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ELECTRIC CURRENT

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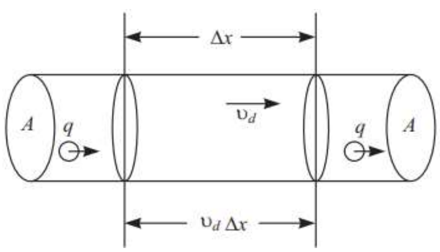
The free electrons move in a direction opposite to the field through the conductor. This constitutes an electric current. Conventionally, the direction of current is taken as the direction in which a positive charge moves

The electric current through a conductor is the rate of transfer of charge across a surface placed normal to the direction of flow.

$$I_{av} = \frac{q}{t}$$

The SI unit of current is ampere. Its symbol is A



Total charge in the volume element under consideration is given by

$$\Delta q = nAe\, v_d\, \Delta t$$

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

OHM'S LAW

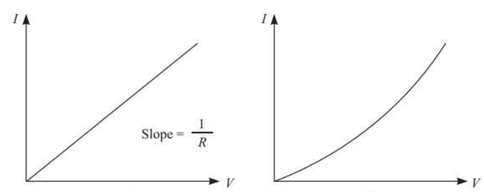
In 1828, Ohm studied the relation between current in a conductor and potential difference applied across it

The electric current through a conductor is directly proportional to the potential difference across it, provided the physical conditions such as temperature and pressure remain unchanged.

$$V \propto I$$

$$V = RI$$

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



The SI unit of resistance is ohm. It is expressed by symbol Ω (read as omega)

Resistance and Resistivity

$$R \propto \frac{\ell}{A}$$

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

Where ρ is a constant for the material at constant temperature. It is called the specific resistance or resistivity of the material.

If l = 1m and A = 1m^2 , then ρ = R ohm-metre. Thus resistivity of a material is the resistance offered by a wire of length one metre and area of cross section one m^2 . The unit of resistivity is ohm metre (Ωm)

Reciprocal of resistivity is called **conductivity** (specific conductance) and is denoted by σ :

$$\sigma = \frac{1}{\rho}$$

Unit of conductivity is Ohm^{-1} metre^{-1} or mho-metre^{-1} or Sm^{-1}.

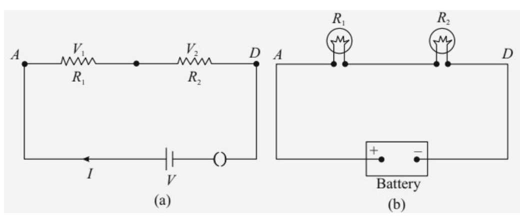
GROUPING OF RESISTORS

Series Combination

Resistors in series by joining them end-to-end such that the same current passes through all the resistors.

Equivalent resistance in series combination is

$$\boldsymbol{R = R_1 + R_2 + R_3 + \ \ldots}$$

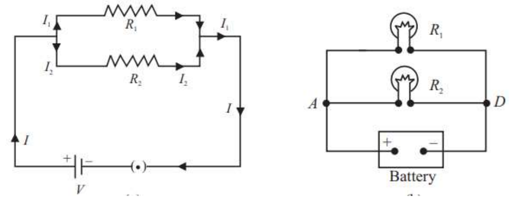


Parallel Combination

The resistors in parallel by joining their one end at one point and the other ends at another point. In parallel combination, same potential difference exists across all resistors

Reciprocal of equivalent resistance of parallel combination is equal to the sum of the reciprocals of individual resistances.

$$\frac{1}{R_{equ}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ \ldots..$$



TYPES OF RESISTORS

1) carbon resistors
2) wire wound resistors

TEMPERATURE DEPENDENCE OF RESISTANCE

The resistivity of a conductor depends on temperature. For most metals, the resistivity increases with temperature and the change is linear over a limited range of temperature :

$\rho = \rho 0\ [1 + \alpha\ (T - T0\ )]$ where ρ and ρ0 are the resistivity's at temperatures T and T0 , respectively

$$\alpha = \frac{(R_2 - R_1)}{R_0(T_2 - T_1)} = \frac{1}{R_0}\frac{\Delta R}{\Delta T}$$

Temperature coefficient Magnetism of resistance is numerically equal to the change in resistance of a wire of resistance 1Ω at 0° C when the temperature changes by 1° C. This property of metals is used in making resistance thermometers.

ELECTROMOTIVE FORCE (EMF) AND POTENTIAL DIFFERENCE

EMF is the short form of electromotive force. EMF of a cell or battery equals the potential difference between its terminals when these are not connected (open circuit) externally

E = V +Ir

E.M.F. of a cell depends on :

– the electrolyte used in the cell;

– the material of the electrodes; and

– the temperature of the cell.

Elementary Idea of Primary and Secondary cells

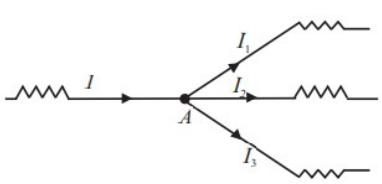
Primary Cells : In these cells, the chemical energy is directly converted into electrical energy. The material of a primary cell is consumed as we use the cell and, therefore, it cannot be recharged and reused. Dry cell ,Daniel Cell, Voltaic Cell etc are examples of primary cells

Secondary Cells : These are chemical cells in which electrical energy is stored as a reversible chemical reaction. When current is drawn from the cells the chemical reaction runs in the reverse direction and the original substances are obtained. These cells, therefore, can be charged again and again. Acid-accumulator, the type of battery we use in our inverter or car,is a set of secondary cells.

KIRCHHOFF'S RULES

Kirchhoff formulated two rules which enable us to know the distribution of current in complicated electrical circuits or electrical networks

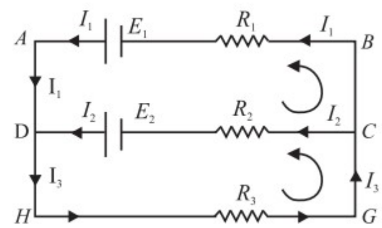
Kirchhoff's First Rule (Junction Rule) : It states that the sum of all currents directed towards a junction (point) in an electrical network is equal to the sum of all the currents directed away from the junction.



$$\sum_{i=0}^{n} I_n = 0$$

Kirchhoff's Second Rule (Loop Rule) : This rule is an application of law of conservation of energy for electrical circuits. It tells us that the algebraic sum of the products of the currents and resistances in any closed loop of an electrical network is equal to the algebraic sum of electromotive forces acting in the loop

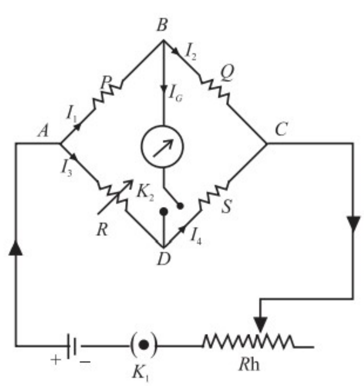
$$\sum IR = \sum E$$



Wheatstone Bridge

It is an arrangement of four resistances which can be used to measure one of them in terms of the other three

$$\frac{\boldsymbol{P}}{\boldsymbol{Q}} = \frac{\boldsymbol{R}}{\boldsymbol{S}}$$



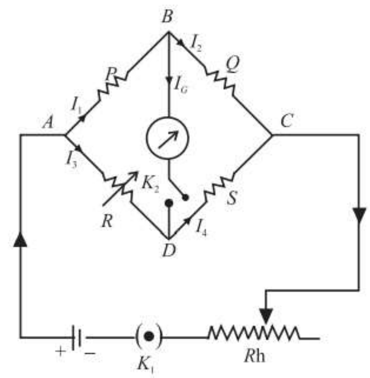
POTENTIOMETER

The potentiometer can also be used for measurement of internal resistance of a cell, the current flowing in a circuit and comparison of resistances.

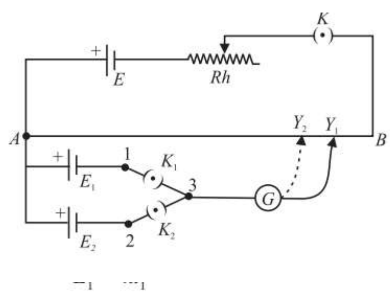
The measurements with potentiometer have following advantages :

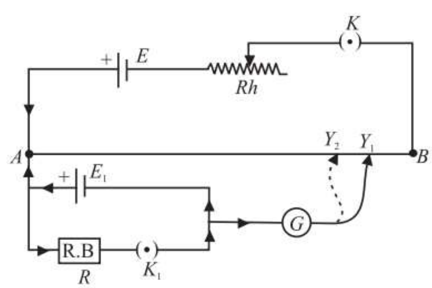
When the potentiometer is balanced, no current is drawn from the circuit on which the measurement is being made.

It produces no change in conditions in a circuit to which it is connected. It makes use of null method for the measurement and the galvanometer used need not be calibrated



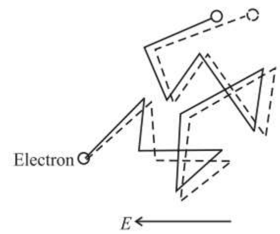
Comparison of E.M.Fs of two Cells





$E_1/E_2 = l_1/l_2$

DRIFT VELOCITY OF ELECTRONS



A metallic solid consists of atoms arranged in a regular fashion. Each atom usually contributes free electrons, also called conduction electrons. These electrons are free to move in the metal in a random manner, almost the same way as atoms or molecules of a gas move about freely in the a container. It is for this reason that sometimes conduction electrons are referred to as electron gas

$$I = +\frac{ne^2A}{m}\frac{V}{\ell}\tau$$

$$\frac{V}{I} = \frac{m}{ne^2\tau}\frac{\ell}{A} = R$$

POWER CONSUMED IN AN ELECTRICAL CIRCUIT

The electrical power lost in a conductor as heat is called joule heat. The heat produced is proportional to :

(i) square of current (I),
(ii) resistance of conductor (R), and
(iii) time for which current is passed (t)

$$p = VI = I^2R = \frac{V^2}{R}.$$

Check Yourself

1) The resistance of the wire varies inversely as:

   A. Area of cross section
   B. Resistivity
   C. Length

D. Temperature

2) Resistance are connected in end to end in
   A. Parallel combination
   B. Series combination
   C. Circular combination
   D. Random combination
3) In parallel combination the current passing through each resistor is
   A. Same
   B. Zero
   C. Different
   D. low
4) Ohm's law is not applicable to
   A. Dc circuit
   B. Small resistance
   C. High current
   D. Semiconductor

5) Reciprocal of resistivity is known as
   A. Conductivity
   B. Voltage
   C. Resistance
   D. None of the above

Stretch Yourself

1. In a potentiometer circuit, balance point is obtained at 55 cm from end A when an unknown e.m.f. is measured. The balance point shifts to 30 cm from this end when a cell of 1.02 V is put in the circuit. Standard cell E always supplies a constant current. Calculate the value of unknown e.m.f.
2. A current of 0.50 A flows through a resistance of 400Ω. How much power is lost in the resistor?
3. State Kirchhoff's rules governing the currents and electromotive forces in an electrical network?
4. Define resistivity of a conductor. How does the resistance of a wire depend on the resistivity of its material, its length and area of cross-section

Hint to Check Yourself

1A 2B 3C 4D 5A