

Electric Current

I = electric current, # of coulombs of charge that passes a given point

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

Units: C/s = 1 ampere = 1 A

Drift Velocity

v_e = conduction velocity; average velocity between collisions $\approx 10^5$ m/s

v_d = drift velocity; average velocity of electrons through conductors $\approx 10^{-3}$ m/s

$$v_d = \frac{eE}{m}\tau$$

e = elementary charge (1.602×10^{-19} C)

E = e-field

m = mass of electron (9.11×10^{-31} kg)

τ = average time between collisions, mean free time

Carrier Density

let n = charge carrier density, # of free charges per cubic meter ($1/\text{m}^3$)

$$\text{pure metal } n = \frac{\rho N_A}{M}$$

$$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$$

ρ = volume density (kg/m^3)

M = molar mass (kg/mol)

$$I = neAv_d$$

$$I = n \frac{e^2 E \tau}{m} A$$

e = charge electron

Current Density

let \vec{J} = current density (A/m^2)

$$|\vec{J}| = \frac{I}{A}$$

$$|\vec{J}| = nev_d$$

$$|\vec{J}| = n \frac{e^2 \tau}{m} E$$

Ohm's Law

$$\boxed{V = IR}$$

$$\vec{J} = \sigma \vec{E}$$

σ = electric conductivity, a measure of how well the material conducts charge

let ρ = electric resistivity, a measure of how well the material resists current flow

Units of ρ : $\Omega \text{ m}$

$$\rho = \frac{1}{\sigma}$$

$$\Delta V = \left(\rho \frac{l}{A} \right) I$$

let R = resistance

$$R = \rho \frac{l}{A}$$

Units of R : $1 \frac{V}{A} = 1 \text{ ohm} = 1 \Omega$

Resistivity

ρ is not constant, it varies with temperature

$$\rho = \frac{m}{ne^2\tau}$$

$$\rho = \rho_0(1 + \alpha(T - T_0))$$

let α = temperature coefficient of resistivity ($1/^\circ\text{C}$)

$$R = R_0(1 + \alpha(T_f - T_0)) \text{ , if } l \text{ and } A \text{ are constant}$$

Conductivity

$$\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m}$$

Power Supplies

example: battery (electro chemical cell)

- two dissimilar metals and an electrolyte

let ε = electromotive force, voltage generated/created by chemical reaction inside battery, (fixed)
quantity doesn't change

V_t = terminal voltage, voltage that's available to some external circuit (varies)

r = internal resistance (varies)

$$V_t = \varepsilon - Ir$$

Power in Circuits

$$\Delta U = q\Delta V$$

Power:

$$P = \frac{\Delta U}{\Delta t} = \Delta V i$$

Power in ANY circuit element: $P = Vi$

$$\text{Power dissipated by resistor: } P = Vi = i^2 R = \frac{V^2}{R}$$