Current Electricity

Electric Current I

It is the rate of flow of electric charge flowing though any section of wire.

Ohm's Law

Electric current flowing through a conductor is directly proportional to the potential difference across the two ends of the conductor; physical quantities such as temperature, mechanical strain, etc. remaining constant.

$V = RI$

Where, R is a constant for a given conductor

Electrical resistance:

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

Where, *r* is the specific resistance or electrical resistivity of the material

Conductance and Electrical conductivity:

Conductance $G = \frac{A}{\rho l}$

Electrical conductivity (*s*) is defined as the reciprocal of resistivity.

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

The other form of Ohm's law is

$J = \sigma E$

J = current density

E = electric field applied

Motion of electrons due to thermal energy

Free electrons are in continuous random motion. They undergo change in direction at each collision and the thermal velocities are randomly distributed in all directions.

Average thermal velocity, $u = \frac{u_1 + u_2 + u_3 + \ldots\ldots + u_n}{n}$ is zero … 1

Drift velocity

- $\vec{v_d}$ is defined as the velocity with which the free electrons get drifted towards the positive terminal under the effect of the applied electric field.
- $J = \frac{I}{A} = \frac{q}{At} = \frac{ne}{At}$

we know that $I = neAv_d \ or \ \frac{I}{A} = nev_d$

Therefore, $J = nev_d$

Limitations of Ohm's Law

The Ohm's law ceases to be valid in following cases:

V ceases to be proportional to I.
Sign of V affects the relation between V and I.
There is more than one value of V for the same current.

Finding resistance of the carbon resistor

TABLE 3.2 RESISTOR COLOUR CODES			
Colour	**Number**	**Multiplier**	**Tolerance**
Black	0	1	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
No colour			20

The resistance of the carbon resistor is found by using the table

Here, first two bands from one end indicate the first two significant figures of resistance in ohms.
Third band indicates the decimal multiplier.

The last band stands for tolerance. Its absence indicates a tolerance of 20%.

Temperature Dependence of Resistivity

- On increasing temperature, the number of collisions of electrons and ions in conductors increases; this, in turn, increases their resistivity.
- Relation between resistivity and temperature:

  $\rho = \rho_0 (1 + \alpha t)$
  Here, α is the temperature coefficient of resistance of the material of a conductor
- The resistivity of a metallic conductor increases with increase in temperature.
- The resistivity of an alloy has a weak temperature dependence.
- The resistivity of a semiconductor decreases rapidly with increasing temperature.

Alloys are used for preparing standard resistance coils because of their high resistance and low temperature coefficient of resistance.

Superconductivity

- Superconductivity is the phenomenon in which a material loses its resistivity completely.
- Superconducting cables can be used for power distribution without loss.
- Speed of a computer can be increased by superconducting wires.
- Superconductivity can help produce a very strong magnetic field without power loss.
- Superconductivity exists at subzero temperature, which hinders its use at normal temperature.

Thermistor

- Thermistor is a heat-sensitive semiconductor device whose resistance changes very rapidly with change in temperature.
- It is used for remote sensing, voltage stabilisation, temperature control, etc.

Electric Energy

It is the work done by the source of *emf* in maintaining the electric current in the circuit for a given time.

$W = VIt$

Electric Power

It is the rate at which work is done by the source of *emf* in maintaining the electric current in a circuit.

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

Emf

Potential difference between the two poles of the cell in an open circuit is called *emf* of the cell.

Internal resistance (r) of cell

Resistance offered by the electrolyte of the cell when the electric current flows through it is,

$r = \left(\frac{E}{V} - 1\right)R$

where,

E – *emf* of cell

r – Internal resistance of the cell

R – External resistance

K – Key

V – Voltmeter

Combination of cells

Series combination of the cells

The equivalent emf of a series combination of n cells (E_{eq})

$E_{eq} = E_1 + E_2 + \ldots\ldots\ldots\ldots + E_n$

The equivalent internal resistance of a series combination of n cells (r_{eq})

$r_{eq} = r_1 + r_2 + \ldots\ldots\ldots\ldots\ldots\ldots + r_n$

Parallel combination of the cells

For a parallel combination of n cells with emfs E_1 , E_2........ and E_n and internal resistances r_1, r_2............. and r_n

Equivalent emf:

$E_{eq} = \frac{E_1}{r_1} + \frac{E_2}{r_2} + \ldots\ldots\ldots\ldots\ldots \frac{E_n}{r_n}$

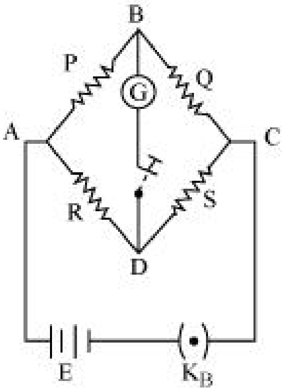
Equivalent internal resistance(r_{eq}) :

$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_1} \ldots\ldots\ldots\ldots + \frac{1}{r_n}$

Kirchhoff's laws:

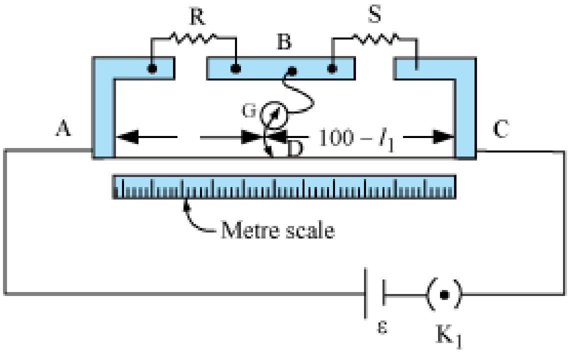
- First law: In any electrical network, the algebraic sum of the currents, $\sum I$, meeting at a junction is always zero.
- Second law: The algebraic sum of all the potential drops and emfs along any closed path in a network is zero.

Wheatstone bridge:



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

Metre Bridge:



Here, $\frac{R}{S} = \frac{R_{cm} l_1}{R_{cm}(100 - l_1)}$ $\therefore R = \frac{S l_1}{100 - l_1}$

- **Causes of probable errors while using a metre bridge:**
  - Uneven thickness of the wire used in the metre bridge
  - Contact resistances developed at the ends of the wire of the metre bridge
  - Ends of the wire not coinciding with the 0 and 100 cm marks of a metre scale

- We can minimise the errors in a metre bridge by using wire of uniform thickness and repeating the experiment by changing the position of the unknown resistance.

- In Kelvin's method, the resistance of galvanometer is given by

$G = R \times \left(\frac{l_g}{100 - l_g}\right)$, where R is the resistance and l_g is the point where the galvanometer shows the same defection as shown while the jockey was not touching the wire.

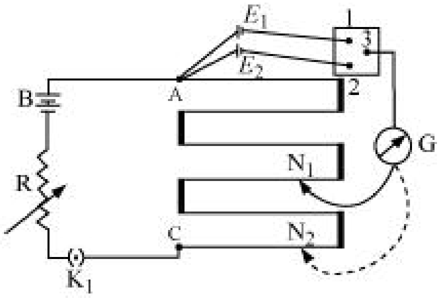
Potentiometer

It works on the principle that on passing a constant current, the potential drop across any portion of the wire is directly proportional to the length of that portion.

i.e., $V \, \alpha \, l$

Applications of a Potentiometer

Comparison of emfs of two cells

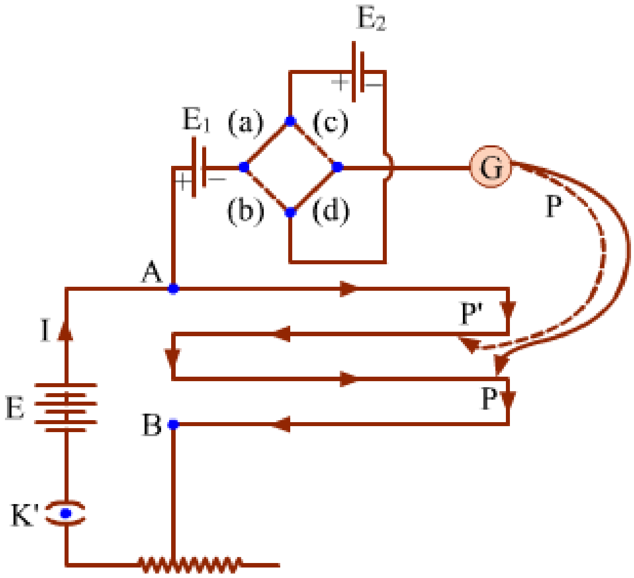


$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

Measurement of internal resistance of a cell

$$r = R\left(\frac{l_1}{l_2} - 1\right)$$

Comparison of emfs using the sum and difference method



$$\frac{E_1}{E_2} = \frac{L_1 + L_2}{L_1 - L_2}$$

Precautions to be taken while using a potentiometer

The potentiometer wire must be uniform.

The resistance of potentiometer wire should be high.

The emf of the battery must be greater then the emfs that are to be compared.

Advantages of a potentiometer

It can measure the terminal potential difference as well as the emf of a cell.

Its accuracy can also be increased by increasing the length of the wire.

Disadvantages of a potentiometer

It cannot directly indicate the value of the potential difference.

It is not portable.