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 $n = \frac{\rho N_A}{M}$

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

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: Ω m

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

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

let R = resistance

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

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

Resistivity

ρ is not constant, it varies with temperature

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

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

let α = temperature coefficient of resistivity (1/°C)

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

Conductivity

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

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:

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

Power in ANY circuit element: $P = Vi$

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

Power in Circuits

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

Units: J/s or W

Power Supply:

$$P = IV$$

Resistors:

$$P = I^2 R$$

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