ECE 101 Exploring Electrical Engineering

- ***Circuits 1***
  - Electric Charge
  - Voltage
  - Current
  - Resistance
  - Power

Many of the slides are modified from course notes by P.K. Wong and M. Holtzman

Electric Charge

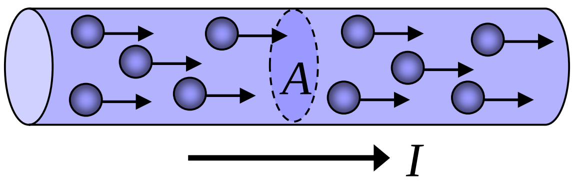
- Particles can be neutral or charged
- Particle's electric charge (q or Q) affects its motion in the presence of changes in electric potential (aka electric field)
- Charge can be positive or negative.
- SI unit for charge: coulomb (1 C = 1 A · s)
- Charge of a single electron is ≈ 1.602×10^{-19} C.

Voltage

- If there is a difference in electric potential between two spatial points, then a non-zero electric field will exist between them.
- This potential difference causes charged particles to move.
- The voltage *V* is the amount of work done in moving a charge.
- SI unit for voltage: volt (V) (1 V = 1 J/C)
- Voltage represents external energy supplied to circuit

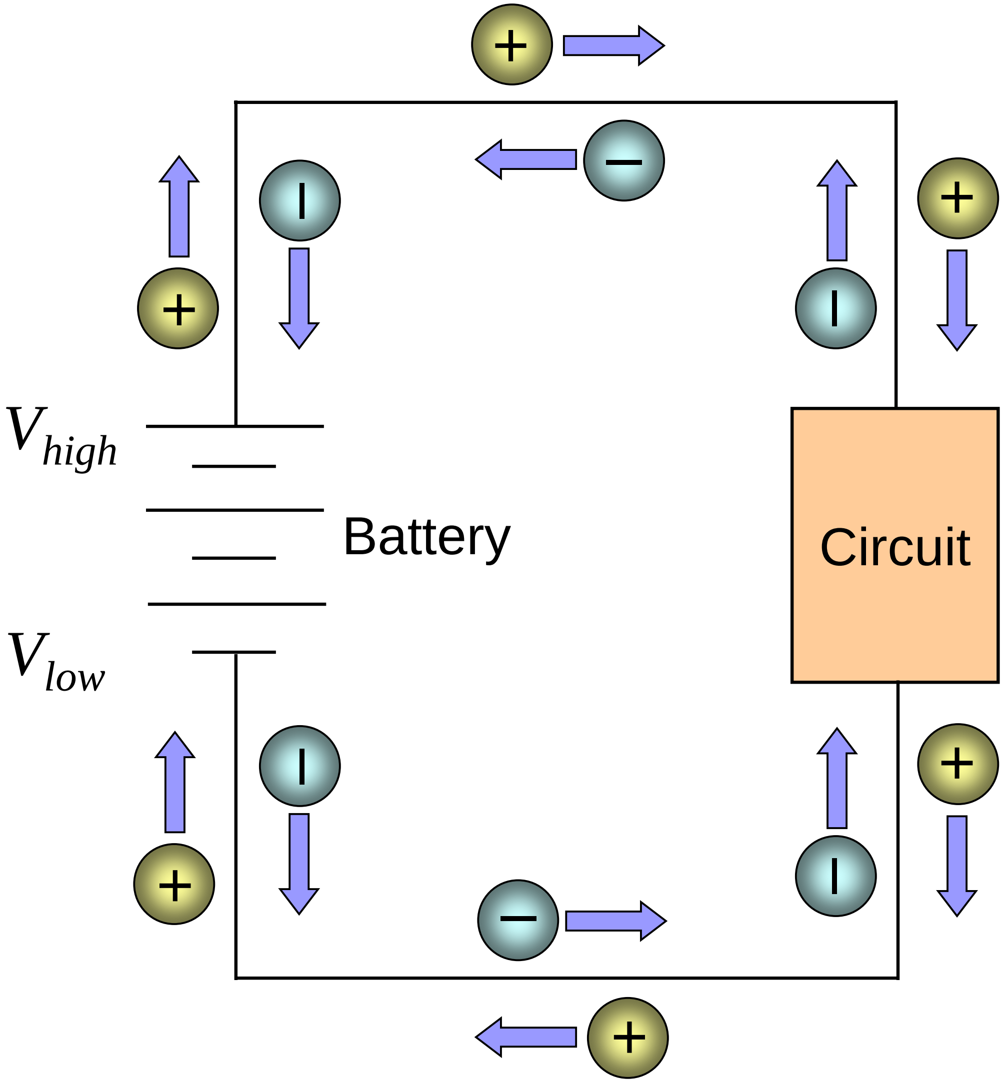
Current

- Electric current I is the rate at which charge flows through a cross-sectional area A.



Average: $I_{ave} = \frac{\Delta q}{\Delta t}$ Instantaneous: $I = \frac{dq}{dt}$

  - Charge carriers: electrons (–), ions & holes (+)
  - Direct current (DC) $\longrightarrow$ Carriers move in one direction only.
  - Alternating current (AC) $\longrightarrow$ Carrier direction varies periodically with time.
  - In circuit analysis, conventional current is assumed, even if electrons are the primary charge carriers.
- SI unit for current: ampere (A) (1 A = 1 C/s)



Positive charge moving:

From V_{high} to V_{low}

$\rightarrow$ Energy is dissipated

From V_{low} to V_{high}

$\rightarrow$ Battery supplies energy

Negative charge moving:

From V_{low} to V_{high}

$\rightarrow$ Energy is dissipated

From V_{high} to V_{low}

$\rightarrow$ Battery supplies energy

Resistance

- The resistance R is a measure of the opposition to direct current through a material.

- Interactions of charge carriers with the structure of the material impedes the current.
- Classes of materials:
  - Conductor (low R : e.g., ??)
  - Insulator (high R : e.g., ??)
  - Semiconductor (intermediate R, e.g. ??)

- SI unit for resistance: ohm (Ω)

Ohm's Law

- Current I through some materials is directly proportional to the potential difference ΔV between its ends.

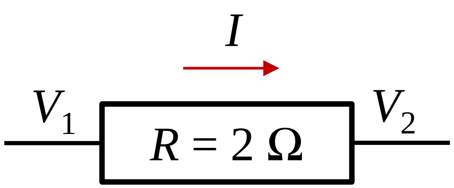
  $I \propto \Delta V$

- The resistance R is defined as: $$R = \frac{\Delta V}{I}$$

- The general form of Ohm's Law is:

$$\Delta V = IR \qquad R = \frac{\Delta V}{I} \qquad I = \frac{\Delta V}{R}$$

Example:



$$I = \frac{\Delta V}{R} = \frac{V_1 - V_2}{R}$$

V_1	V_2	I
5 V	0 V	2.5 A
5 V	2 V	1.5 A
2 V	5 V	–1.5 A
1 V	–3 V	2 A
3 V	3 V	0 A

If the potential difference ΔV is zero, no current flows through the resistor.

Note:

It is understood that Ohm's Law refers to a potential difference. The Δ is usually omitted.

$$V = IR \qquad R = \frac{V}{I} \qquad I = \frac{V}{R}$$

Application of Ohm's Law

- Given: Material of known resistance R
  Voltage V is applied across the material
  Result: Current $I = V / R$ will flow through it.

- Given: Material of known resistance R
  Known current I flowing through it
  Result: Voltage $V = I \cdot R$ exists across the material (known as a "voltage drop").

- Given: Known voltage V across the material
  Known current I through the material
  Result: Resistance of the material is $R = V / I$.

Power

- Power is the rate at which energy is generated or dissipated by an electrical element.

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

where

V = Voltage (V or J/C)

I = Current (A or C/s)

R = Resistance (Ω)

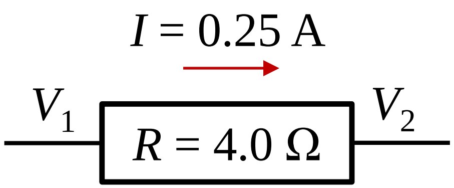
Important because:

Measures output of a circuit (sound, light, heat, …)

Physical component can handle only a certain amount of power

- SI unit for power: watt (W) (1 W = 1 J/s)

Example:



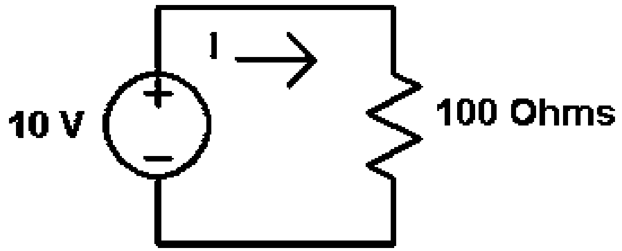
What is the voltage drop across the resistor?

$$V_{drop} = IR = (0.25\ \mathrm{A})(4.0\ \Omega) = 1.0\ \mathrm{V}$$

What is the power dissipated by the resistor?

$$P = I^2 R = (0.25\ \mathrm{A})^2 (4.0\ \Omega) = 0.25\ \mathrm{W}$$

Example:



- Find I and P.

Questions:

- We have $P=V^2/R$ and I^2R. If R is increased, does P increase or decrease?
- Which has higher resistance, a 60 W bulb or a 120 W bulb?
- Which has a thicker filament, a 60 W bulb or a 120 W bulb?

Hint: Household power is supplied with a fixed voltage. The current varies depending on the "load", the resistance of whatever is connected to the source.