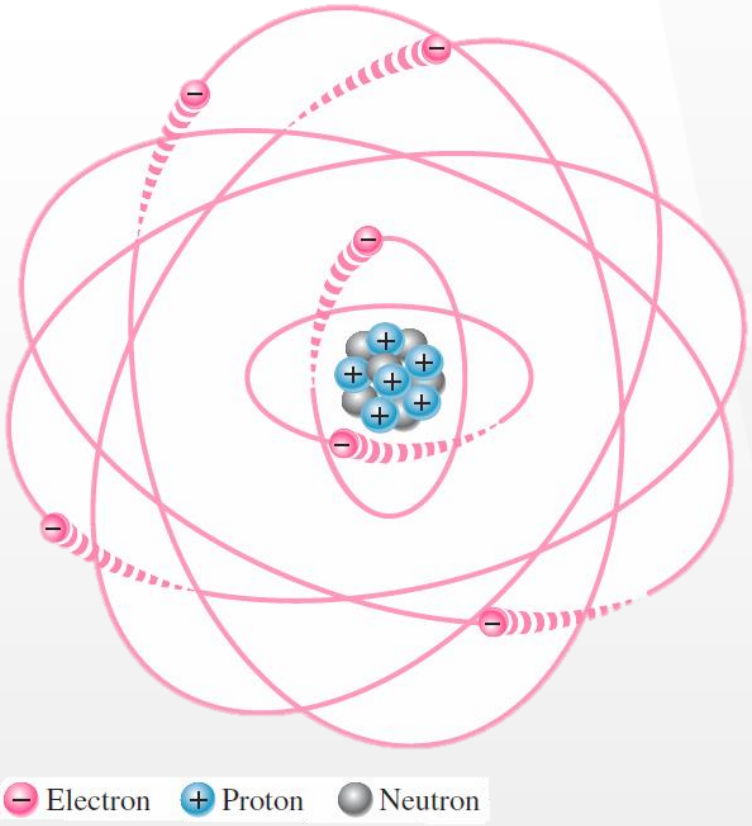
Chapter 2: Voltage, Current, and Resistance

Instructor: Jean-François MILLITHALER

http://faculty.uml.edu/JeanFrancois_Millithaler/FunElec/Spring2017

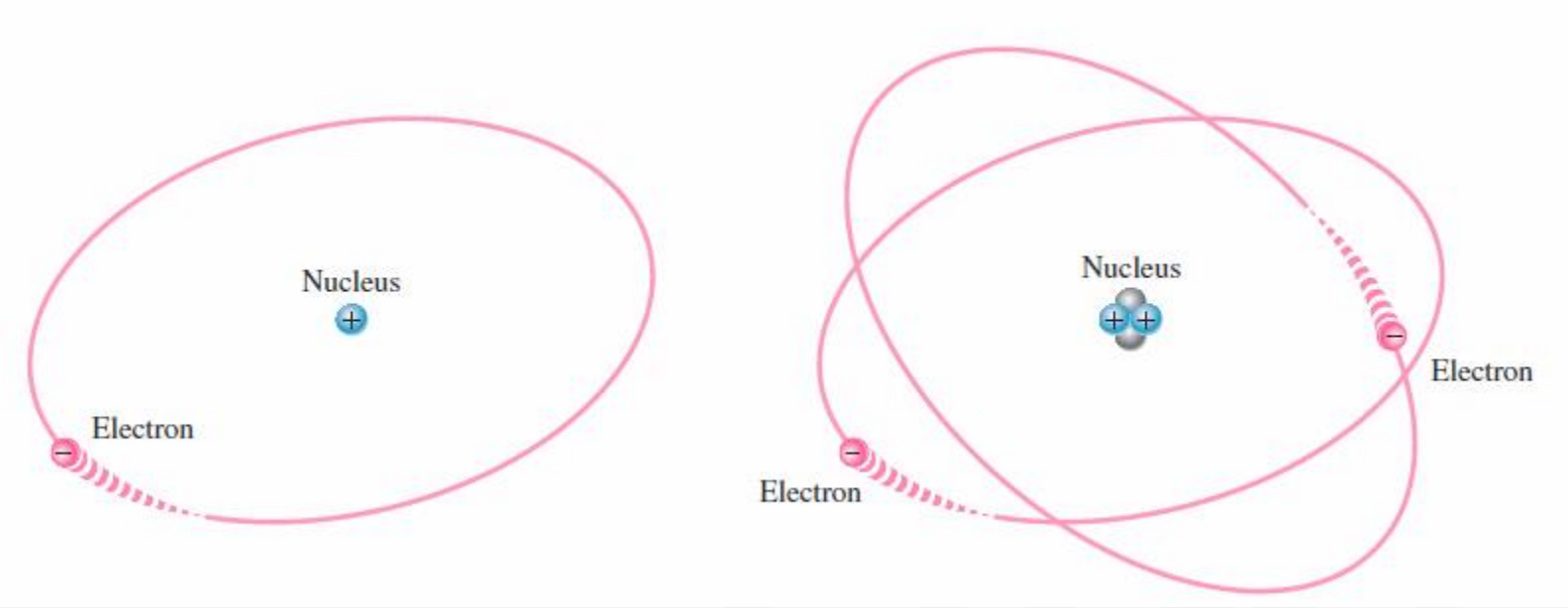
Atom

Visualization of atomic structure



- **Nucleus**: positively charged (protons and neutrons)
- **Electrons**: negatively charged
- Atomic number = number of protons
- # electrons = # protons

Atoms

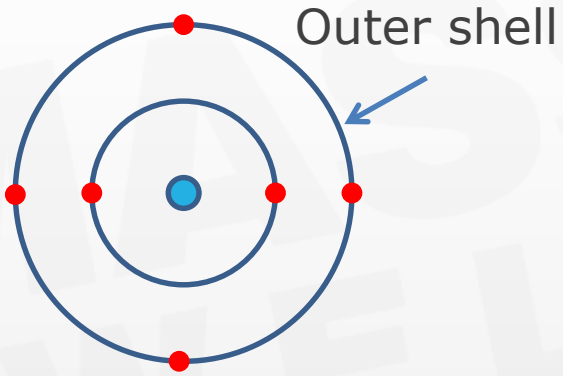


Hydrogen atom

Helium atom

Shells

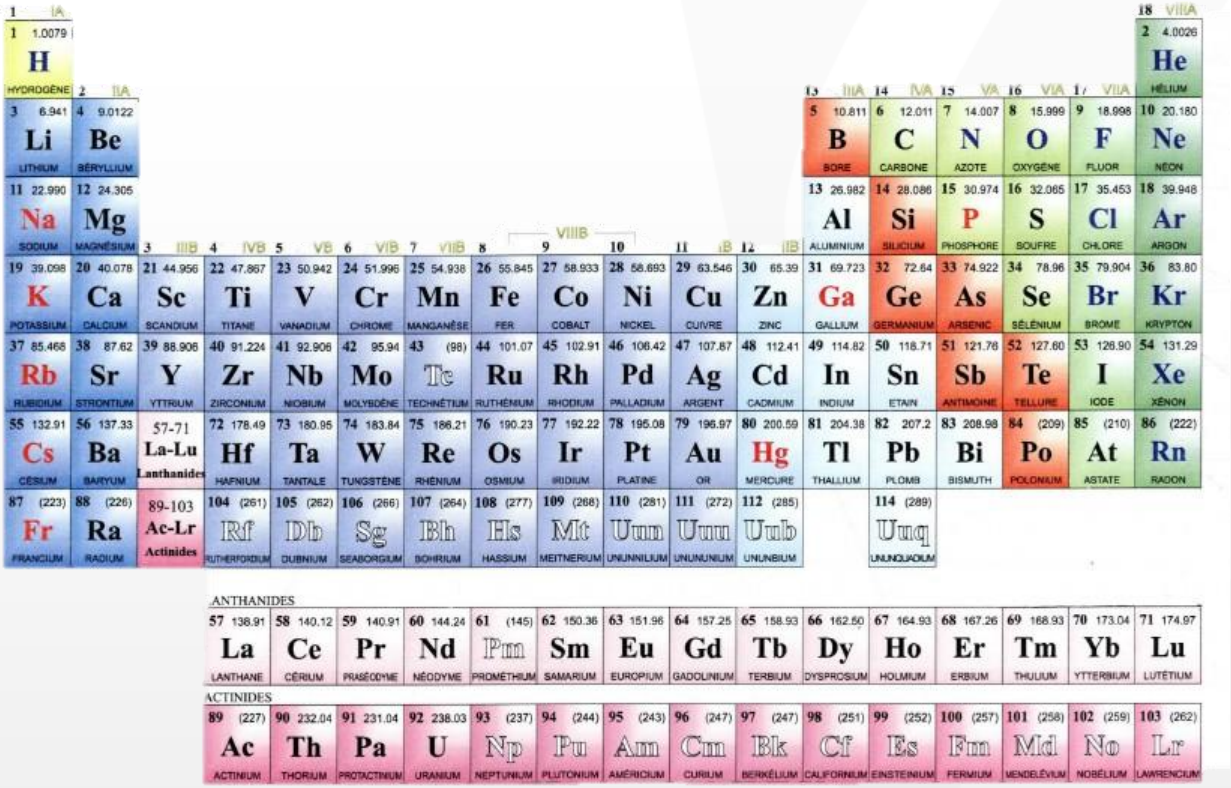
- Electrons are orbiting at different energy levels
- They are called shells
- They allow a fixed number of electrons ($2N^2$)
  - Shell 1 allows $2x1^2 = 2\ e^-$
  - Shell 2 allows $2x2^2 = 8\ e^-$
  - Shell 3 allows $2x3^2 = 18\ e^-$
  - Next is more complicated …



- Electrons in the outer shell (valence shell) are involved in chemical reactions and they account for electrical and thermal conductivity in metals

Mandeleïv Table

Dimitri Ivanovitch Mandeleïv, Russian scientist, 1834-1907



Atoms are looking for the most stable configuration

Atoms can become ions

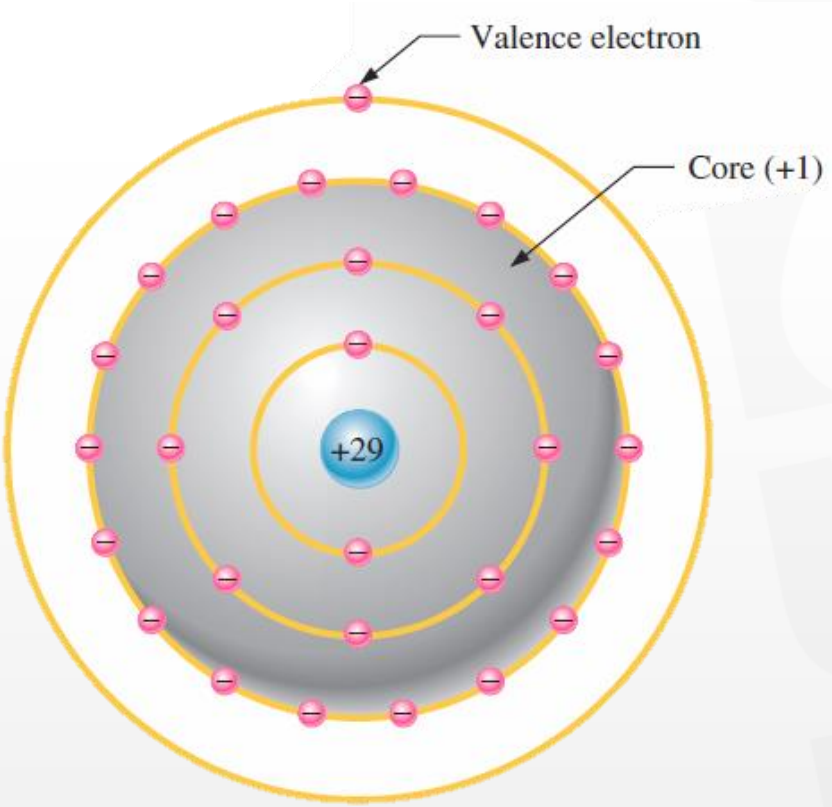
Ex: H ➡ H^+

Conductors

Semiconductors

Insulators

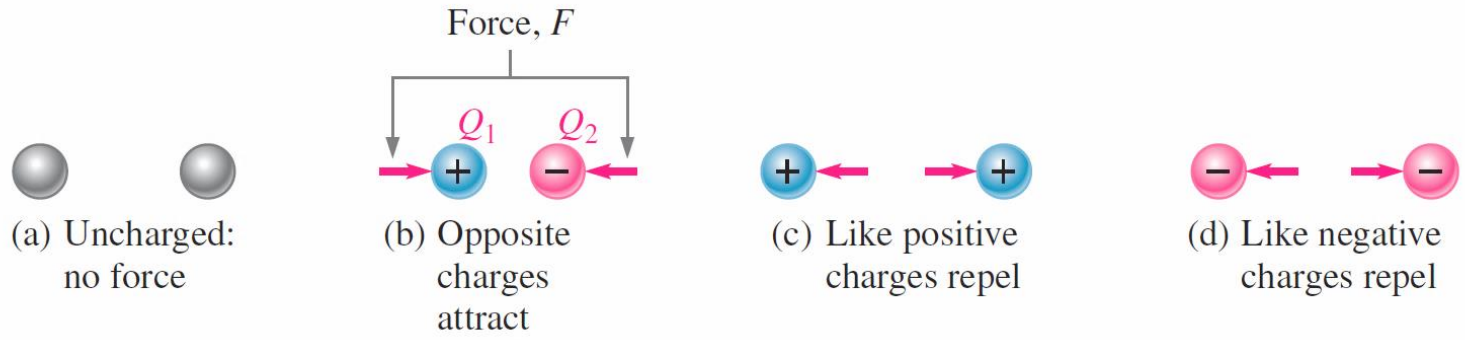
Copper atom



- Inner shell = Core
- Outer shell: 1 e^-
- With energy this e^- can move freely
- Copper = excellent conductor

Electrical charge

- There is a force (F) between electrical charges.



- The force is directly proportional to charge.
- The force is inversely proportional to square of distance.

Coulomb: the unit of charge

Charles Augustin Coulomb, French scientist, 1736-1806

- One **coulomb** is the total charge possessed by 6.25×10^{18} e^-
- Charge of a single e^- = 1.6×10^{-19} C
- Total charge $Q = \frac{number\ of\ e^-}{6.25 \times 10^{18} e^-/C}$

Voltage

Alessandro Volta, Italian scientist, 1745-1827

- Voltage = energy per unit of charge

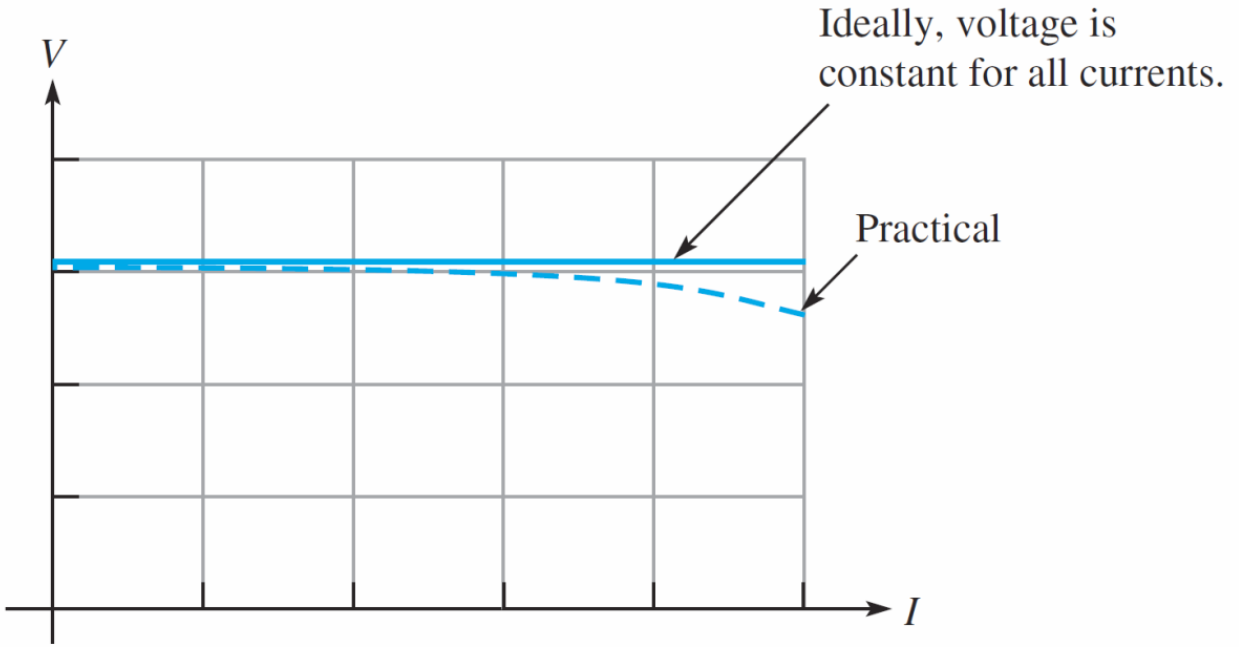
$$V = \frac{W}{Q}$$

- V is voltage in volts, W is energy in joules (J), and Q is charge in coulombs (C).

- One volt is the potential difference (voltage) between two points when one joule of energy is used to move one coulomb of charge from one point to the other.

Voltage

- Ideal voltage source can provide a constant voltage
- Doesn't exist but can be closely approximated in practice

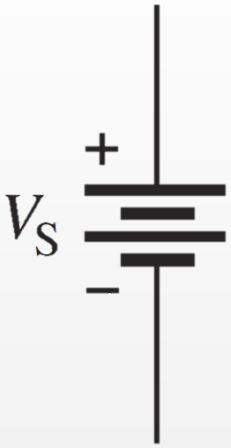


Voltage source graph

Voltage

Batteries and Sources

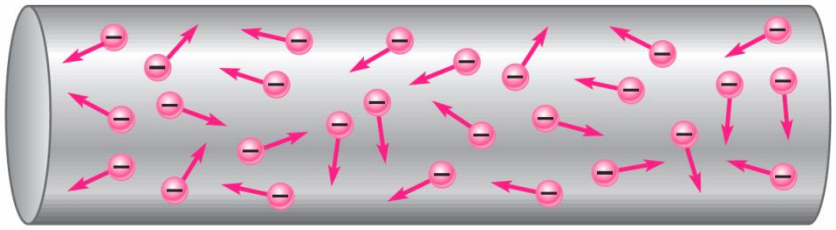
- Voltage is responsible for establishing current



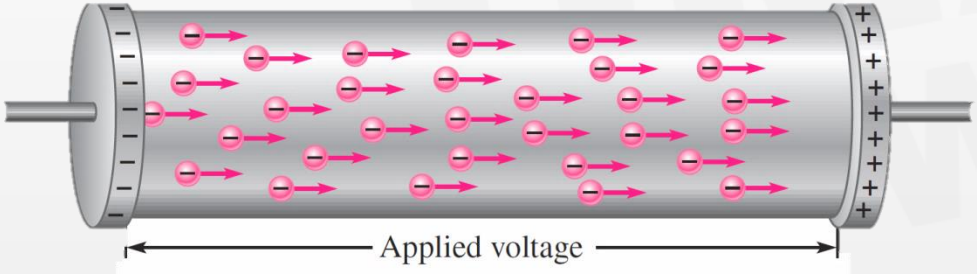
Symbol for dc voltage sources

Current

André Marie Ampère, French scientist, 1775-1836



- Random motion of free electrons in a material



- Electrons flow from negative to positive when a voltage is applied across a conductive material

Current

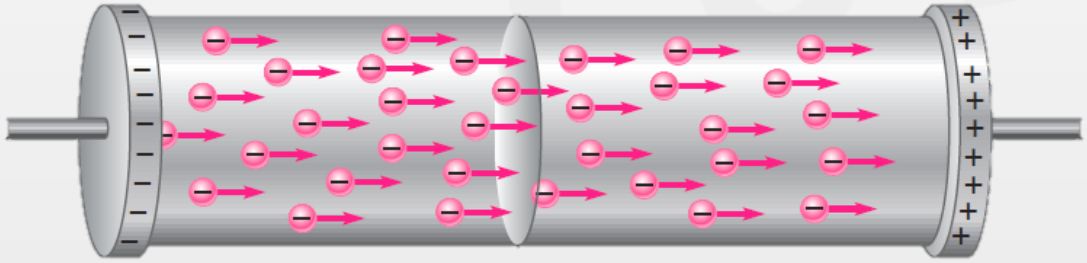
Ampere: the unit of current

- Electrical current is the rate of flow of charge

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

- I is current in amperes (A), Q is the charge of the electrons in coulombs (C), and t is time in seconds (s)

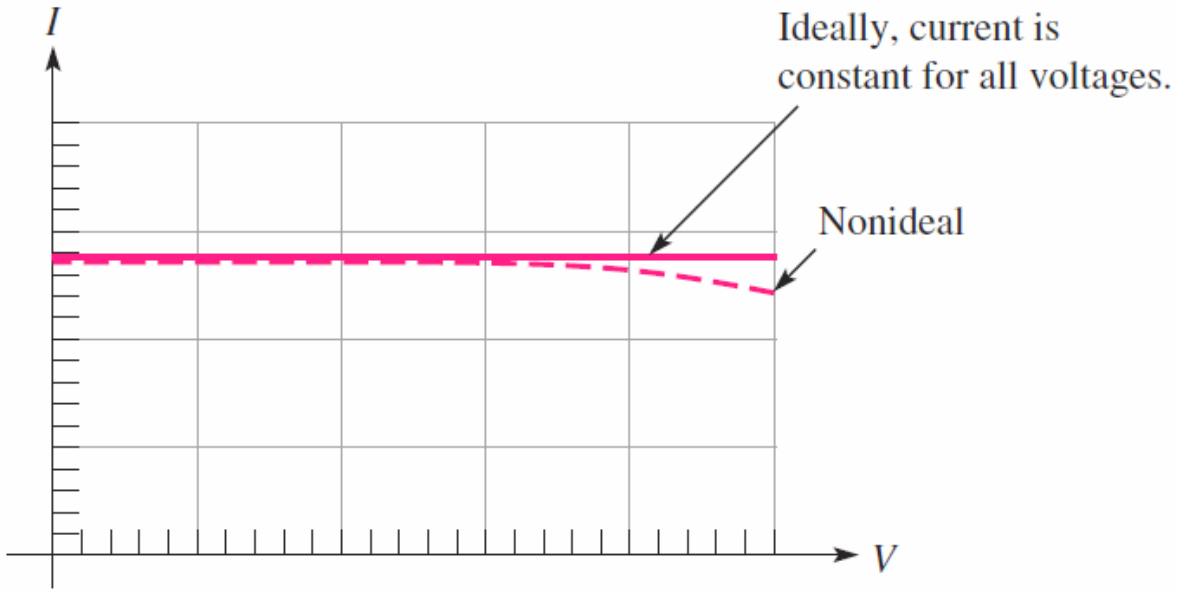
- One **ampere** (1 A) is the amount of current that exists when a number of electrons having a total charge of one coulomb (1 C) move through a given cross-sectional area in one second (1 s).



Current

- An ideal current source can provide a constant current in any load.
- Does not exist but can approximated in practice

Symbol

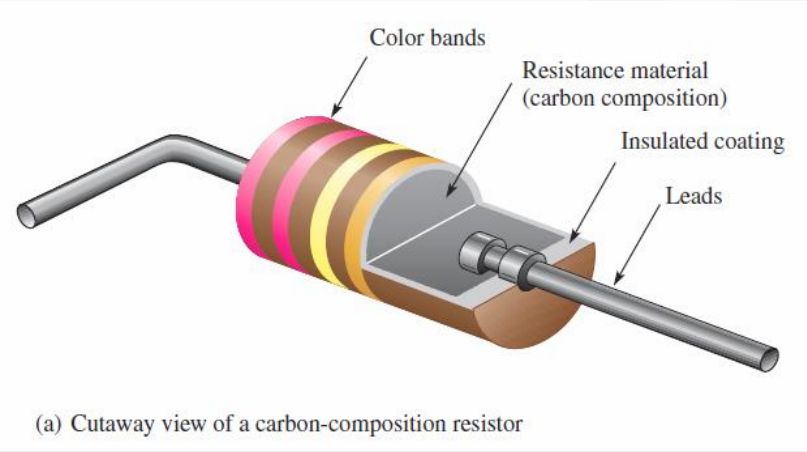


I-V characteristic

Resistance

Georg Simon Ohm, German scientist, 1787-1854

- **Resistance** is the opposition to current
- One **ohm** (1 Ω) of resistance exists when there is one ampere (1 A) of current in a material with one volt (1 V) applied across the material



(a) Cutaway view of a carbon-composition resistor

Conductance

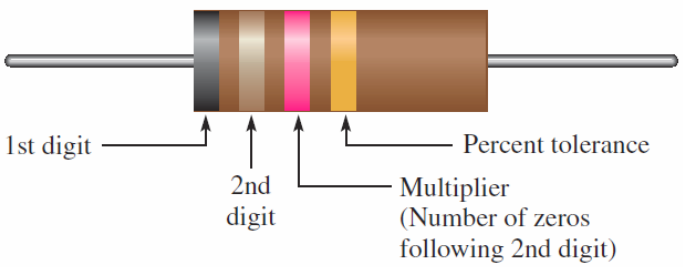
Ernst Werner von Siemens, Russian scientist, 1816-1892

- **Conductance** is the reciprocal of resistance

$$G = \frac{1}{R}$$

- The unit of conductance is the **siemens**, symbolized by **S**.

Resistance color-code



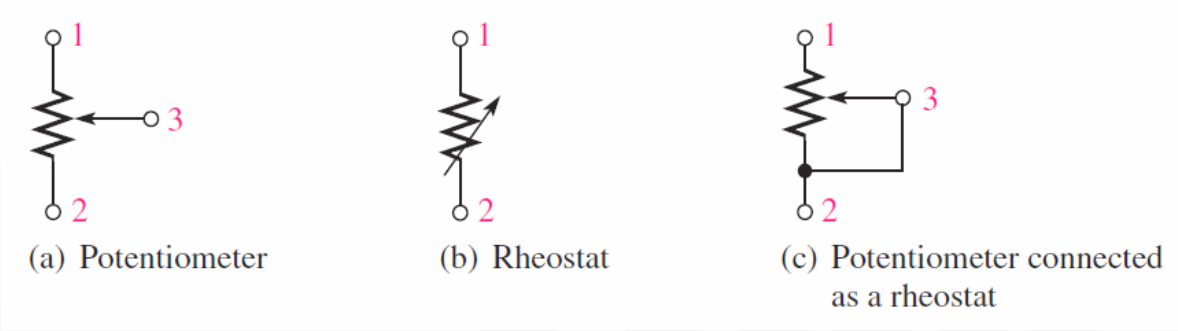
	Digit	Color
Resistance value, first three bands: First band—1st digit Second band—2nd digit *Third band—multiplier (number of zeros following the 2nd digit)	0	Black
	1	Brown
	2	Red
	3	Orange
	4	Yellow
	5	Green
	6	Blue
	7	Violet
	8	Gray
	9	White
Fourth band—tolerance	±5%	Gold
	±10%	Silver

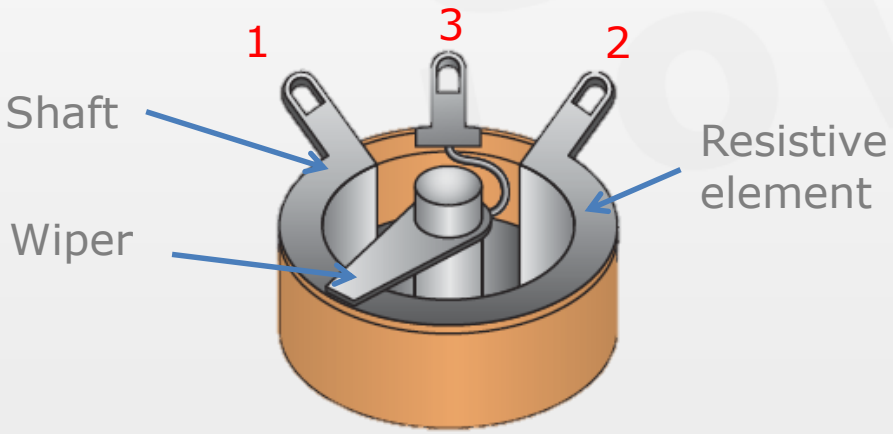
Mnemonic phrase

Better Be Right Or Your Great Big Venture Goes West

Variable resistors

- Variable resistors include the potentiometer and rheostat. The center terminal of a variable resistor is connected to the wiper.

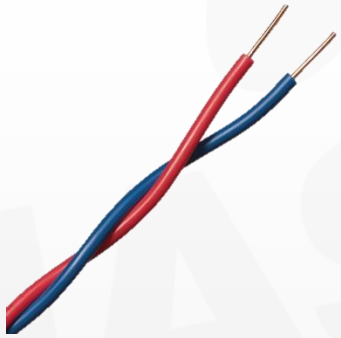




Wire resistance

- Resistance of wire is:

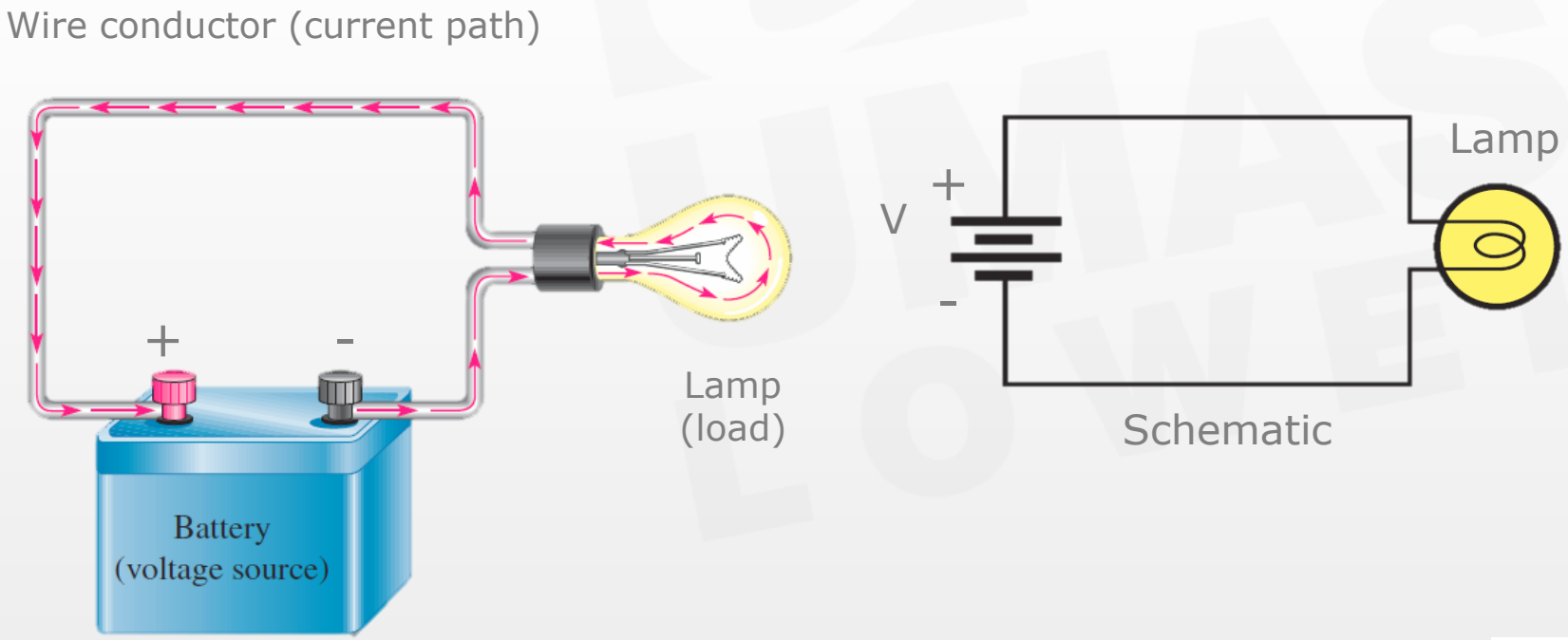
$$R = \frac{\rho l}{A}$$



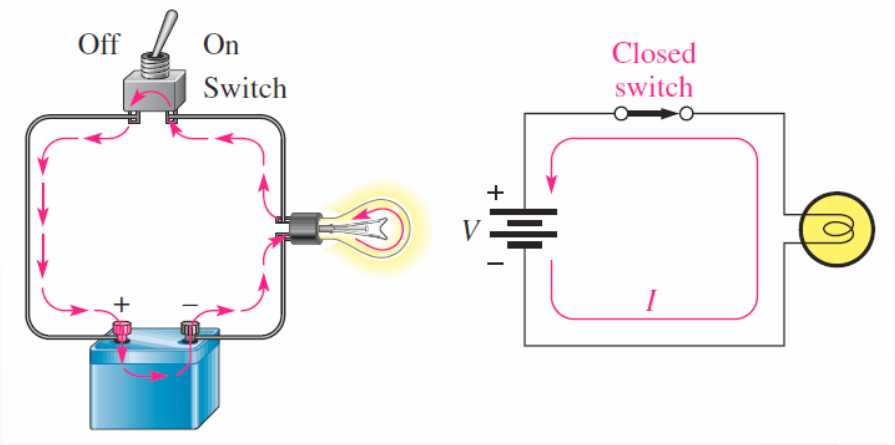
- ρ is the resistivity in Ω.m, l the length in meter (m), and A is the cross sectional area in m^2

Circuits

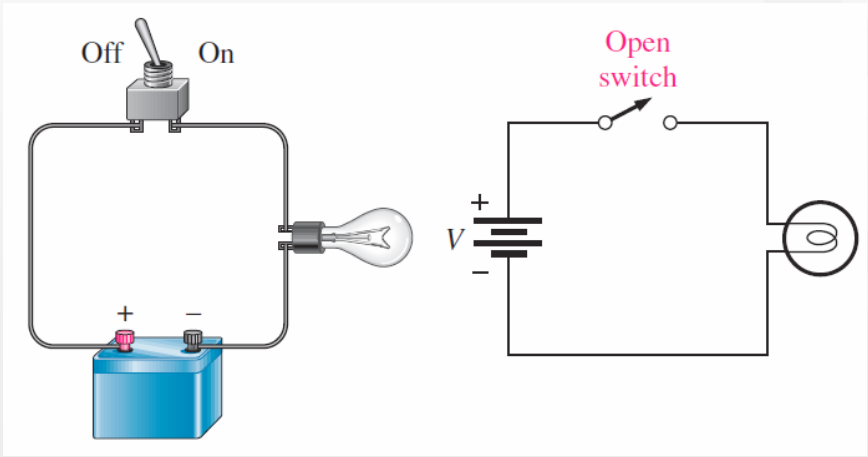
Voltage source + Load + path for current



Circuit and switch

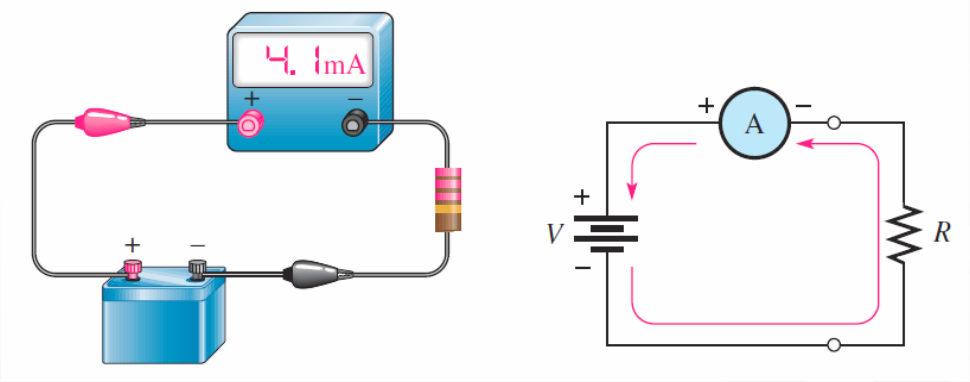


- Switch ON circuit is closed

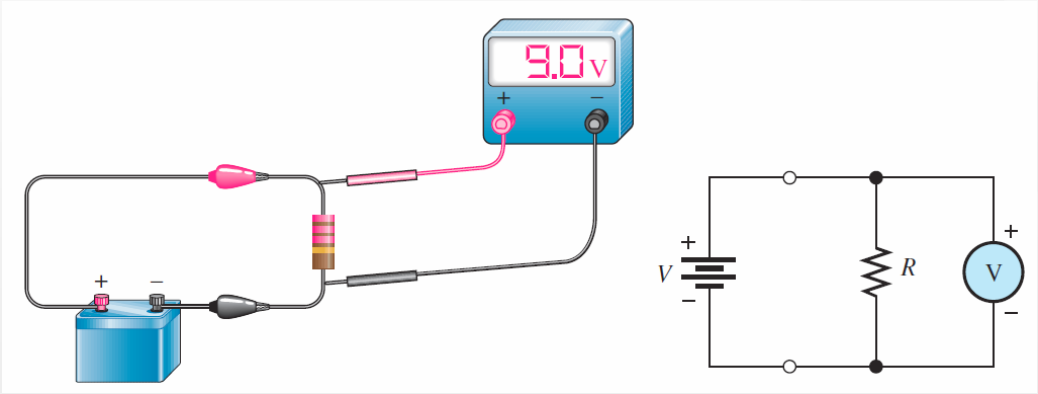


- Switch OFF circuit is open

Ammeter & Voltmeter



- Ammeter in series



- Voltmeter in parallel