Ohm's Law

MET-05

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OHM’S LAW

Ohm’s Law, discovered by Georg Simon Ohm and published in his 1827.

“A law stating that electric current is proportional to voltage and inversely proportional to resistanc”

Voltage= Current× Resistance

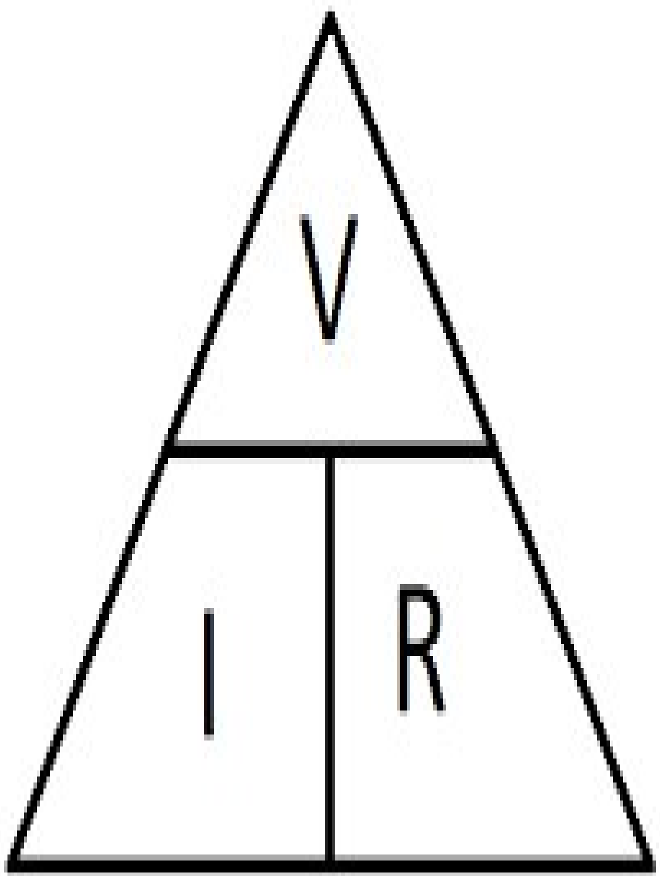
V= I×R

V= voltage, I= current and R= resistance

The SI unit of resistance is **ohms** and is denoted by **Ω**

This law is one of the most basic laws of electricity. It helps to calculate the power, efficiency, current, voltage, and resistance of an element of an electrical circuit.

OHM,S LAW



$I = V/R$

$V = IR$

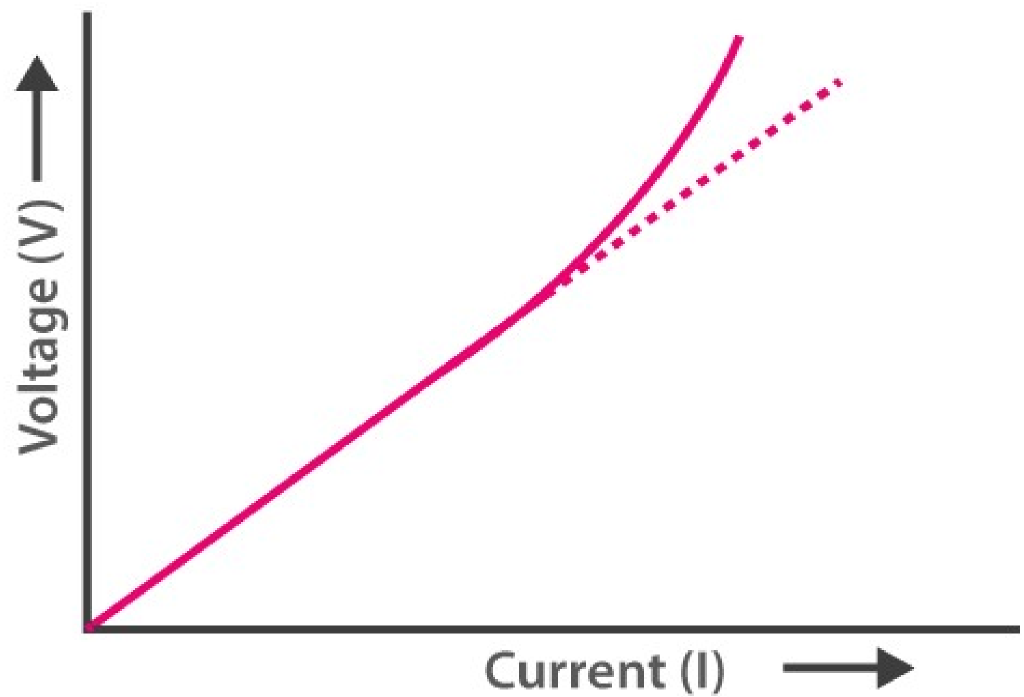
$R = V/I$

OHM'S LAW FORMULAS

Known Values	Resistance (R)	Current (I)	Voltage (V)	Power (P)
Current & Resistance	---	---	$V = I \times R$	$P = I^2 \times R$
Voltage & Current	$R = \frac{V}{I}$	---	---	$P = V \times I$
Power & Current	$R = \frac{P}{I^2}$	---	$V = \frac{P}{I}$	---
Voltage & Resistance	---	$I = \frac{V}{R}$	---	$P = \frac{V^2}{R}$
Power & Resistance	---	$I = \sqrt{\frac{P}{R}}$	$V = \sqrt{P \times R}$	---
Voltage & Power	$R = \frac{V^2}{P}$	$I = \frac{P}{V}$	---	---

LIMITATIONS OF OHM'S LAW

- Ohm's law is not applicable in unilateral networks
- It is not applicable for the non-linear network.



SPECIFIC RESISTANCE

The resistance of a conductor depends mainly on three things;

The LENGTH of the conductor.

The CROSS SECTIONAL AREA of the conductor.

The MATERIAL of which the conductor is made.

RESISTANCE AND LENGTH

For a given material, resistance and length formula clearly speaks that the resistance is directly proportional to its length.

$$R \propto L$$

Which implies that-

When the length of the material is increased, its value of resistance also increases.

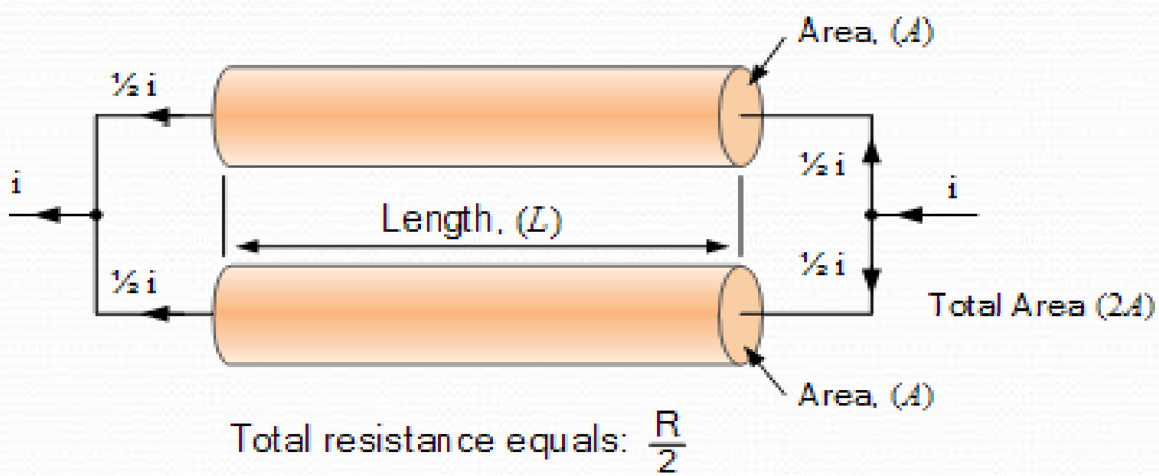
When the length of the material decreases, its value of resistance will also decrease.

RESISTANCE AND AREA

RESISTANCE IS INVERSELY PROPORTIONAL TO CROSS SECTIONAL AREA

Which is written as;

$$R \propto 1/A$$



SPECIFIC RESISTANCE

Resistance is directly proportional to its length. - R∝L

Resistance is inversely proportional to cross sectional area - R ∝ 1/A

Than

$$R = \rho \frac{1}{A}$$

Specific Resistance

Where: R is the resistance in ohms (Ω), L is the length in metres (m), A is the area in square metres (m^2), and where the proportional constant ρ (the Greek letter "rho") is known as **Specific Resistance or Resistivity**.

Materials such as copper and aluminium are known for their low levels of resistivity thus allowing electrical current to easily flow through them making these materials ideal for making electrical wires and cables.

Silver and gold have much low resistivity values, but for obvious reasons are more expensive to turn into electrical wires the factors which affect the resistance (R) of a conductor in ohms can be listed as:

The resistivity (ρ) of the material from which the conductor is made.
The total length (L) of the conductor.
The cross-sectional area (A) of the conductor.
The temperature of the conductor.

SPECIFIC CONDUCTANCE

Specific Conductance is the ability of a substance to conduct electricity. It is the reciprocal of **specific** resistance.

$$1\ /\text{ohm} = \text{ohm}^{-1} = \text{mho}(\boldsymbol{\Omega}^{-1})$$

EFFECT OF TEMPERATURE ON RESISTANCE

The change in resistance of a material with the increase in temperature can be expressed by means of the temperature coefficient of resistance.

Consider a conductor having resistance **R_o at o°c**

and **R_t at t°c**.

that the change in the resistance i.e **(R_t – R_o)** is

- Directly proportional to the initial resistance **R_o**
- Directly proportional to the rise in temperature **t°c**.
- Depends on the nature of the material for conductor metals and alloy

TEMPERATURE COEFFICIENT OF RESISTANCE

$$(\mathbf{R_t - R_o}) \propto \mathbf{R_o t}$$

$$(R_t - R_o) = \alpha R_o t$$

$$R_t = R_o(1 + \alpha_o t)$$

Where $\boldsymbol{\alpha_o}$ is constant and called as the temperature coefficient of resistance at 0°c and its value depends upon the nature of material and temperature.

$$\Delta R \propto R_0 t$$

$$\Delta R = \alpha R_0 t$$

$$Rt - \Delta R = \alpha R_0 t$$

$$Rt = \alpha R_0 t + R_0$$

$$Rt = R_0(\alpha t + 1)$$

$$Rt = R_0(1 + \alpha t)$$

$$Rt = R_0 + \alpha R_0 t)$$

$$\alpha R_0 t = Rt - R_0$$

$$\alpha = \frac{\Delta R}{R_0 t}$$

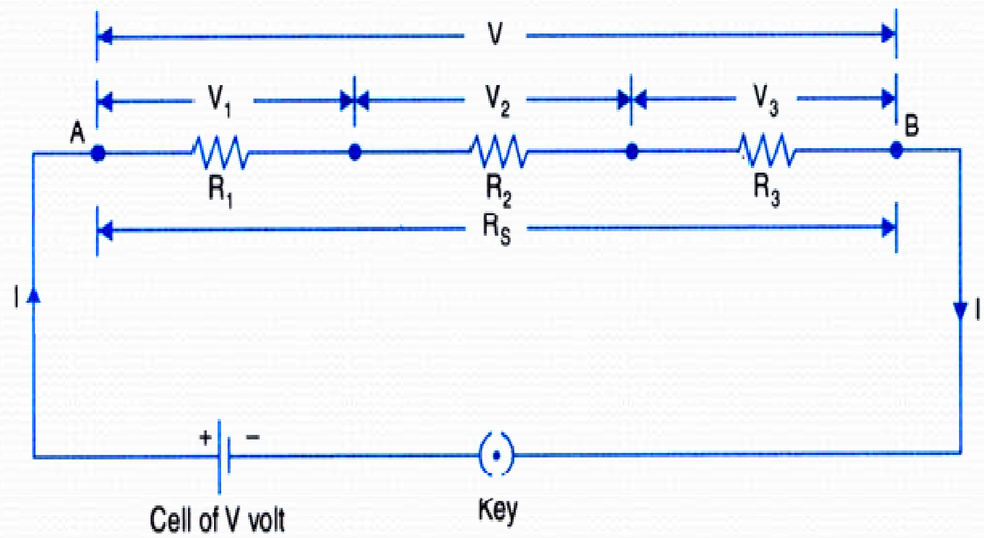
In a material where the resistance INCREASES with an increase in temperature, the material is said to have a **POSITIVE TEMPERATURE COEFFICIENT**.

When resistance FALLS with an increase in temperature, the material is said to have a **NEGATIVE TEMPERATURE COEFFICIENT**

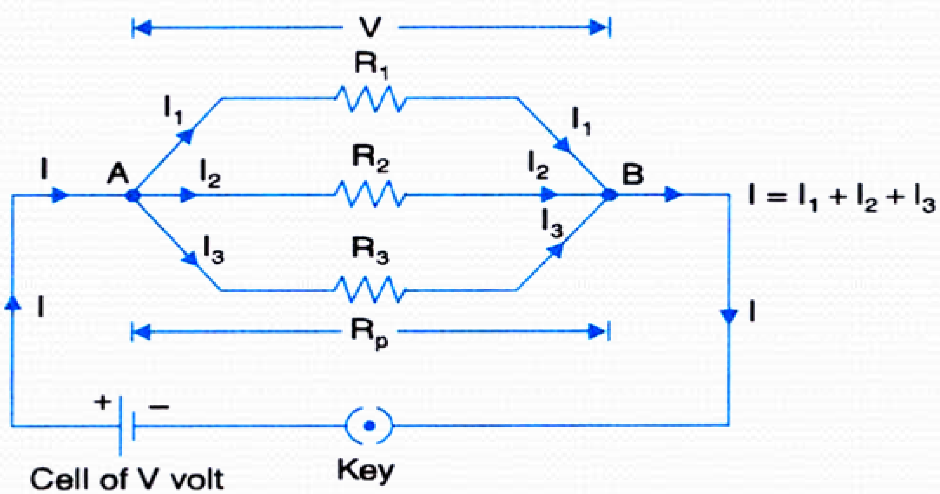
COMBINATION OF RESISTANCES

Resistance can be joined to each other by two ways:

1. Series combination



2. Parallel combination



SERIES COMBINATION

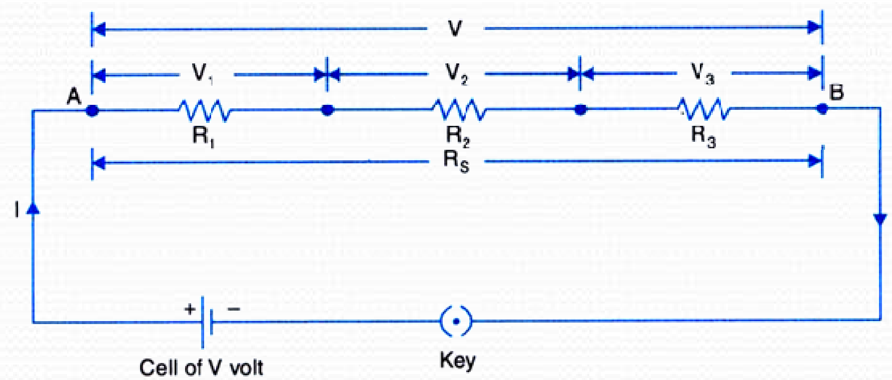
Ohm's law, the potential difference across $R_1 = V_1 = I\,R_1$

$R_2 = V_2 = I\,R_2$

$R_3 = V_3 = I\,R_3$

Potential difference V across this series connection of resistors

$$V = V_1 + V_2 + V_3$$
$$= I\,R_1 + I\,R_2 + I\,R_3$$
$$= I\,(R_1 + R_2 + R_3)$$

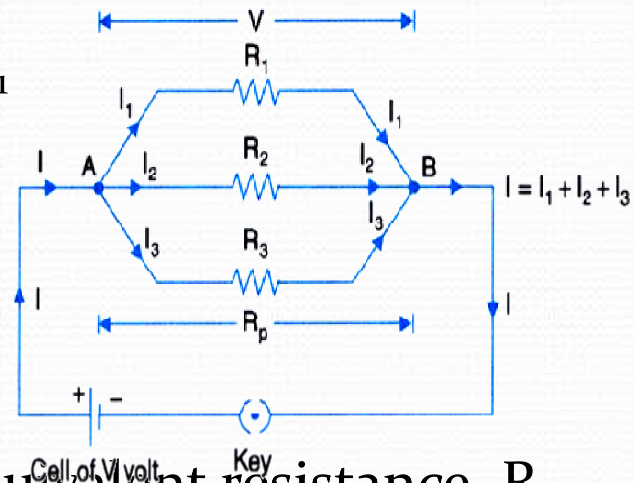


The equivalent resistance, $R_{eq} = V/I = (R_1 + R_2 + R_3)$.

For n number of resistors connected in series, the equivalent resistance $R_{eq} = R_1 + R_2 + R_3 \ldots\ldots\ldots\ldots R_n$.

Equivalent resistance is the total resistance of the circuit

PARALLEL COMBINATION



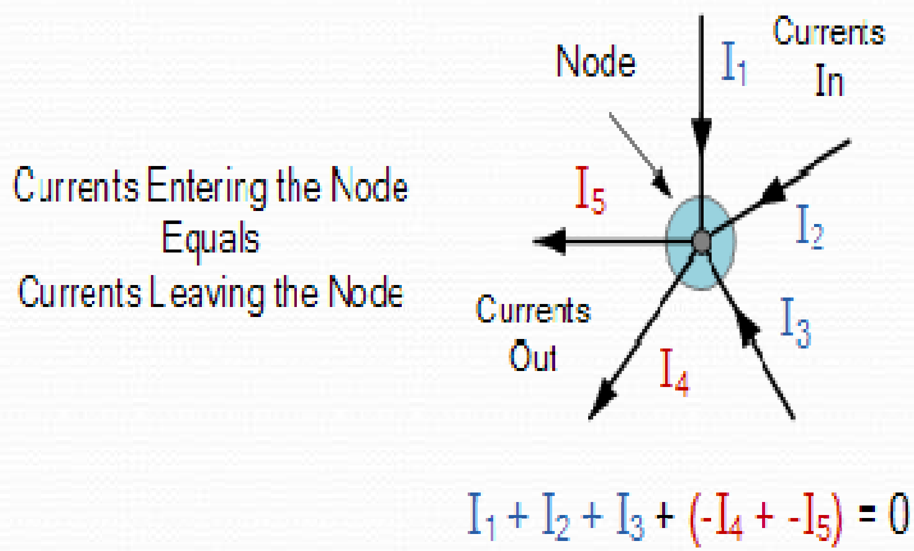
- Current $I = I_1 + I_2 + I_3$.
- The potential difference applied to R1 = $V = I_1 R_1$
- The potential difference across $R_2 = V = I_2 R_2$
- The potential difference across $R_3 = V = I_3 R_3$
- Thus $I = I_1 + I_2 + I_3$
- $= V/ R_1 + V/ R_2 + V/ R_3$
- $=V (1/ R_1 + 1/ R_2 + 1/ R_3)$
- If this parallel combination is replaced by an equivalent resistance, R_{eq}
- Then $I = V/ R_{eq}$
- $1/ R_{eq} = 1/ R_1 + 1/ R_2 + 1/ R_3$
- Thus, for n number of resistors in parallel, $1/ R_{eq} = 1/ R_1 + 1/ R_2 + 1/ R_3 \ldots\ldots\ldots\ldots 1/ R_n$.
- in a parallel connection, the total resistance of a circuit is determined by adding the reciprocal of the resistance of each individual resistors.

Kirchhoff’s Law

Kirchhoffs First Law – The Current Law, (KCL)

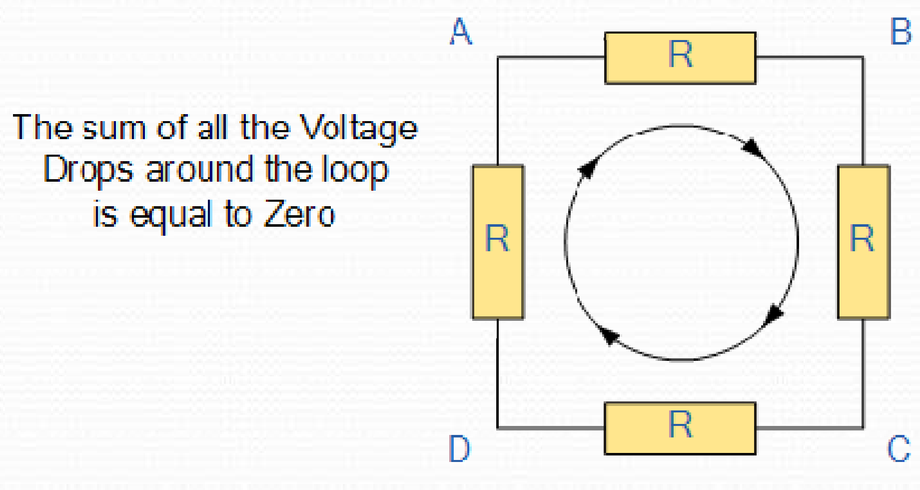
“*total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node*“. In other words the algebraic sum of ALL the currents entering and leaving a node must be equal to zero

$I_{(exiting)} + I_{(entering)} = 0.$



Kirchhoffs Second Law – The Voltage Law, (KVL)

Kirchhoffs Voltage Law or KVL, states that "*in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop*" which is also equal to zero. In other words the algebraic sum of all voltages within the loop must be equal to zero.



$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$$

What is an Electrical Energy

- Electrical energy is the energy derived from electric potential energy or kinetic energy of the charged particles. In general, it is referred to as the energy that has been converted from electric potential energy. We can define electrical energy as the energy generated by the movement of electrons from one point to another. The movement of charged particles along/through a medium (say wire) constitute current or electricity.

$$Work\ done = VQ$$

$$since,\ \ I = \frac{Q}{t}$$

$$Work\ done = VIt$$

$$Work\ done = \ I^2Rt$$

$$Work\ done = \frac{V^2}{R}t$$

Electric power

- Electric power is the rate at which energy is transferred to or from a part of an electric circuit. A battery can deliver energy, or a circuit element like a resistor can release energy as heat. For any circuit element, the power is equal to the voltage difference across the element multiplied by the current. By Ohm's Law, $V = IR$, and so there are additional forms of the electric power formula for resistors. Power is measured in units of Watts (W), where a Watt is equal to a Joule per second (1 W = 1 J/s).