Lesson 7
Resistance

The resistance of an electrical conductor depends on four factors (see p. 603).

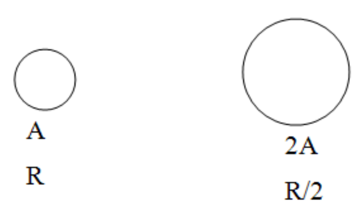
1. **Length**

- The longer the conductor the greater the resistance.
- Resistance varies directly as the length of the conductor ($R \alpha L$)

Example:
A certain piece of copper wire has a resistance of $2.0 \times 10^{-3}\ \Omega$. Another piece of copper wire with the same cross-sectional area, but twice the length will have what resistance?

2. **Cross-sectional area**

- The larger the cross-sectional area or thickness of the conductor, the less resistance it has.



- Resistance varies inversely as cross-sectional area

$$R \alpha \frac{1}{A}$$

- Gauge number of a wire indicates its cross-sectional area. A small gauge number corresponds to a large cross sectional area.

Example:
A 1.0 m piece of wire with a cross-sectional radius of 3.0 mm has a resistance of $9.0 \times 10^{-4}\ \Omega$. If the wire is stretched until its radius is reduced to 1.0 mm, what will be the resistance of a 1.0 m piece of stretched wire?

3. Type of Material

- Some materials are better conductors than others.
- Materials that are excellent conductors have many free electrons and a low resistance.
- Less efficient conductors have a higher resistance to electron flow.
- Silver, copper, gold – low resistance.
- Iron – higher resistance.
- General measure of the resistance of a substance is called the resistivity (ρ). If the resistivity is doubled, then the resistance is also doubled.

$$\frac{R_1}{R_2} = \frac{\rho_1}{\rho_2}$$

Example:
A conductor has a length of 2.0 m, a diameter of 2.0 mm and a resistance of 0.0040 Ω. Wire B of the same material has a length of 0.50 m, a diameter of 1.0 mm and what resistance?

4. **Temperature**

- Resistance of most materials is lower as the temperature drops.
- At extremely low temperatures (-270 °C) the resistance of some materials drops to 0. These are called superconductors. In recent years, high temperature superconducting materials have exhibited these properties at temperatures as high as -133 °C. The goal is to have transmission lines that carry electricity without energy loss. Currently there is a global race to produce a wire material that can carry currents at the highest possible temperature without losing superconducting properties.
- In semi-conductors the resistance gets higher as the temperature drops (eg. carbon, silicon, germanium).
- In general for ordinary materials, the greater the molecular motion at higher temperatures tends to increase the resistance (since moving charge is impeded by molecules).

If temperature is maintained at a constant value, we can mathematically link the other three factors.

Since $R \alpha L$ and $R \alpha \frac{1}{A}$

We can write,

$$R \alpha \frac{L}{A}$$

Or

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

where ρ is a proportionality constant called resistivity.

Resistivity (ρ) is different for every substance and has units of Ω·m since,

$$\rho = R\frac{L}{A} = \frac{\Omega \cdot m^2}{m} = \Omega \cdot m$$

There are tables of resistivities for different materials. The best conductors tend to have the smallest resistivities.

Example:
A current flows through a copper wire 1.8 m long an 1.2 mm in diameter. Find the resistance between the ends of the wire given the resistivity of copper is 1.72×10^{-8} Ω·m.