Electric Circuits

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11.1 Electric Current

Electric Current

Electric current is the movement of charge carries, such as electrons, through a material. It measures the number of coulombs of charge that move through an area in a given time. The unit of electric current is the ampere, or coulombs per second.

$$I = \frac{Q}{\Delta t} = \frac{dq}{dt}$$

In a wire, each of the charge carriers move with many different velocities, with the net movement of charge carriers being represented by the drift velocity, v_d. We can also calculate electric current through the formula

$$I = nqv_dA$$

Where:

- n is the number of charged particles per cubic meter of volume
- q is the quantity of of the charge
- A is the cross-sectional area of the wire

To create a movement of a fluid in a pipe, there must be a pressure difference between the ends of a pipe. Likewise, to create an electric current, there must be a potential difference between the ends of the wire. This electric potential difference is also referred to as an electromotive force, or ϵ. We can create this force through a battery or generator.

Electric Current Density

Recall that the electric current directly depends on the cross sectional area of the wire. If we were to measure a smaller cross sectional area within the wire, we would get a smaller value. The quantity that stays the same for both areas is the electric current density, which is a vector quantity. This can be intuitively derived:

$$J = \frac{I}{A} = nqv_d$$

Current is the dot product of current density and area.

$$I = \vec{J} \cdot \vec{A} = ||\vec{J}||\,||\vec{A}|| \cos\theta$$

The idea of charge flow as current implies that electric current has a direction, but not like a traditional vector quantity. Electric current is relative to the charge carriers and does not obey the laws of vector addition. By convention, the direction of current in a wire is based on the movement of positive charges, however, the charge carriers in a wire are electrons, which have a negative charge. Therefore, electrons in a wire move in the opposite direction as conventional current.

Current and Electric Field

Recall that an electric field causes charge carriers to move through a wire. An increase in electric field strength causes an increase in electromotive force, which increases the current density. Current density and electric field are proportionally related to each other.