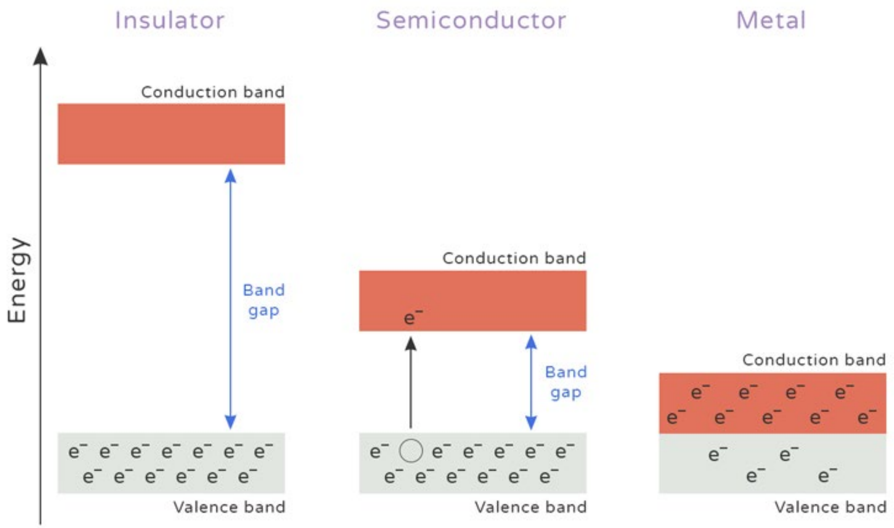
Electronics Basics

York College & University Centre

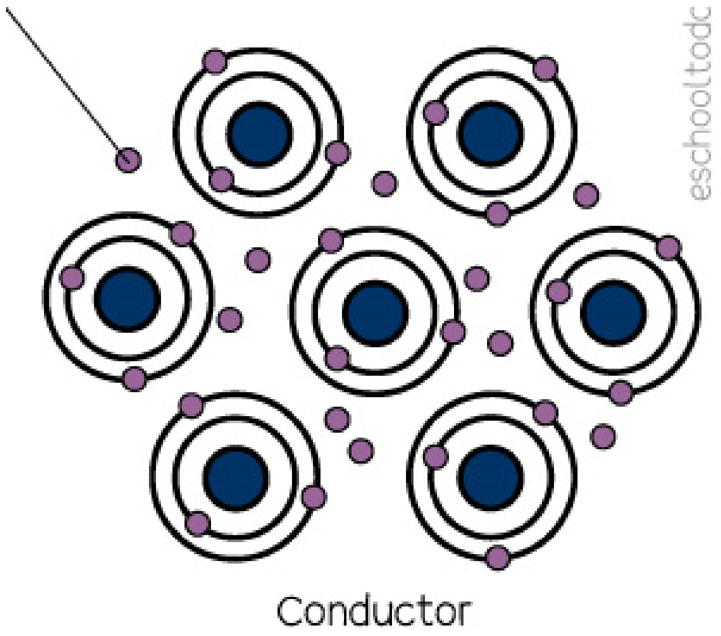
Atomic Structure

- In a single atom, electrons occupy shells (discrete energy levels).
- In solids, these levels overlap and form continuous energy bands.
- The valence band holds bound electrons.
- The conduction band holds electrons free to move.
- The band gap is the energy needed to jump from the valence to conduction band.



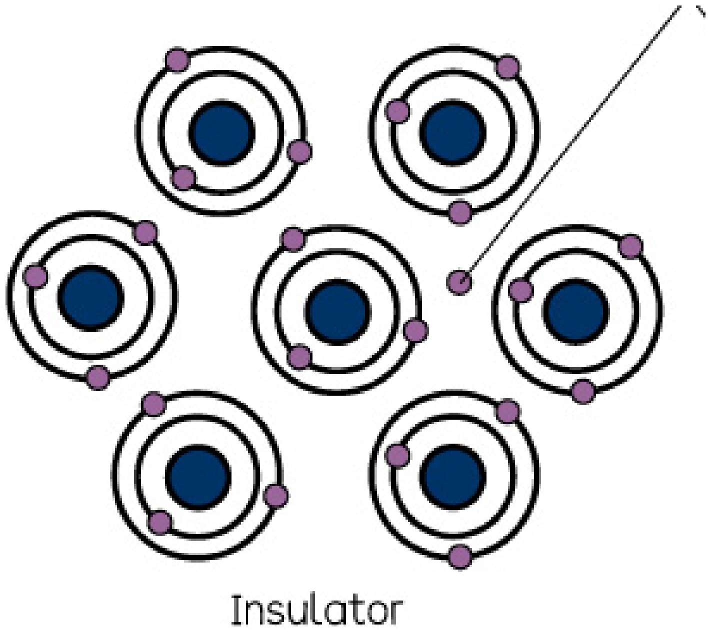
Metals

- In metals the conduction band overlaps, so electrons are already free to move.
- These delocalised electrons form an electron sea around positive ion cores.
- No voltage → random motion, no net current.
- Voltage applied → electrons drift → electric current.



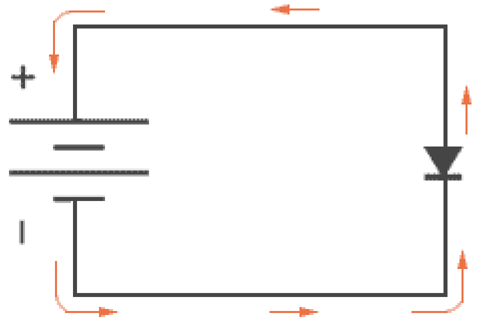
Insulators

- Atoms hold electrons tightly in their outer shells.
- The valence band is full and separated from the conduction band by a large band gap.
- Electrons cannot move freely → no conduction under normal conditions. (blocks electric current)
- Examples: glass, rubber, plastic, wood.
- Insulators are used to stop current flow and provide safety in circuits.



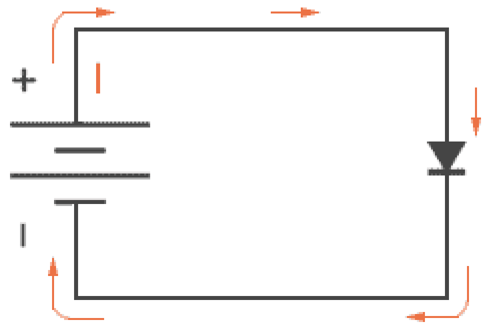
Conventional vs Electron Flow

- **Electron Flow**
  - Actual physical movement of electrons.
  - Electrons drift from negative (–) to positive (+) terminal.
  - Matches what’s really happening in the conductor.



Electron Current

- **Conventional Current Flow**
  - Defined historically before electrons were discovered.
  - Current assumed to flow from positive (+) to negative (–).
  - Still used today in circuit diagrams and engineering.



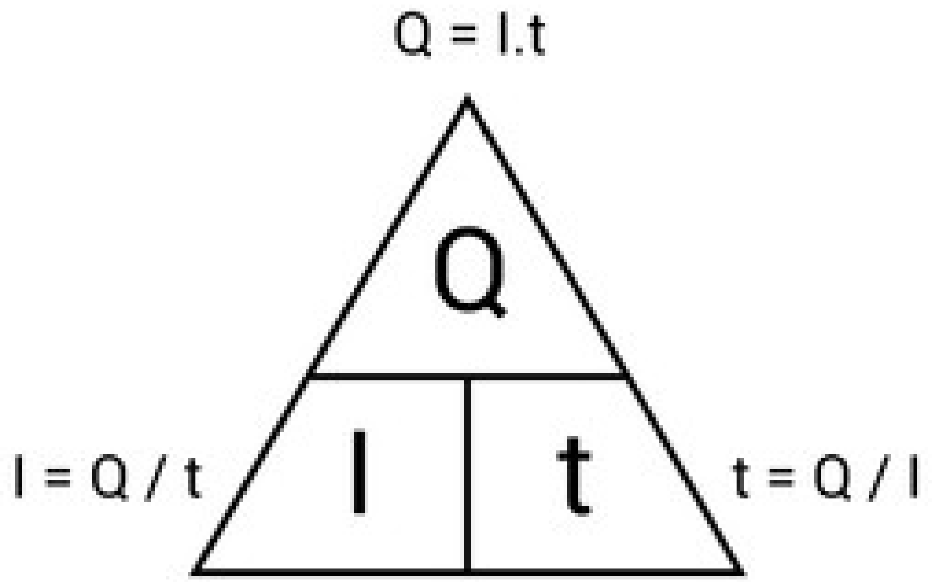
Conventional Current

Charge

- We measure charge (Q) in coulombs (C)

- Electron charge is $1.6 * 10^{-19}$ C

- $Q = I \ * t$ (charge = current * time)



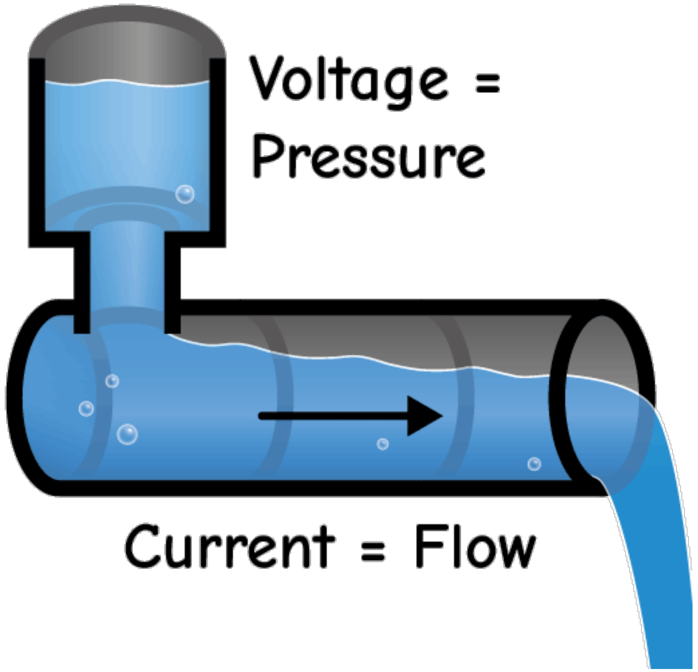
Current

- Current is the flow of charge per second
- It has the symbol I with the unit Ampere (A)

Analogy

- Like the flow of water in a pipe → how much passes a point each second.
- Wider pipe = less resistance → more flow.
- Narrow pipe = more resistance → less flow.

$$I = \frac{Q}{t}$$



Voltage

- Voltage is the energy per unit charge

- It has the symbol V with the unit Volt (V)

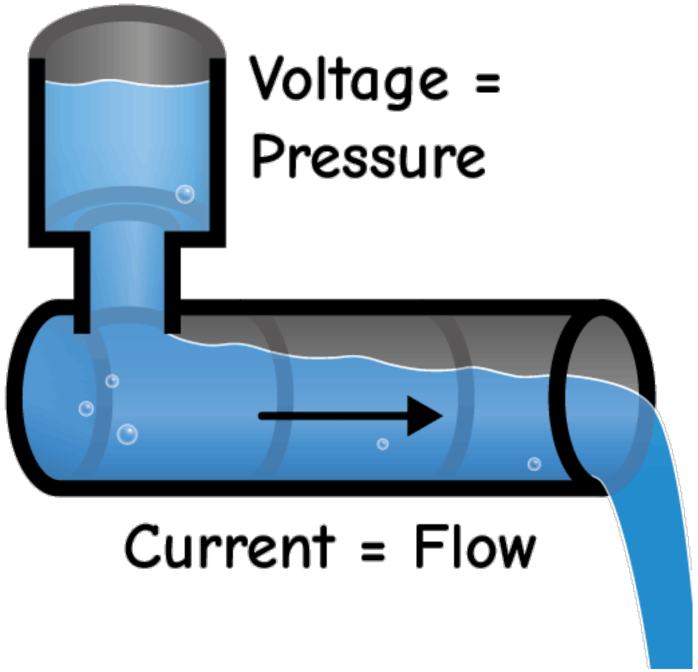
Analogy

- Like water pressure pushing water through a pipe.

- High voltage = each charge carries more energy.

- Source of voltage: batteries, power supplies, generators.

$$V = \frac{W}{Q}$$

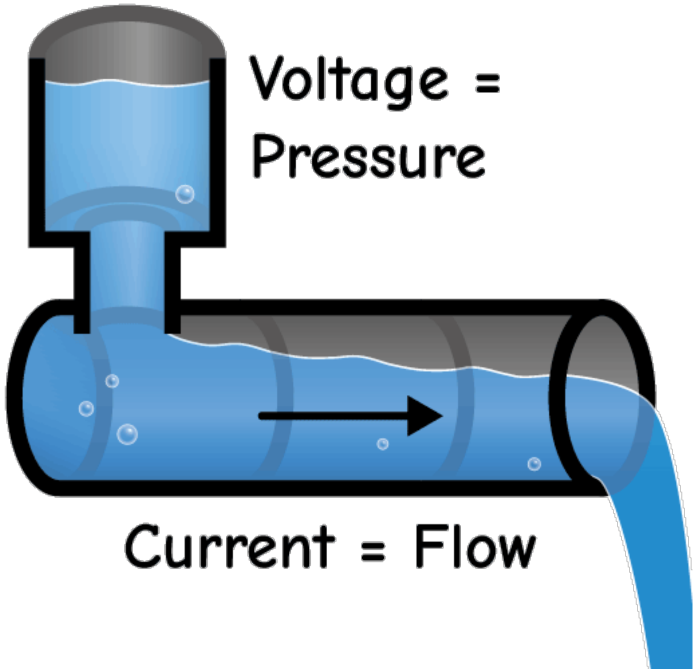


Resistance

- Resistance is the opposition to current flow
- It has the symbol R with the unit Ohm (Ω)

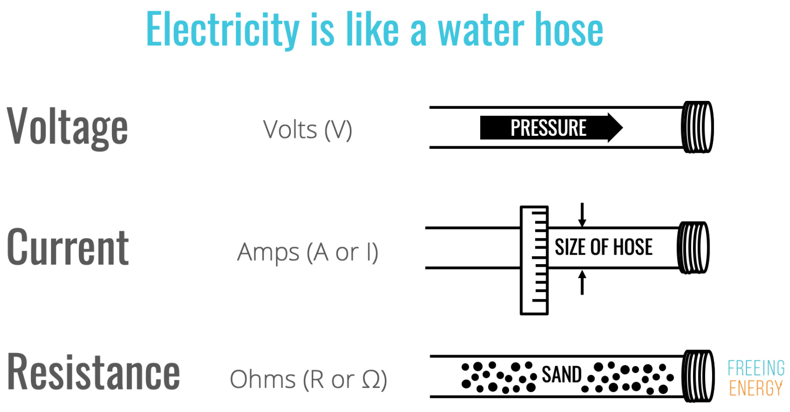
Analogy

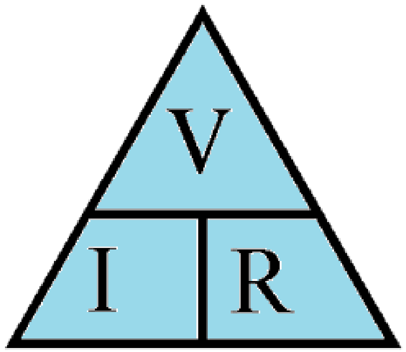
- Like a **narrow pipe** restricting water flow.
- Factors affecting resistance:
  - Material (copper vs rubber)
  - Length (longer wire = more resistance)
  - Thickness (thicker wire = less resistance)
  - Temperature (hotter wire = more resistance)



V = IR

- Ohm’s Law links voltage (V), current (I), and resistance (R).
- V=IR only really works for DC circuits





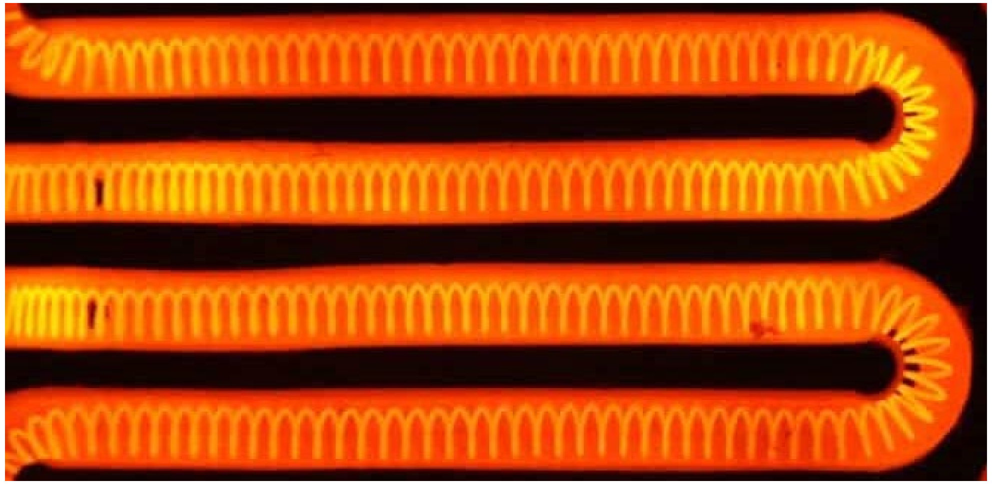
$V = I \times R$

$I = V / R$

$R = V / I$

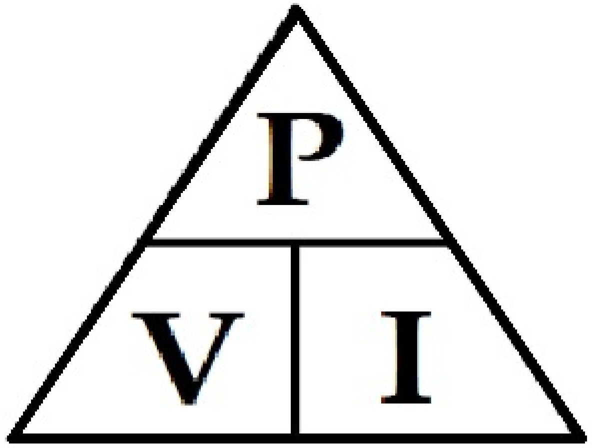
Energy

- Energy is the ability to do work or cause change.
- It has the symbol E and the unit Joule (J)
- It has the formula: $$E = V \times I \times t$$
- Where:
  - V = Voltage (volts)
  - I = Current (amps)
  - t = Time (seconds)
- Examples:
  - A 60W bulb lit for 1 hour uses 216,000J.
  - Phone battery stores energy in the range of 10,000–15,000 J.



Power

- Power is the rate of energy transfer.
- It has the symbol P and the units Watts (W)
- Higher voltage or higher current → more power delivered.
- Power tells us how much energy a device uses per second.
- Examples:
  - Phone charger ≈ 10 W
  - Kettle ≈ 2000 W
  - Light bulb ≈ 60 W



Electric Force

- There are a few rules which dictate how electricity functions
- Electric force or Coulomb’s Law dictates:
  - Like charges repel, unlike charges attract
  - Force gets stronger if charges are larger or closer
- The force is equivalent to the equation:

$$F = k_e \frac{q_1 q_2}{r^2}$$

- Where:
  - F is the force (newtons, N)
  - q_1 and q_2 are the charges (coulombs, C)
  - R is the distance between them (metres, m)
  - K_e is coulombs constant which is $8.99 * 10^9$