11.3 Resistance and Ohm’s Law

Resistance: the opposition to motion of charge through a conductor. Water analogue: rocks in a river slow down the current.

Units of resistance = Ohms ($\Omega$)

Unit analysis (kinda weird):

$$ R = \frac{V}{I} = \frac{F}{A} = \frac{kg \cdot m^2 \cdot s}{C^2} = \frac{kg \cdot m^2}{C^2 \cdot s} $$

Circuit Components & Symbols 3
Resistors - block current flow.

Symbol: $$\text{Symbol: }$$

Demo resistor types.

Terminal Voltage & Internal Resistance
Batteries aren't perfect conductors: some power is lost within the battery due to internal resistance (ever felt a hot battery?)

This gives rise to terminal voltage: the voltage measured at the terminals of a battery (duh);

BUT, when internal resistance is accounted for, maximum optimal voltage is larger (but not usable).

Ohm’s Law
Voltage, current, and resistance are unified through Ohm's Law, named after Georg Simon Ohm, a German physicist and mathematician, who discovered this relation in the early 1800's.

Mathematically (Resource P. 7)

$$ V = IR $$

$$ I = \text{Volts (V)} $$

$$ I = \text{Current (A)} $$

$$ R = \text{Ohms (}$\Omega$)$

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

AP Equation

1. Current Example
Calculate the current in the following circuit:

$$ I = ?? \text{ A} $$

$$ V = 12 \text{ V} $$

$$ R = 4.5 \Omega $$

$$ I = \frac{V}{R} = \frac{12 \text{ V}}{4.5 \Omega} = 2.7 \text{ A} $$
2. Resistance Example

Calculate the resistance in the following circuit:

\[ R = \frac{V}{I} = \frac{1.50 \text{ V}}{0.140 \text{ A}} = 10.7 \Omega \]

3. Voltage Example

Calculate the voltage in the following circuit:

\[ V = IR = 0.260 \text{ A} \times 105 \Omega = 27.3 \text{ V} \]

Material Properties

Substances in this class will be considered ‘ohmic’ – having the same resistance over a large range of voltages.

A plot of voltage vs. current produces a straight line for ohmic materials.

Nonohmic substances have differing resistances as voltage changes.

Resistance Factors

Many things affect resistance of conductors:

Type of material,

length (proportional: longer = greater resistance),

cross sectional area (inversely proportional: larger area = lower resistance),

temperature (proportional).

Resistivity

Atomic properties of a material influence the resistance of a component also.

For any material, resistance is calculated using:

\[ R = \frac{\rho l}{A} \]

(\(\rho\) = resistivity of material (\(\Omega\) m), \(l\) = length of material (m), \(A\) = cross sectional area (\(m^2\))

\[ \rho = \rho_0 (1 + \alpha \Delta T) \]

(\(\rho_0\) = resistivity at 20 °C, \(\alpha\) = coefficient of resistivity, \(\Delta T\) = temperature difference (°C))

Thermal Effects

As materials heat, resistivity (therefore resistance) increases.

Demo: Resistance of Hot Light Bulb!

Calculate the new resistivity of your substance using:
**Thermal Effects**
Resistivity and resistance are directly related:

\[ R = R_0 \left(1 + \alpha \Delta T\right) \]

- \( R_0 \): resistance at 20 °C
- \( \alpha \): coefficient of resistivity (R. 7)
- \( T \): temperature difference (°C)

**4. Resistivity Example**
What is the resistance of a tungsten filament at 1500 °C if its resistance is 9.5 Ω at 20°C?

\[
R = R_0 \left(1 + \alpha \Delta T\right) \\
= 9.5 \Omega \left(1 + 4.5E - 3/°C \bullet (1500°C - 20°C)\right) \\
= 73 \Omega
\]

**Superconductivity**
As materials cool, resistivity decreases. Some materials obtain a resistance of zero at low temperatures (called critical temperature). Applications for this are in super computers, where electric lines lose power in the form of heat.

**Superconductivity**
Meissner Effect – Current in superconductors makes magnets levitate. High-speed trains use this effect for smooth transport.

Some new materials have a critical temperature as high as 138 K (-222 °F). \( \text{YBa}_2\text{Cu}_3\text{O}_7 \) is the formula.

**Homework**
11.3 Problems
Due: Next Class