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 ($1/m^3$)

pure metal $n = \dfrac{\rho N_A}{M}$

$N_A = 6.022 \times 10^{23}$ 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: Ω 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 ohm = 1 Ω

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/°C)

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

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: $P = Vi$

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

Power in Circuits

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

Units: J/s or W

Power Supply:

$$P = IV$$

Resistors:

$$P = I^2 R$$

$$P = \frac{V^2}{R}$$