PHYS2

Electric Resistance

Electric Resistance

Electric Resistance

- is the measure of the difficulty of making current pass through the component. For a component in which the current, I, when the potential difference, V, resistance is given by the equation of

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

Where:

R = resistance, Ω (ohm)

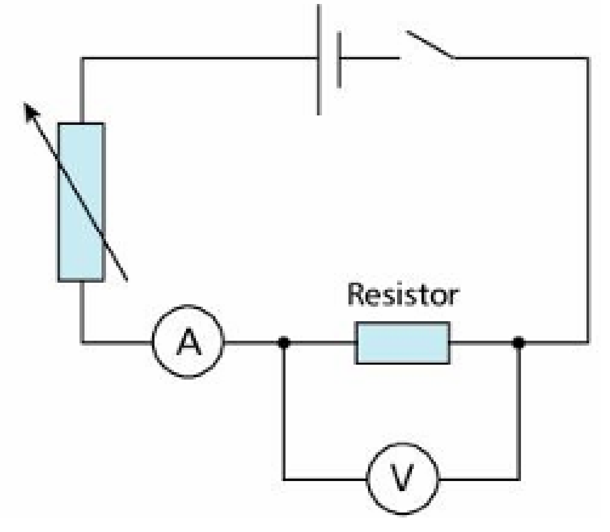
V = P.d across the components, V (voltage)

I = current, A (amperes)

Electric Resistance

Measurement of Resistance

a resistor is a component designed to have a certain resistance which is the same regardless of the current passing it. The resistance of a resistor can be measured using the circuit shown below:



Electric Resistance

Measurement of Resistance

Ammeter – is used to measure the current in the resistor. This device must be in series with the resistor so the same current passes through both resistor and the ammeter.

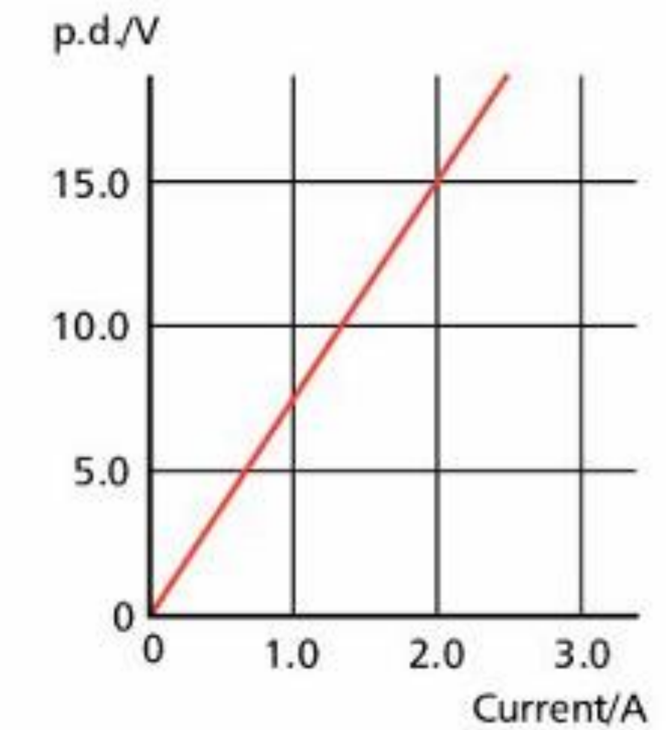
Voltmeter – is used to measure the potential difference across the resistor. This device must be in parallel with the resistor so that they have the same p.d.

Variable Resistor – is used to adjust the current and p.d. as necessary. To investigate the variation of current with p.d., the variable resistor is adjusted in steps. At each step, the current and p.d. are recorded from the ammeter and voltmeter respectively. The measurements can be plotted on a graph of p.d. against current as shown in the figure below.

Electric Resistance

Measurement of Resistance

Variable Resistor



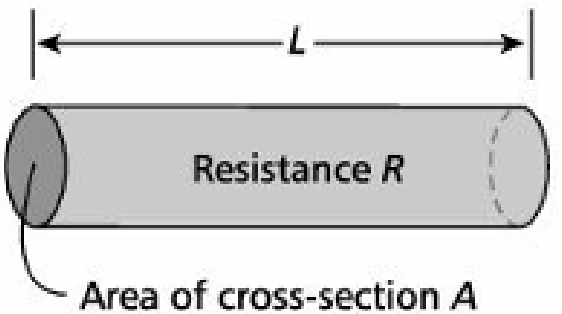
Electric Resistance

Ohm's Law

- states the relationship between electric current and potential difference. The current that flows through most conductors is directly proportional to the voltage applied to it, provided physical conditions do not change.

Resistivity

- For a conductor of length L, and uniform cross sectional area A, it's resistance R is:



Electric Resistance

Resistivity

$$\text{Resistivity, } \rho = \frac{R\ A}{L}$$

Where:

ρ = resistivity, Ω-m (ohm-meter)

R = resistance, Ω (ohm)

A = cross section area, m^2

L = conductor length, m

Electric Resistance

Electrical Power

- is the rate at which energy is transferred is known as power. Power, P is measured in watts (W)

$$P = \frac{\Delta W}{\Delta t}$$

- using the basic equation for current, I, and potential difference, V. Given equation for Power can be rearrange as follows

$$V = \frac{\Delta W}{\Delta Q} \qquad I = \frac{\Delta Q}{\Delta t}$$

Electric Resistance

Electrical Power

$$P = \frac{\Delta W}{\Delta t}$$

$$V = \frac{\Delta W}{\Delta Q}$$; $\Delta W = V\Delta Q$ (subs. in ΔW in P)

$$P = \frac{V\,\Delta Q}{\Delta t}$$; use current, $I = \frac{\Delta Q}{\Delta t}$

P = VI or P = IV

by substituting V=IR in Power formula, alternative formula for Power can be obtain as shown below

Electric Resistance

Electrical Power

$$P = I\,V$$

$$P = I^2\,R$$

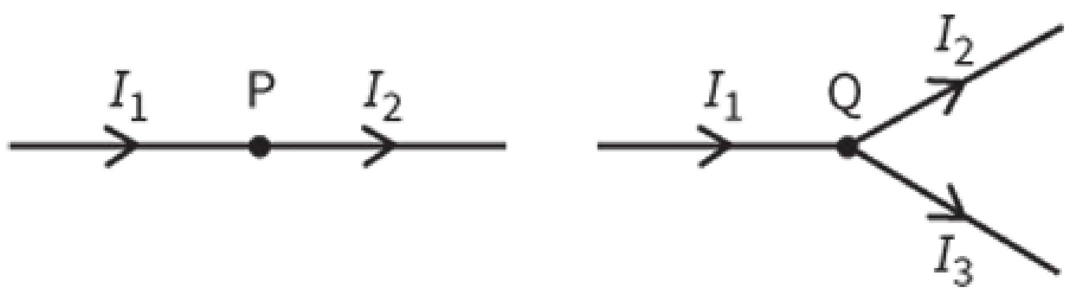
$$P = \frac{V^2}{R}$$

Electric Resistance

Kirchhoff's Law

Kirchhoff's 1st Law

- states that the sum of the currents entering any point in a circuit is equal to the sum of the currents leaving that same point.



$I_1 = I_2$ $\qquad$ $I_1 = I_2 + I_3$

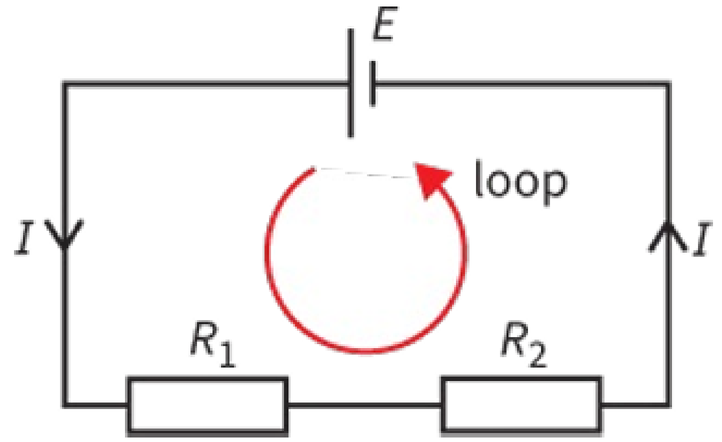
Electric Resistance

Kirchhoff's 2nd Law

- states that the sum of the electromotive force (e.m.f.) around any loop in a circuit is equal to the sum of the potential difference (p.d) around the loop.

$$E = IR_1 + IR_2$$

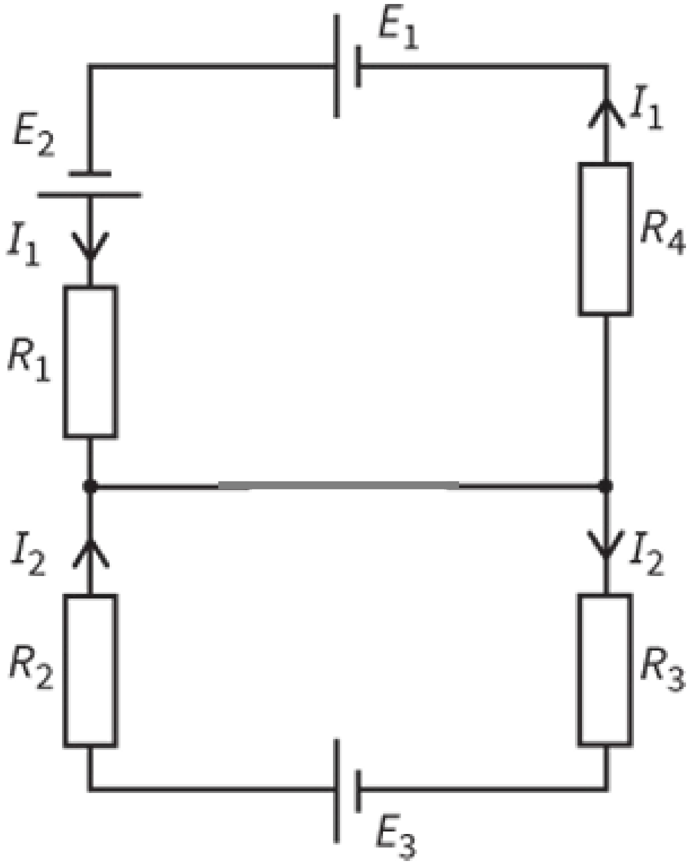
e.m.f. of battery = sum of p.d.s across the resistors



Electric Resistance

Kirchhoff's 2nd Law

Signs and Directions



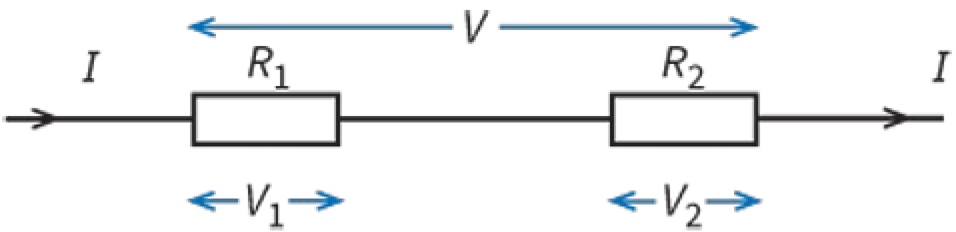
sum of e.m.f.s = $E_1 + E_2 - E_3$

sum of p.d.s = $I_1R_1 - I_2R_2 - I_2R_3 + I_1R_4$

Electric Resistance

Resistor Combination

Resistor in Series



According to Kirchhoff's first law, the current in each resistor is the same. The p.d., V across the combination is equal to the sum of the p.d. across the two resistors.

$$V = V_1 + V_2$$

Electric Resistance

Resistor Combination

Resistor in Series

Since $V = IR$, $V_1 = IR_1$ and $V_2 = IR_2$;

then, $IR = IR_1 + IR_2$

Factoring and cancelling common terms,

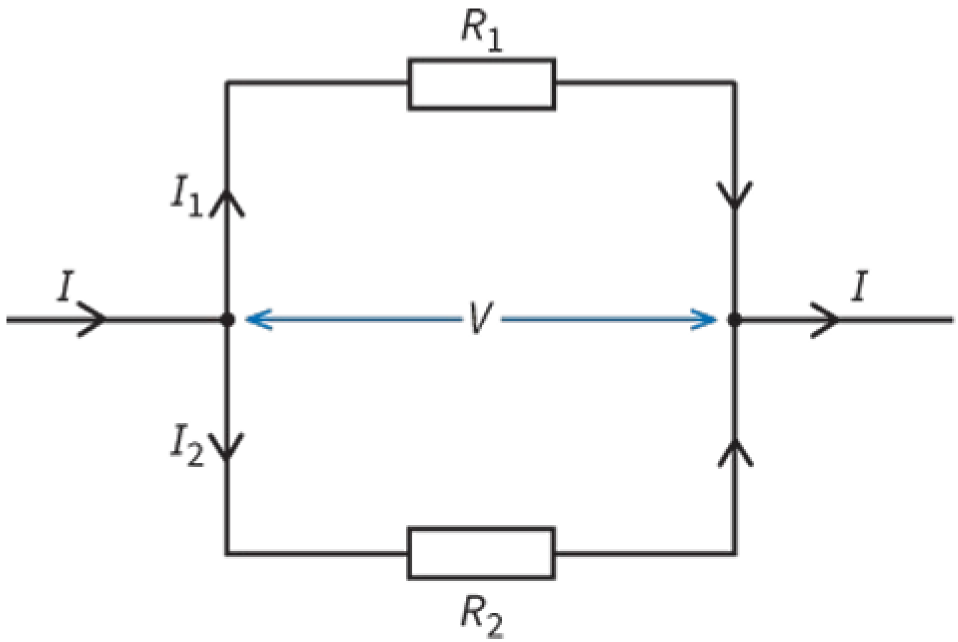
$$R = R_1 + R_2$$

Thus, Total Resistance (Rt) in a series:

$$R = R_1 + R_2 + R_3 + \ldots\ldots\ldots + R_n$$

Electric Resistance

Resistor in Parallel



According to Kirchhoff's first law, sum of the currents entering any point in a circuit is equal to the sum of the currents leaving that same point.

Electric Resistance

Resistor in Parallel

$$I = I_1 + I_2$$

Applying Kirchhoff's 2nd law,

$$\begin{aligned} I &= \frac{V}{R} \\ I_1 &= \frac{V}{R_1} \\ I_2 &= \frac{V}{R_2} \end{aligned}$$

Substituting and cancelling common factors,

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

Electric Resistance

Resistor in Parallel

Thus, Total Resistance (Rt) in a parallel:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \frac{1}{R_n}$$

Sample problem

1. The current through a component is 2mA when the potential difference across it is 12V. Determine (a) the resistance at this current (b) the potential difference when the current is 50μA, assuming its resistance is unchanged.

2. Determine the resistance of a heating element designed to operate at 60W and 12V.

3. Calculate the power supplied to a 10Ω resistor when the potential difference across it is 12V

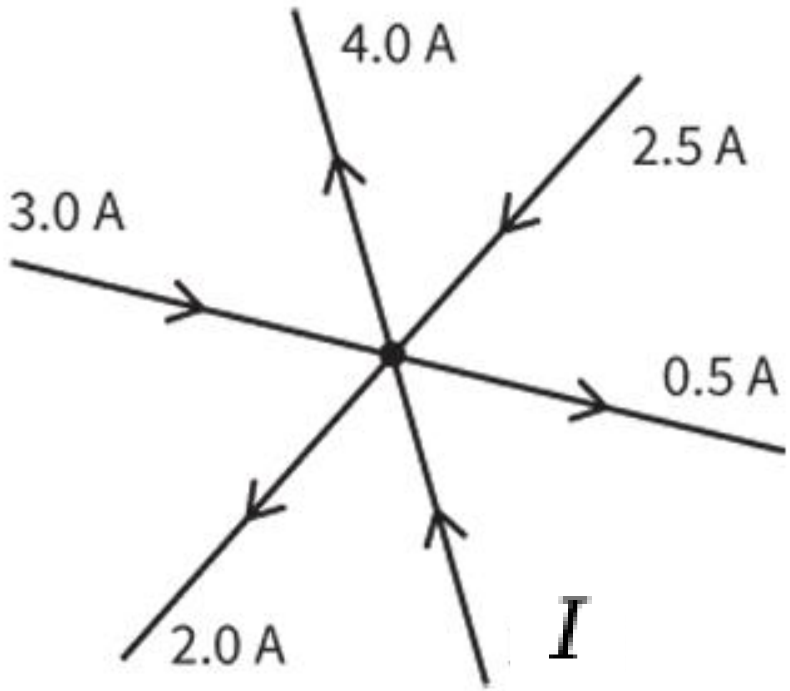
4. Calculate the resistance of a uniform wire with a diameter of 0.32mm and length of 5m. The resistivity of the material is 5×10^{-7} Ωm.

5. Calculate the resistance of a rectangular strip of copper with length of 0.08m, 15mm thickness and width of 0.8mm. The resistivity of copper is $1.7 \times 10^{-8}\ \Omega m$.

6. Calculate the rate at which energy is transferred by a 230V mains supply that provides a current of 8.0 A to an electric heater.

7. A power station produces 20 MW of power at a voltage of 200 kV. (a) Calculate the current supplied to the grid cables. (b) The grid cables are 15 km long, with a resistance per unit length of $0.20\ \Omega\ km^{-1}$. How much power is wasted as heat in these cables?

Evaluate the value of current I.



Determine the current at all points (A-E) in the circuit shown below