OHM'S LAW AND KIRCHHOFF'S RULE

BRAIN MAP

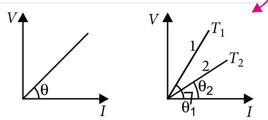
CLASS XII

OHM'S LAW

If the physical conditions of the conductor (length, temperature, mechanical strain etc.) remain same, then the current flowing through the conductor is directly proportional to the potential difference across it's two ends *i.e.*, $I \propto V \Rightarrow V = IR$

Basic Features of Ohm's Law

- Vector form of Ohm's law, $\vec{J} = \sigma \vec{E}$
  where conductivity $\sigma = \frac{1}{\rho}$ and $\vec{J}$ is the current density.
- Graph between V and I for a metallic conductor

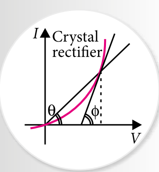


Slope of the line $= \tan\theta = \frac{V}{I} = R$

Here $\tan\theta_1 > \tan\theta_2$ so $R_1 > R_2$ *i.e.* $T_1 > T_2$

V-I curve for non-ohmic substance is not linear

- Static resistance
  $$R_{st} = \frac{V}{I} = \frac{1}{\tan\theta}$$
- Dynamic resistance
  $$R_{dyn} = \frac{\Delta V}{\Delta I} = \frac{1}{\tan\phi}$$

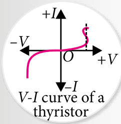


Limitations of Ohm's Law

It is not a universal law that applies everywhere under all conditions. Ohm's law is obeyed by metallic conductors, that too at about normal working temperatures.

Ohm's law is not followed in the following cases

- Materials : Crystal rectifiers, thermistors, thyristors, semi-conductors.



- Conditions :
  (i) At very high temperatures
  (ii) At very low temperatures
  (iii) At very high potential differences.

R is a proportionality constant, known as

Resistance

The property of a substance by virtue of which it opposes the flow of current through it.

$$R = \rho\frac{l}{A} = \frac{m}{ne^2\tau}\cdot\frac{l}{A}$$

ρ is specific resistance of the material of conductor

Resistivity

It is numerically equal to the resistance of a substance having unit area of cross-section and unit length.

Temperature Dependence

For a conductor
then $R_t = R_0(1 + \alpha t + \beta t^2)$
$R_t = R_0(1 + \alpha t)$ $(\beta \approx 0)$
also for resistivity, $\rho_t = \rho_0(1 + \alpha t)$

R_0 = resistance at 0°C
R_t = resistance at t°C
α, β = temperature co-efficients

KIRCHHOFF'S RULE

For circuit containing multiple batteries → Grouping of Batteries

Guidelines to applying Kirchhoff's rule → Problem Solving Strategies

Junction Rule

At any junction of circuit, the sum of currents entering and leaving must be zero.

$\Sigma I = 0.$

It is based on conservation of charge.

Loop Rule

The algebraic sum of changes in potential around any closed loop must be zero.

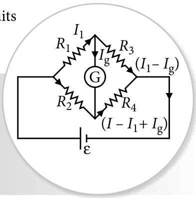
$\Sigma\varepsilon - \Sigma IR = 0$

It is based on conservation of energy.

An important application for few circuits

Wheatstone Bridge

- In balanced condition,
  If $\frac{R_1}{R_2} = \frac{R_3}{R_4}$
  then $I_g = 0$.



Grouping of Batteries

Series grouping

For n identical batteries

$$I = \frac{n\varepsilon}{nr + R}$$
ε = emf
r = Internal resistance

If polarity of m batteries is reversed
$I = (n - 2m)\varepsilon/(nr + R)$

Parallel grouping

- With identical batteries :
  $$I = \frac{\varepsilon_{net}}{R_{net}},\ \varepsilon_{net} = \varepsilon,\ R_{net} = \frac{r}{n} + R$$
- With unidentical batteries :
  $$\varepsilon_{net} = \frac{\Sigma(\varepsilon/r)}{\Sigma(1/r)},\ I = \frac{\varepsilon_{net}}{R_{net}}$$

Mixed grouping

- For n rows of identical batteries with m cells in each row. Then,
  $$\varepsilon_{net} = m\varepsilon,\ R_{net} = \frac{mr}{n} + R,\ I = \frac{\varepsilon_{net}}{R_{net}}$$

Problem Solving Strategies

- *Distribute current at various junctions in the circuit starting from positive terminal.*
- *Pick a point and begin to walk around a closed loop.*
- *Write down the voltage change for that element according to the sign convention.*
- *By applying KVL, select the required number of loops as many as unknowns are available and apply KVL across each loop.*
- *Solve the set of simultaneous equation to find the unknowns.*