Resistance.

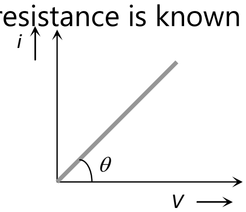
(1) Definition: The property of substance by virtue of which it opposes the flow of current through it, is known as the resistance.

(2) Cause of resistance of a conductor: It is due to the collisions of free electrons with the ions or atoms of the conductor while drifting towards the positive end of the conductor.

(3) Formula of resistance: For a conductor if l = length of a conductor A = Area of cross-section of conductor, n = No. of free electrons per unit volume in conductor, τ = relaxation time then resistance of conductor $R = \rho \frac{l}{A} = \frac{m}{ne^2\tau} . \frac{l}{A}$; where ρ = resistivity of the material of conductor

(4) Unit and dimension:its S.I. unit is Volt/Amp. or Ohm (Ω). Also 1 ohm $= \frac{1 volt}{1 Amp} = \frac{10^8 \, emu \text{ of potential}}{10^{-1} \, emu \text{ of current}}$ = 109 emu of resistance. Its dimension is $[ML^2T^{-3}A^{-2}]$.

(5) Conductance (C): Reciprocal of resistance is known as conductance. $C = \frac{1}{R}$ Its unit is $\frac{1}{\Omega}$ or Ω–1 or "Siemen".

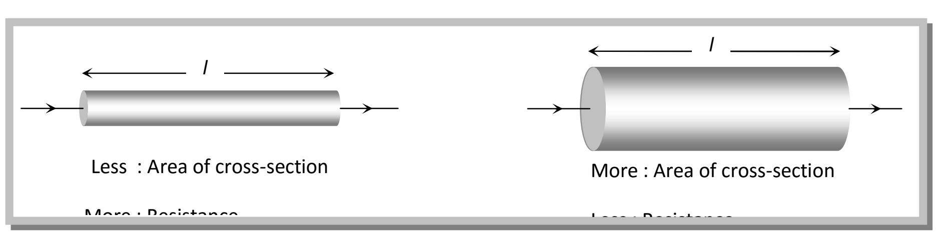


Slope = $\tan\theta = \frac{i}{V} = \frac{1}{R} = C$

(6) Dependence of resistance: Resistance of a conductor depends on the following factors.

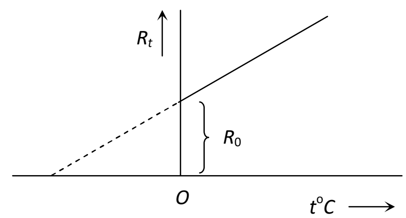
(i) Length of the conductor: Resistance of a conductor is directly proportional to its length i.e. R ∝ l e.g. a conducting wire having resistance R is cut in n equal parts. So resistance of each part will be $\frac{R}{n}$.

(ii) Area of cross-section of the conductor: Resistance of a conductor is inversely proportional to its area of cross-section i.e. $R \propto \frac{1}{A}$



(iii) Material of the conductor: Resistance of conductor also depends upon the nature of material i.e. $R \propto \frac{1}{n}$, for different conductor's n is different. Hence R is also different.

(iv) Temperature: We know that $R = \frac{m}{ne^2\tau} \cdot \frac{l}{A} \Rightarrow R \propto \frac{l}{\tau}$ when a metallic conductor is heated, the atom in the metal vibrate with greater amplitude and frequency about their mean positions. Consequently the number of collisions between free electrons and atoms increases. This reduces the relaxation time τ and increases the value of resistance R i.e. for a conductor **Resistance ∝ temperature**.



If R0 = resistance of conductor at 0oC

Rt = resistance of conductor at toC

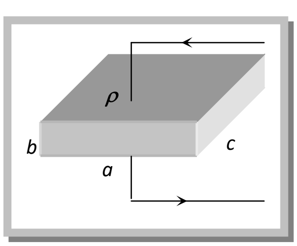
and α, β = temperature co-efficient of resistance (unit → peroC)

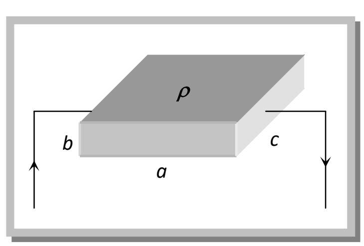
Then $R_t = R_0(1 + \alpha t + \beta t^2)$ for t > 300oC and $R_t = R_0(1 + \alpha t)$ for t ≤ 300oC or $\alpha = \frac{R_t - R_0}{R_0 \times t}$

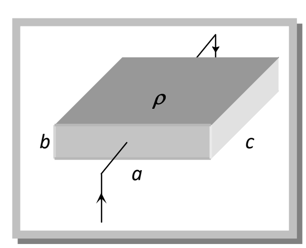
Note: If R1 and R2 are the resistances at t1oC and t2oC respectively then $\frac{R_1}{R_2} = \frac{1 + \alpha t_1}{1 + \alpha t_2}$.

The value of α is different at different temperature. Temperature coefficient of resistance averaged over the temperature range t1oC to t2oC is given by $\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$ which gives R2 = R1 [1 + α (t2 – t1)]. This formula gives an approximate value.

(v) Resistance according to potential difference: Resistance of a conducting body is not unique but depends on its length and area of cross-section i.e. how the potential difference is applied. See the following figures







Length = b	Length = a	Length = c
Area of cross-section = a × c	Area of cross-section = b × c	Area of cross-section = a

Resistance $R = \rho\left(\frac{b}{a \times c}\right)$ Resistance $R = \rho\left(\frac{a}{b \times c}\right)$ $\times$ b

Resistance $R = \rho\left(\frac{c}{a \times b}\right)$

(7) Variation of resistance of some electrical material with temperature:

(i) Metals: For metals their temperature coefficient of resistance $\alpha > 0$. So resistance increases with temperature.

Physical explanation: Collision frequency of free electrons with the immobile positive ions increases

(ii) Solid non-metals: For these $\alpha = 0$. So resistance is independence of temperature.

Physical explanation: Complete absence of free electron.

(iii) Semi-conductors: For semi-conductor $\alpha < 0$ i.e. resistance decreases with temperature rise.

Physical explanation: Covalent bonds breaks, liberating more free electron and conduction increases.

(iv) Electrolyte: For electrolyte $\alpha < 0$ i.e. resistance decreases with temperature rise.

Physical explanation: The degree of ionization increases and solution becomes less viscous.

(v) Ionizedgases: For ionized gases $\alpha < 0$ i.e. resistance decreases with temperature rise.

Physical explanation: Degree of ionization increases.

(vi) Alloys: For alloys α has a small positive values. So with rise in temperature resistance of alloys is almost constant. Further alloy resistances are slightly higher than the pure metals resistance.

Alloys are used to made standard resistances, wires of resistance box, potentiometer wire, meter bridge wire etc.

Commonly used alloys are: Constantan, mangnin, Nichrome etc.

(vii) Super conductors: At low temperature, the resistance of certain substances becomes exactly zero. (E.g. Hg below 4.2 K or Pb below 7.2 K).

These substances are called super conductors and phenomenon super conductivity. The temperature at which resistance becomes zero is called critical temperature and depends upon the nature of substance.