.2)$$

If the area in which the current is running through changes at points 1 and 2, the current between those 2 points remain constant ($I_1 = I_2$) while the current density changes to become

$$\frac{J_1}{J_2} = \frac{A_2}{A_1}.$$

If a positively charged cloud of n particles moves through a space with speed v and charge q , we find that¹

$$\vec{J} = nq\vec{v} = \rho_r\vec{v}. \quad (1.3)$$

The total current through a *slice* of space mentioned prior it calculated using

$$I = \iint_A \vec{J} dA. \quad (1.4)$$

The volume element here is $\vec{v} dA dt = d\tau$

¹ q can be positive or negative

SECTION 2

Continuity Law

The continuity law for current is

$$\nabla \cdot (\vec{J} + \vec{J}_c) = -\frac{\partial \rho_r}{\partial t}. \quad (2.1)$$

Where

$\vec{\mathbf{J}}$ is the conduction current density.

$\vec{\mathbf{J}}_c = \varrho_\tau \vec{\mathbf{v}}_\tau$ is the convection current density.

$\vec{\mathbf{v}}_\tau$ is the velocity of the volume containing the particles.

There are 2 particular cases for the equation above

1. The volume is not moving ($\vec{\mathbf{v}}_\tau = 0 \implies \vec{\mathbf{J}}_c = 0$). The continuity law of static structures is

$$\nabla \cdot \vec{\mathbf{J}} = -\frac{\partial \varrho_\tau}{\partial t}. \quad (2.2)$$

2. The volume is not moving and we are in a steady state, so the charge density of the particles doesn't change much as they are static so $\partial \varrho_\tau / \partial t = 0$ so

$$\oint \vec{\mathbf{J}} \, dA = 0. \quad (2.3)$$