## 27.1 Electric Current

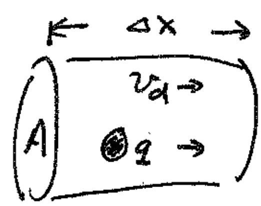
Current = net flow of changes
= Rate at which charge flows through a surface

$$I_{av} \equiv \frac{\Delta Q}{\Delta t} \rightarrow I \equiv \frac{dQ}{dt} \qquad [A] = \frac{[\text{Coulomb}]}{[\text{sec}]}$$

Conventional assigned to the flow of positive charge as the direction of current.
So the direction of current is opposite to the flow of electrons

## Microscopic Model of Current

$n \equiv$ number of mobile charge per unit volume




$$\Delta Q = (n A \Delta x)\, q$$

$$= (n A v_d \Delta t)\, q$$

$$I_{av} = \frac{\Delta Q}{\Delta t} = n q v_d A$$

$q \equiv$ Charge on each carrier
$v_d$ = Carrier speed
= drift speed

$V_d$ = drift speed.

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Volume of one mole of Copper $V = \frac{m}{\rho} = \frac{63.5\,g}{8.95\,g/cm^3} = 7.09\,cm^3$

$$n = \frac{6.02\times10^{23}\text{ electrons}}{7.09\text{ cm}^3}\left(\frac{1\times10^{6}\text{ cm}^3}{1\text{ m}^3}\right) = 8.49\times10^{28}\text{ electrons}/m^3$$ — each Copper atom Contributes One free electron

$$V_d = \frac{I^{\text{ given}}}{n q A_{\text{ given}}} = \frac{10\,C/s}{(8.49\times10^{28}\,e/m^3)(1.6\times10^{-19}\,C)(3.31\times10^{-6}\,m^2)}$$

$$= 2.22\times10^{-4}\,m/s$$

## 27.2 Resistance

Define Current density $J \equiv \frac{I}{A} = nqv_d$

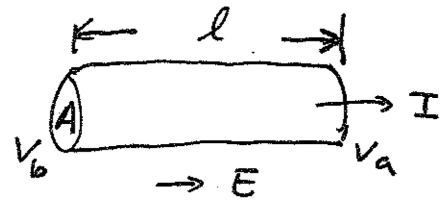
If there is ~~an~~ a potential difference across a Conductor

A current density $J$ and electric field $E$ are established

$$\vec{J} = \sigma \vec{E} \qquad \sigma \equiv \text{Conductivity}$$

→ Material that obey this relation are said to follow Ohm's law

→ ohmic material



$\Delta V = V_b - V_a$

$$J = \sigma E = \sigma \frac{\Delta V}{l}$$

$$J = \frac{I}{A} \quad \Rightarrow \Delta V = \frac{l}{\sigma} J = \frac{l}{\sigma}\frac{I}{A} = \left(\frac{l}{\sigma A}\right) I = RI$$

$$R \equiv \frac{l}{\sigma A} = \frac{1}{\sigma}\frac{l}{A}$$

$$R \equiv \frac{\Delta V}{I} \qquad [\Omega] = \frac{[\text{Volt}]}{[A]}$$

$$\rho = \frac{1}{\sigma} \equiv \text{resistivity}$$

## 27.3 Model for Electrical Conduction

Drift velocity. Let electron's mass ~~q~~ $m_e$

$$F = qE = m_e a \rightarrow a = \frac{qE}{m_e}$$

$$v_f = v_i + at = v_i + \frac{qE}{m_e} t$$

$$\overline{v_f} = v_d = \overline{v_i} + \overline{\frac{qE}{m_e} t}, \quad \overline{v_i} = 0$$

due to random motion

random motion of electrons

$$v_d = \frac{qE}{m_e} \tau$$

(21.7)
$l \equiv$ mean free path

$\tau \equiv$ average time between successive collisions

$$\therefore J = nqv_d = \frac{nq^2E}{m_e}\tau, \quad \sigma = \frac{nq^2\tau}{m_e}. \quad \rho = \frac{1}{\sigma} = \frac{m_e}{nq^2\tau} \quad \tau = \frac{l}{\bar{v}}.$$

## 27.4 Resistance and temperature

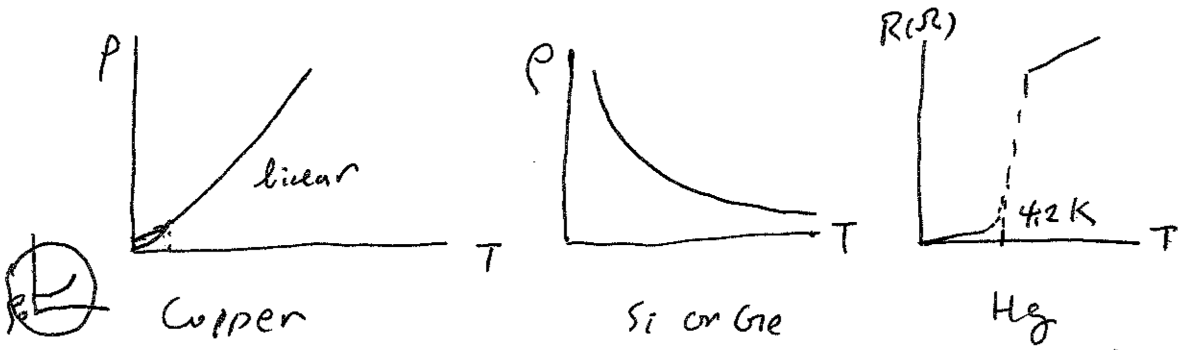
Define the temperature coefficient of resistivity

$$\alpha = \frac{1}{\rho_0}\frac{\Delta\rho}{\Delta T} \qquad \begin{array}{l}\Delta T = T - T_0 \\ \Delta\rho = \rho - \rho_0\end{array}$$

$$\rightarrow \quad \rho = \rho_0\left[1 + \alpha(T - T_0)\right]$$ – temperature dependence of the resistivity

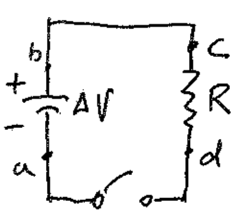
$\Delta\rho = \rho - \rho_0$
$\Delta T = T - T_0$ $\qquad$ $T_0$ is usually taken at 20°C

or $$\boxed{R = R_0\left[1 + \alpha(T - T_0)\right]}$$ Resistance's temperature dependence




Copper $\qquad$ Si or Ge $\qquad$ Hg
Normal metal

## 27.5 Electric power




Simple circuit of resistor and battery

Energy will be delivered to the resistor
the system loses electric energy as the
charge Q passes through the resistor

$$\frac{dU}{dt} = \frac{d}{dt}(Q\Delta V) = \frac{dQ}{dt}\Delta V = I\Delta V$$

$$\rightarrow \mathcal{P} \equiv \frac{dU}{dt} = \text{power}$$

$$\therefore \mathcal{P} = I\Delta V \qquad \text{But } \Delta V = IR$$

$$= I^2R$$

$$= \frac{(\Delta V)^2}{R}$$