WEEK 7-9

ELECTRIC CONDUCTION THROUGH MATERIALS OHMS LAW

Introduction:

The invention of electricity has pave way for modern facilities, like radio, television and other electric electronics. The motion of electric charges through a conductor when an electric field (potential gradient) is maintained in a conductor constitute electric current.

Electric Conductor

Any materials that allows the passage of electric current is called a conductor. The three materials that conduct electricity are:

(a) Solid (metal)
(b) Liquid (Electrolyte)
(c) Gases (ionized gas)

In metals, the electric charges carried are free electrons. In liquid conductor (electrolyte), the electric charges carrier are ions. In an ionized gas, the electric charges carriers are ions and electrons.

Basic Quantities of Electricity

The three basic quantities in the study of electricity are:

i. Potential difference (V)
ii. Current (I)
iii. Resistance (R)

Potential Difference (v)

The potential difference between any two points in an electric field is the work done in moving a unit positive charge from one point to another. The instrument for measuring potential differences is called voltmeter. The unit of potential difference is volts (v). Voltmeter should be connected in parallel to a cell or battery or load to be measured. It is a high resistance meter and must never be connected in series.

Current (I)

The instrument used in measuring current is called ammeter. The unit of current is amperes (A). Ammeter should be connected in series to a cell or battery in a circuit.

Ohm's Law

Ohm's law states that the current passing through a metallic conductor is directly proportional to the potential differences between any two points provided the temperature remains constant.

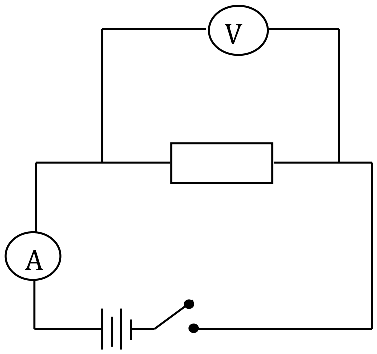
Mathematically, Ohm's law is stated as $V = IR$

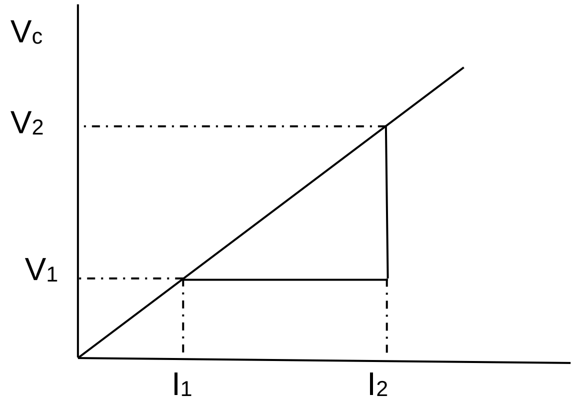
Where V is potential difference in volts (V)

I is current in Amperes (A)

R is constant known as the resistance in ohm (Ω)

Diagrammatical representation of ohm's law experiments





The slope of the graph i.e change in voltage over change in current is equal to resistance (R) of the wire in ohm's

Electric Resistance (R)

Electric resistance is defined by ohm as the ratio of voltage against current i.e. (v/1). The symbol of electric resistance is R and its unit is ohm (Ω) . Resistor is an instrument that opposed the flow of current

Calculation I

An electric conductor has a resistance of 5Ω when a current of 2A passes through it. What is the voltage development?

Solution

V = IR

I = 2A

R = 5Ω

V = ?

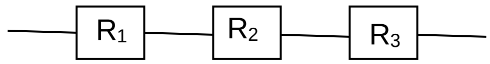
V = 2 x 5 = 10v

:. V = 10v

Parallel and series Connection of Resistors

Series Connection

When resistors are connected end to end in such a way that the same amount of current passes through them, the resistors are connected in series. Different voltages are developed. The effective resistance or total resistance i.e. $R_T = R_1 + R_2 + R_3 + \ldots$

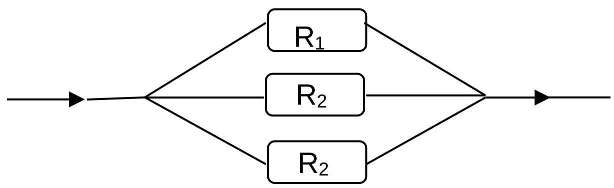


Series Connection of Resistors

Parallel Connection

When resistors are connected side by side such that different current passes through them but same voltage is developed, the resistors are connected in parallel. The effective resistance

$= \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R3} + \ldots..$



Calliulation II

Two resistors of resistance 2Ω and 3Ω are in series in a circuit when a current of 5A passes through them.

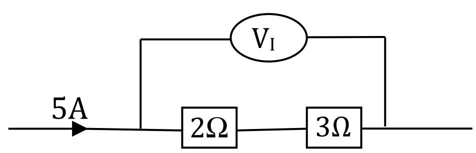
Calculate

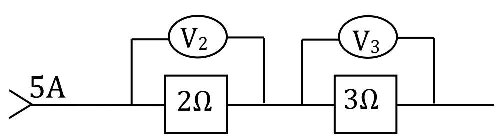
1. Total voltages developed in the circuit,
2. Voltages developed in each of the resistors.

Solution

1

V = IR
I = 5A
R = $R_T = R_2 + R_3$
i.e R_T = 2 +3 = 5Ω





:. V_T = 5 x 5 = 25v

:. V_1 = 25V

2

a. V_2 = $1R_2$
5 x 2 = 10V

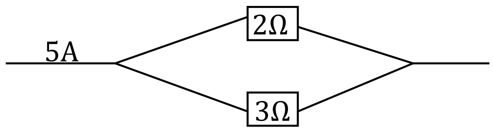
b. V_3 = $1R_3$
5 x 3 = 15V

Note. V_T = $V2 + V_3$

i.e. V_T = 10 x 15 = 25V

Calculation 3

If in calculation II, the resistors are in parallel, calculate the voltage developed and current in each resistor.



$V = IR$

$I = 5A$

$R = R_T$

a. $V_2 = 1R_2$

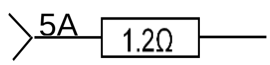
But $= \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$$\frac{1}{R_T} = \frac{1}{2} + \frac{1}{3} = \frac{3+2}{6} = {}^5\!/_6$$

$1 \times 6 = 5xR_T$

$6 = 5R_T$

$RT = 6/5 = 1.2\Omega$



$V = 1R_T$

$5 \times 1.2 = 6v$

ii. $V_{R2} = I_2R_2$

$V_{R2} = 6V$

$R_2 = 2\Omega$

$$I_2 = {}^{V_{R2}}\!/_{R_2} = {}^6\!/_2 = 3A$$

$I_2 = 3A$

$V_{R3} = I_3R_3$

$V_{R3} = 6V$

$R_3 = 3\Omega$

$$I_2 = {}^{V_{R3}}\!/_{R_3}$$

$$I_3 = {}^6\!/_3 = 2A$$

Internal Resistance (r)

The internal resistance of a cell (r) is the resistance offered by the electrolyte or chemicals to the motion of the current. It is denoted by the symbol (r) closed to the cell.

Terminal potential difference (P.D) and Electromotive Force (EMF)

Terminal Potential difference is the potential difference across the terminals of the cell when it is delivering current to an external resistor while electromotive force is the potential difference across the cell when it is not delivering current to an external resistor.

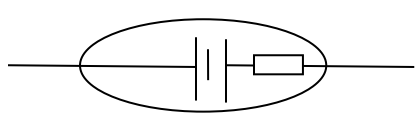


Diagram showing the position of internal resistor.

Relationship Between E, R. r and I

The relationship between Electromotive Force (E), external resistance (R), Internal resistance r and current (I) is given by

$I = \frac{V}{R+r} = {}^{V}/_{R}$

Identical Cells Connection (Parallel and Series)

When identical cells are connected in series, the effective e.m.f i.e. nE and the effective internal resistance is given by nr.

n is the number of cells.

When identical cells are connected in parallel, the effective e.m.f is that of one cell and the effective internal resistance is given by r/n. Where n is the number of cells.

<u>Calculation</u>

1. A cell of e.m.f 12V and r = 0.5Ω is connected across a resistor with a resistance of 5.5Ω. Calculate the magnitude of the current flowing and list voltage.

<u>Solution</u>

$$I = \frac{E}{R+r}$$

E = 12v, r = 5.5Ω

r = 0.5Ω I = ?

$$I = \frac{12}{5.5+0.5} = \frac{12}{6} = 2A$$

:. I = 2A

Lost voltage

$$Re\ c\ allI = \frac{E}{R+r}$$

I (R + r) = E

IR + Ir = E

But IR = V

i.e. V + in = V

Ir = E – V

Ir or E-V is the lost voltage

Lost voltage = 2 x 0.5 = IV i.e. Ir.

Or

12 - 11 = 1v i.t for v-v (v = IR = 2 x 5.5 = 11V)

Resistivity

Every electrical conductor has a resistance. The resistance of a materials in form of wire is directly proportional to the length (L) of the materials and inversely proportional to the cross-sectional area (A)

Mathematically

$R\alpha \, {}^{L}/_{A}$

$R = {}^{PL}/_{A} \, ButA \rightleftarrows\rightleftarrows = \pi d \, {}^{2}/_{4}$

$\therefore R = 4p \, {}^{L}/_{\pi d2}$

ρ is a constant known as the resistivity of the material in Ohm meter (Ωm)

d is the diameter of the wire in metres

L is the length in metre

R is the resistance in ohm.