1. **Electric Current**

   Free electrons in conductor move in response to $\mathbf{E}$.

   Current $i = \frac{\Delta Q}{\Delta t}$ (Coulomb/s) = Ampere (A)

   (a) $i$ points (by definition) opposite flow of $e^-$

   (b) Conductor has zero charge despite current

   (c) $e^-$ scatter ("bump") off atomic lattice and loose $kT$ (heat)

   Net constant drift velocity ($10^{-9} m/s$)

   Random speeds $\sim 10^6 m/s$.

2. **Source of potential**

   Battery: chemical energy $\rightarrow$ electric potential

   Ideal circuit symbol $+V$
Ohm's Law

For most materials, current proportional to voltage difference:

\[ V = iR \]

Volts = Amps \times Ohms

Symbol: "\( \Omega \)" ohms

Typical circuit has wires with negligible resistance:

Light bulb resistance >> wire

Circuit symbol for resistance: \( R \)

Light bulb circuit:

\[ P = iV = \frac{\text{Coulombs} \times \text{Volts}}{s} = \frac{\text{Coulombs}}{s} \times \frac{i}{s} = \frac{i}{s} \]
6. Power dissipated by resistor

\[ P = iV = \frac{V^2}{R} = i^2R \]

Example: 60W bulb
Home voltage 120V

\[ R = \frac{V^2}{P} = \frac{(120V)^2}{60W} = 240 \Omega \]

6. Simple circuits: Kirchhoff’s rules

\[ i_1 = i_2 + i_3 \]

\[-iR, iR, \text{ Voltage drop} \]

\[ V - iR - iR = 0 \quad \Rightarrow \quad i = \frac{V}{2R} \]

\[ i_2 = \frac{V}{R} \]

\[ i_1 = \frac{V}{R} \]

\[ i = \frac{2V}{R} \]

"Connected"
power dissipated $\propto$ bulb brightness

(a) series bulb: $i = \frac{V}{2R}$

$$P = i^2 R = \frac{V^2}{4R}$$

Power supplied by battery:

$$P = V \cdot i = \frac{V^2}{2R} = 2 \times \left( \frac{V^2}{4R} \right)$$

(b) parallel bulb: $i = \frac{V}{R}$

$$P_p = i^2 R = \frac{V^2}{R}$$

Power supplied by battery:

$$P = V \cdot i = \frac{2V^2}{R} = 2 \times \left( \frac{V^2}{R} \right)$$
Household power

- typical 20 A fuse limits current in household wiring.
- Fire burns & breaks circuit before hot wiring sets house on fire.

1200 W microwave oven

\[ V_i = 1200 \text{ W} \]

\[ i = \frac{1200 \text{ W}}{120 \text{ V}} = 10 \text{ A} \]

60 W light bulb

\[ V_i = 60 \text{ W} \]

\[ i = \frac{60 \text{ W}}{120 \text{ V}} = \frac{1}{2} \text{ A} \]

Cost = (kWh rate) \times \frac{\text{W}}{1000} \times \text{hours}

kWh rates:
- 1st 200kWh: 6.7 \$/kWh \Rightarrow \frac{1}{2} \text{ kW refrigerator}
- then: 7.8 \$/kWh = 12 \text{ kWh/day} \Rightarrow 24.8 \$/month