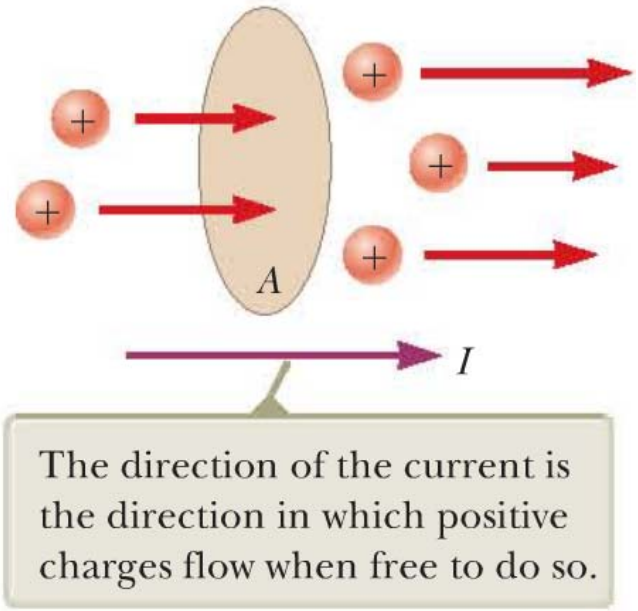
Class 17: Current and Resistance

Current

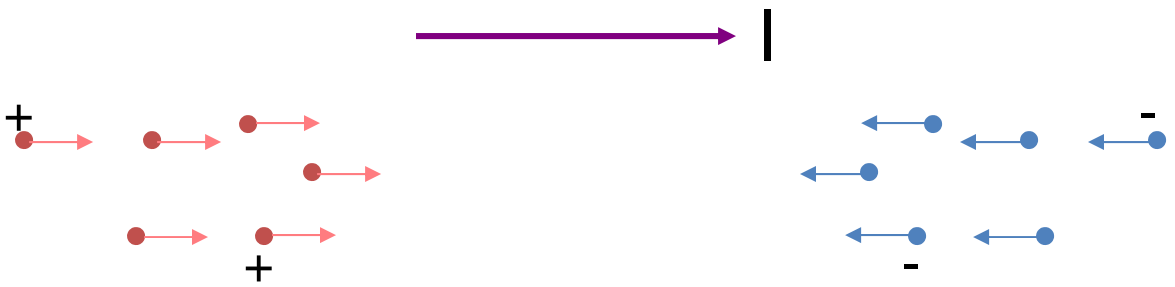


If dQ is the amount of charge passes through A in a short time interval dt, current is defined as:

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

Units of current:

Ampere (A) ≡ C/s

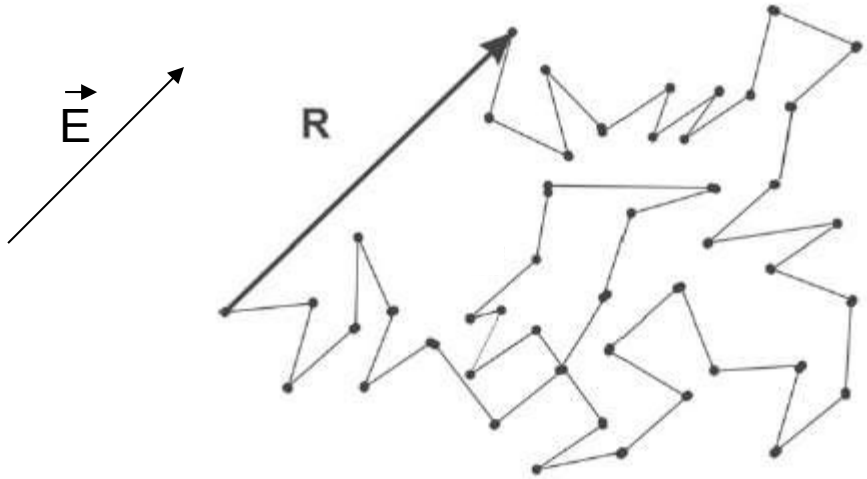


Electrically these two cases produce the same current, *but they can be distinguished with a magnetic field.*

Drifting velocity v_d

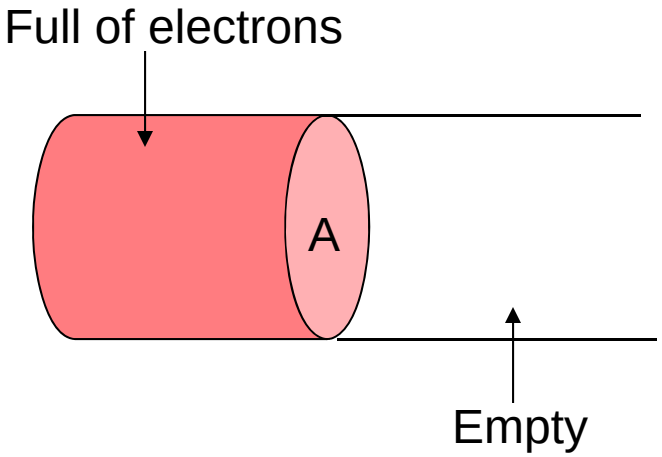
At any instant, electrons contributing to the current is moving very fast at about 10^6 m/s.

They also make collision with atoms and impurities very often, about 10^{14} times per second.

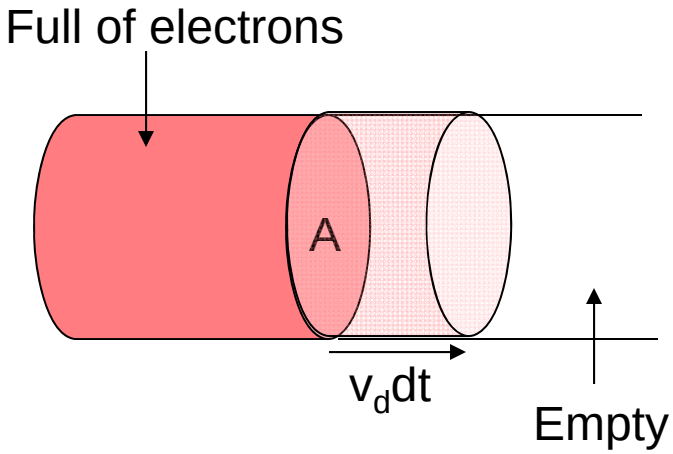


As a result, electrons drift very slowly along the electric field direction with a drifting velocity $v_d \sim 10^{-4}$ m/s.

Microscopic Model of Current



How many electron will pass the area A in a short time interval dt?



If n is the number of electrons per unit volume.

Number of electrons pass through area A = n×volume = $n(v_d dt)A$

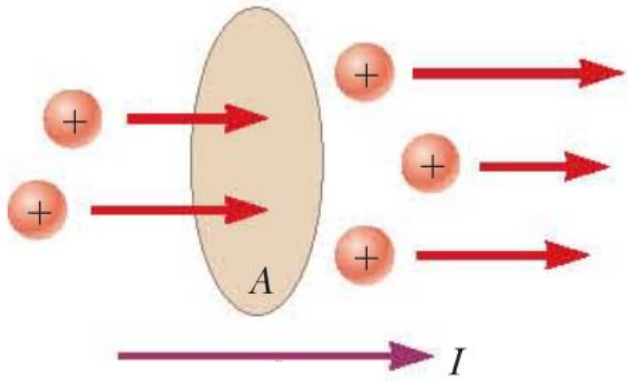
If the charge of electron is e.

Charge pass through area A is

$$dQ = ne(v_d dt)A$$

$$\therefore I = \frac{dQ}{dt} \Rightarrow \boxed{I = nev_d A}$$

Current Density and Ohm's Law (physics version)



Current density

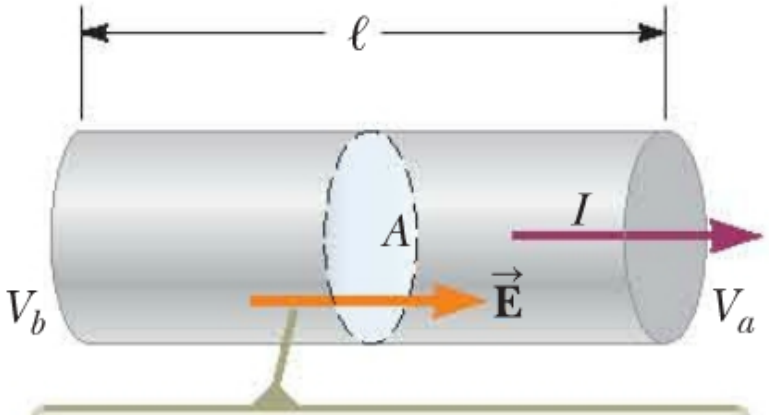
$$J = \frac{I}{A}$$

Ohm's Law:

$$\vec{J} = \frac{1}{\rho}\vec{E}$$

1. ρ is called resistivity. *Do not confuse this with the volumetric charge density.*
2. ρ is a property of materials.

Ohm's Law (electronics version)



A potential difference $\Delta V = V_b - V_a$ maintained across the conductor sets up an electric field $\vec{E}$, and this field produces a current I that is proportional to the potential difference.

$J \rightarrow I$ and $E \rightarrow V$

Ohm's Law:

$$J = \frac{1}{\rho} E \Rightarrow \frac{I}{A} = \frac{1}{\rho} \cdot \frac{\Delta V}{\ell}$$

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

$$\Rightarrow \boxed{\Delta V = I R}$$

where

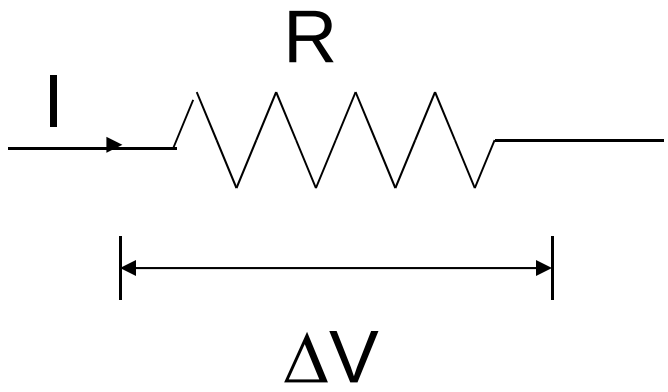
$$\boxed{R = \frac{\rho \ell}{A}}$$

1. R is called the resistance.
2. Units of resistance R is Ohm (Ω). $\Omega \equiv V/A$
3. Units of resistivity ρ is Ωm.

Power

Power dissipated
in resistance R:

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



Units of power:
Watt (W) $\equiv$ J/s