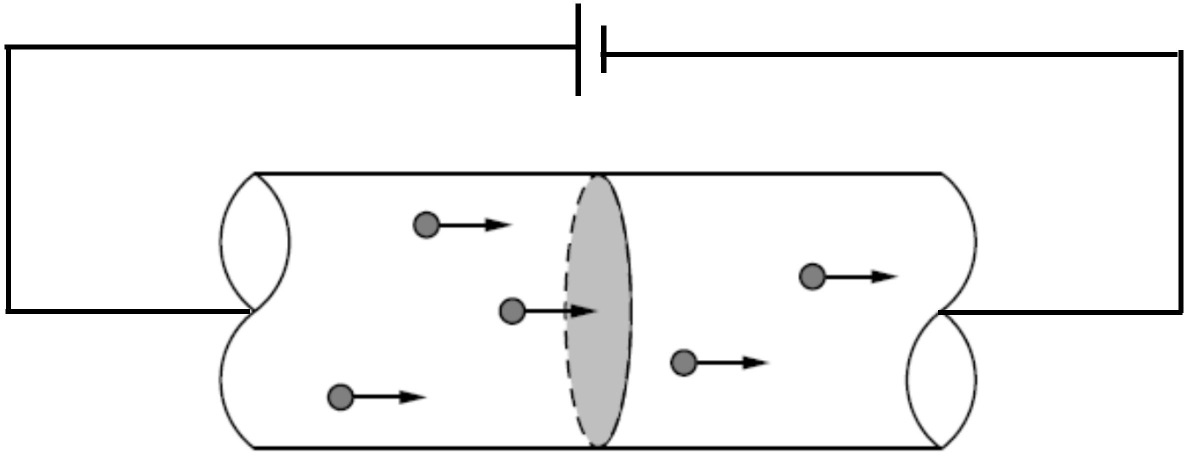
Current Electricity



If the potential difference is applied across the ends of the conductor, charged particles will move. The moving charges constitute an **electric current**.

Electric Current

The electric current (I) is defined as the charge passing through any cross-sectional area of a conductor per unit time. Mathematically, electric current is given by

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

where q is the charge passing through the area in a time t. The SI unit of charge is the **ampere** ($1A = 1C\ s^{-1}$).

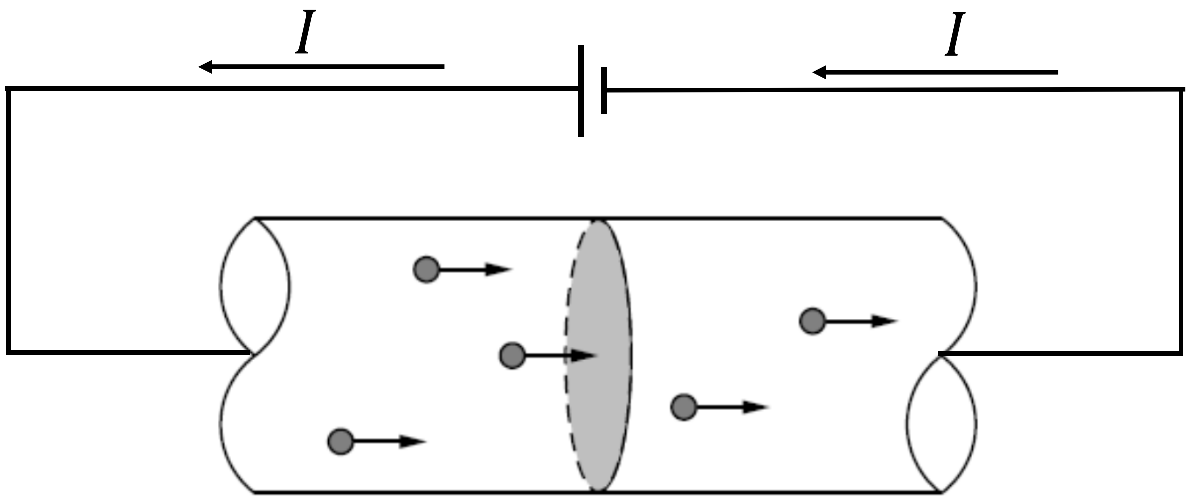
Direction of electric current

Good conductors of electricity are

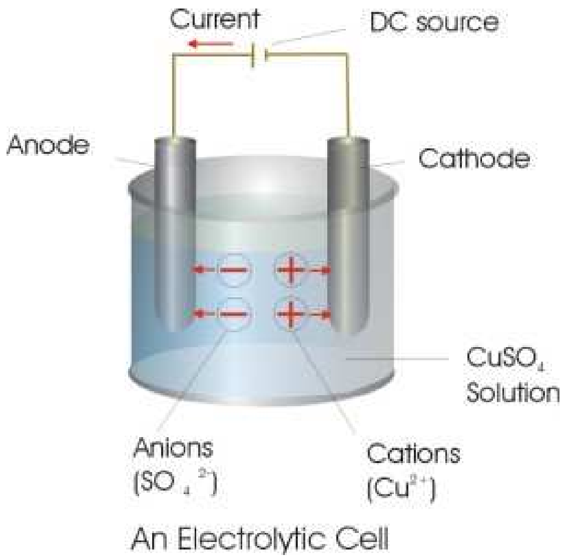
- Metals e.g. Copper wire
- Ionic solution/Electrolyte e.g. Table salt, acid
- Gas (plasma)

In gases and ionic solutions, a charge is carried by both **positive** and **negative** particles. On the other hand, electrons are the carriers of charge in metallic conductors.

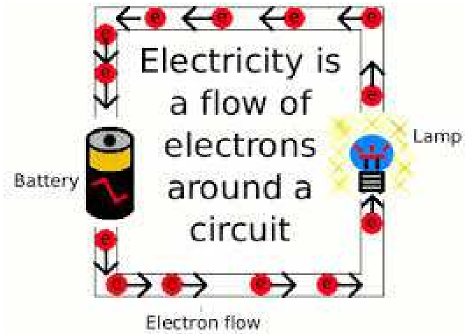
However, by convention, it was adopted that the direction of electric current is the direction in which a **positive charge** would move.



In a solution

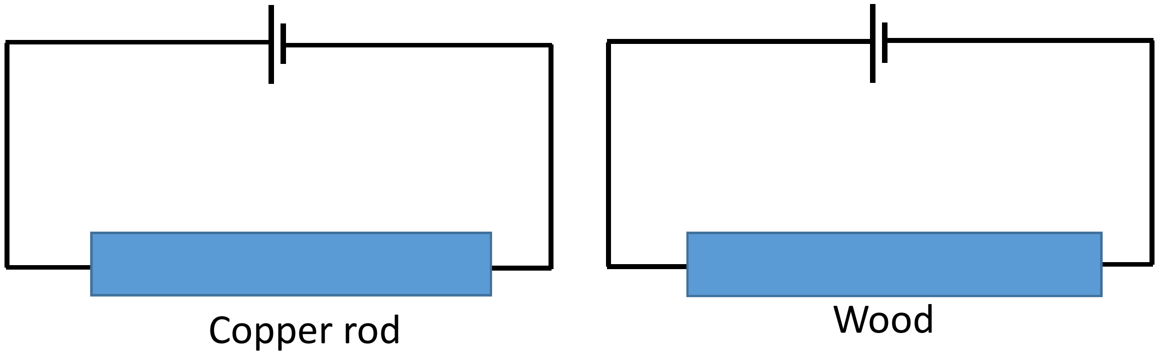


In a metallic conductor



Ohm's law

If the same potential difference is applied between the ends of a rod of copper and of a rod of wood, very different currents result. The characteristic of the conductor that enters here is its resistance.



Resistance

The resistance (R) of a material (resistor) is defined as the ratio of the potential difference V applied across a piece of the material to the current I through the material. We can quantify the resistance by using

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

This equation is called **Ohm's law**, which should be constant for a given material

The SI unit of resistance is the V A^{-1} or **Ohm**: 1V A^{-1} = 1 Ω.

For many materials (e.g. metals), the potential difference V across some part of the material is proportional to the current I flowing through it at constant temperature.

$$V \propto I$$

For such materials, the resistance R = constant. Materials for which the resistance is constant at constant temperature obey **Ohm's law and are called ohmic conductors.**

Resistance and Resistivity

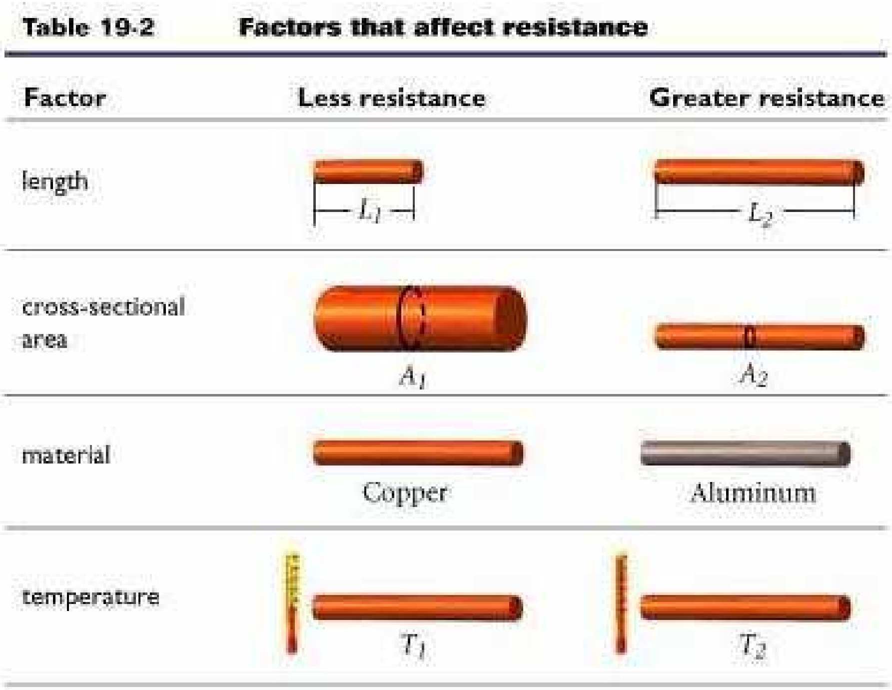


Table 19-2 Factors that affect resistance

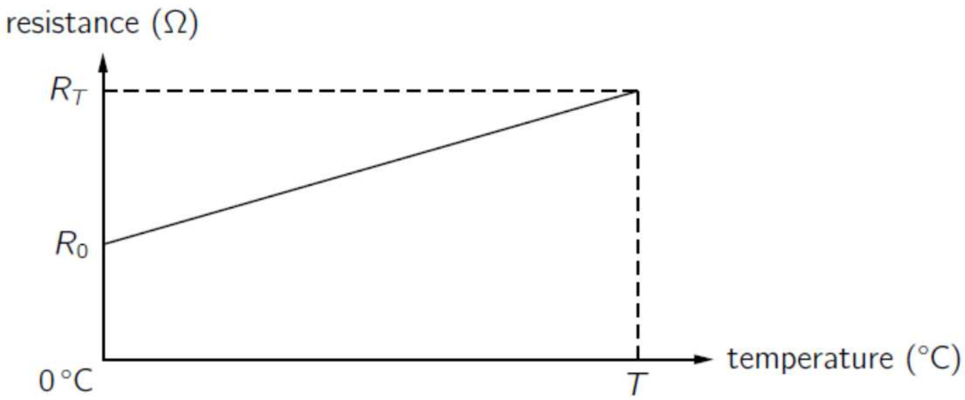
Factor	Less resistance	Greater resistance
length	L_1	L_2
cross-sectional area	A_1	A_2
material	Copper	Aluminum
temperature	T_1	T_2

A physical meaning of **resistance** is a difficulty experienced by electrical charge when passing through a conductor. The resistance depends on the length of a conductor and an area through which the charges flow.

Mathematically, it is given by

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

where ρ is a proportionality constant known as the **resistivity** of a material. Resistivity is an intrinsic property that quantifies how strongly a given material opposes the flow of electric current. For most metals (good conductors) at room temperature $\rho \approx 10^{-8} \Omega m$ and for insulators (bad conductors) $\rho \approx 10^{19} \Omega m$.



$$R_o = R_T(1 + \propto T)$$

where R_o is the resistance at 0°C, R_T is the resistance at temperature T°C and α is the **mean temperature coefficient of resistance** between 0°C and T°C. For typical metals $\alpha \approx 10^{-3}\ {}^{o}C^{-1}$.

Examples

Example 2.1: The resistivity of a wire

A current of 0.5 A passes through a copper wire 1.8 m long and 0.1 mm in diameter at 20^{o}C. If the p.d. across the ends of the wire is 2 V, calculate

1. the resistance of the wire, and
2. the resistivity of copper.

Example 2.2: The resistance of a wire at different temperatures

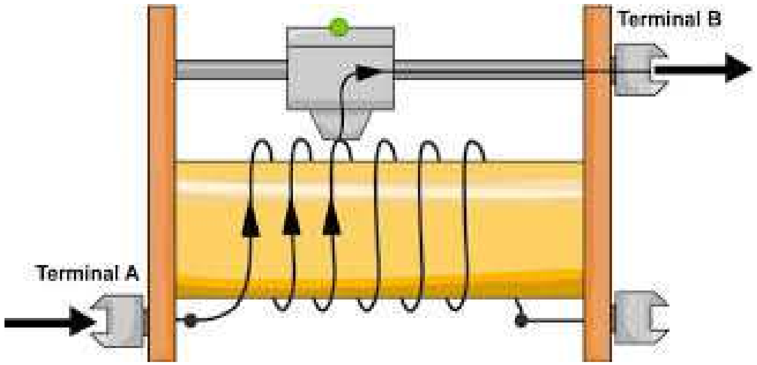
Calculate the resistance of the copper wire in the example above, if its temperature rises from 20^{o}C to 100^{o}C. Take $\alpha_{Cu} = 3.9 \times 10^{-3}\ {}^{o}C^{-1}$.

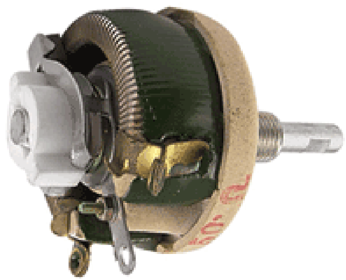
Resistors

Resistor

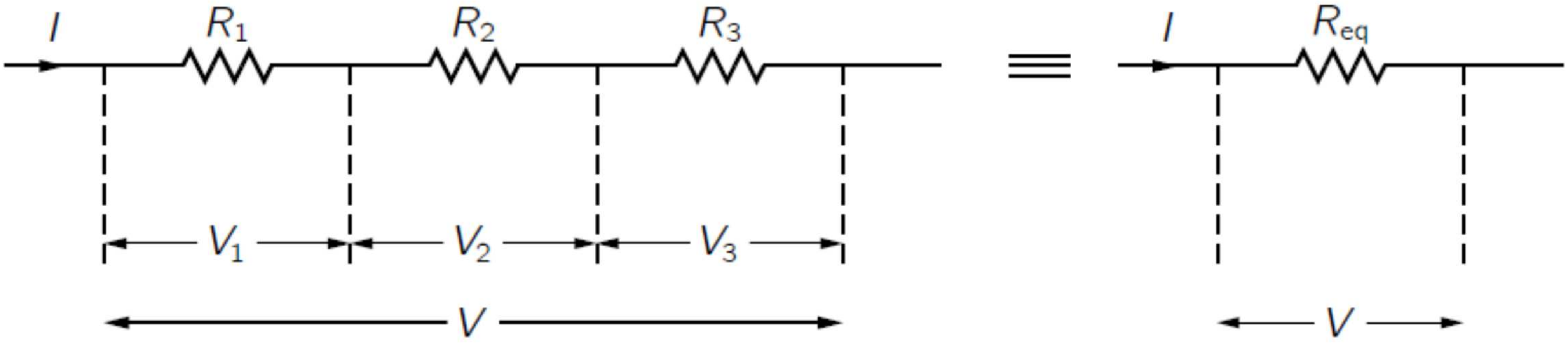
Variable resistor

Rheostat





Resistors in series



The current passing through all the resistor in series is the same.
The sum of p.d across each resistor is equal to the p.d across the equivalent resistor

$$V = V_1 + V_2 + V_3$$

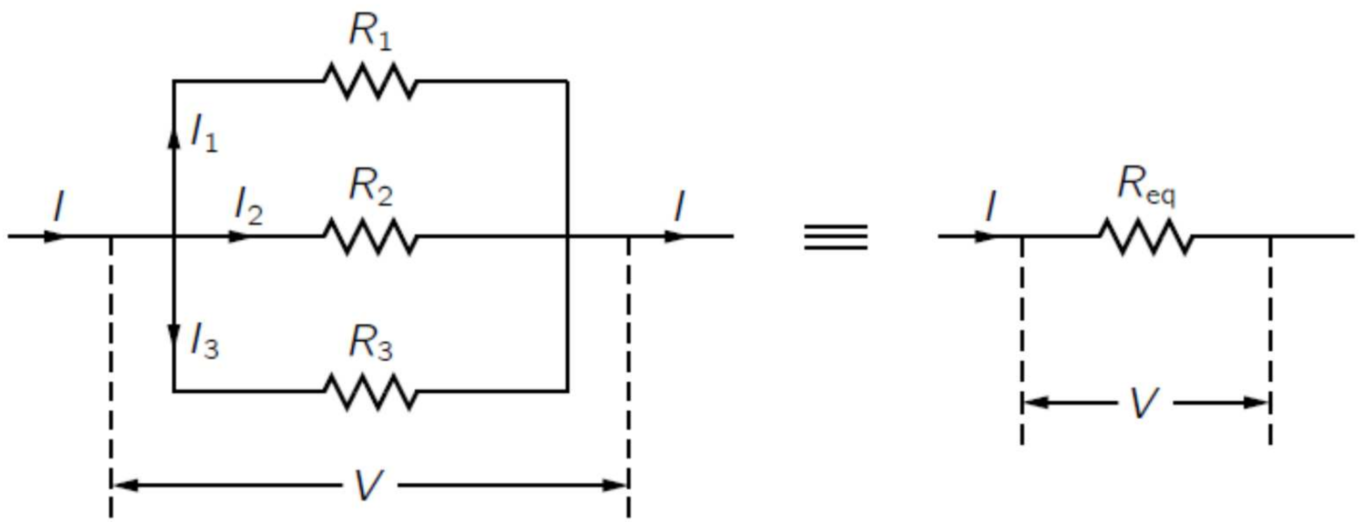
Using $V = IR$

$$IR_{eq} = IR_1 + IR_2 + IR_3$$

Cancelling I yields

$$R_{eq} = R_1 + R_2 + R_3$$

Resistors in parallel



- The p.d across each resistor is the same and also equal to the p.d across the equivalent resistance.
- The current at the node divides such that $I = I_1 + I_2 + I_3$

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

$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

cancelling V yields

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Example

Example 2.3: Equivalent resistance of a resistor combination

Determine the combined resistance R_{AC} for the circuit above.

Calculate the p.d.'s V_{AB}, V_{BC} and VAC

and the currents I_1 and I_2.