STUDY NOTES

Electrical Engineering Material

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ELECTRICAL DEPARTMENT

GOVERNMENT POLYTECHNIC SAMBALPUR

SYLLABUS
Th4. ELECTRICAL ENGINEERING MATERIAL

Name of the Course: Diploma in Electrical Engineering			
Course code:		Semester	3rd
Total Period:	60	Examination :	3 hrs
Theory periods:	4P/week	Internal Assessment:	20
Maximum marks:	100	End Semester Examination ::	80

A. Rationale:

Electrical Engg. Materials hold prime importance for Electrical Engineers in design, installation & maintenance of electrical equipments. With the advent of latest metallurgical processes the materials used in the design processes brings safer and hazard free electrical installations. Hence basic knowledge on electrical Engineering materials is essential.

B. Objectives:

1. To clarify the students on insulating, conducting & magnetic materials.
2. To impart knowledge on the Physical, Electrical & Mechanical properties
3. To impart knowledge on practical uses of various materials in different areas.

C.TOPIC WISE DISTRIBUTION OF PERIODS		
SI No.	**Topic**	**Periods**
1.	Conducting materials	16
2.	Semiconducting materials	10
3.	Insulating materials	09
4.	Dielectric materials	08
5.	Magnetic materials	08
6.	Material for special purposes	09
	Total:	**60**

D. COURSE CONTENT:

1. Conducting Materials:

1 . 1 Introduction
1 . 2 Resistivity, factors affecting resistivity
1 . 3 Classification of conducting materials into low-resistivity and high resistivity materials
1 . 4 Low Resistivity Materials and their Applications. (Copper, Silver, Gold, Aluminum, Steel)

1 . 5 Stranded conductors
1 . 6 Bundled conductors
1 . 7 Low resistivity copper alloys
1 . 8 High Resistivity Materials and their Applications(Tungsten, Carbon, Platinum, Mercury)
1 . 9 Superconductivity
1 . 10 Superconducting materials
1 . 11 Application of superconductor materials

2. **Semiconducting Materials:**

2 . 1 Introduction
2 . 2 Semiconductors
2 . 3 Electron Energy and Energy Band Theory
2 . 4 Excitation of Atoms
2 . 5 Insulators, Semiconductors and Conductors
2 . 6 Semiconductor Materials
2 . 7 Covalent Bonds
2 . 8 Intrinsic Semiconductors
2 . 9 Extrinsic Semiconductors
2 . 10 N-Type Materials
2 . 11 P-Type Materials
2 . 12 Minority and Majority Carriers
2 . 13 Semi-Conductor Materials
2 . 14 Applications of Semiconductor materials
2.14.1 Rectifiers
2.14.2 Temperature-sensitive resisters or thermistors
2.14.3 Photoconductive cells
2.14.4 Photovoltaic cells
2.14.5 Varisters
2.14.6 Transistors
2.14.7 Hall effect generators
2.14.8 Solar power

3. **Insulating Materials:**

3 . 1 Introduction
3 . 2 General properties of Insulating Materials
3.2.1 Electrical properties
3.2.2 Visual properties
3.2.3 Mechanical properties
3.2.4 Thermal properties
3.2.5 Chemical properties
3.2.6 Ageing
3.3 Insulating Materials – Classification, properties, applications
3.3.1 Introduction
3.3.2 Classification of insulating materials on the basis physical and

chemical structure

3.4 Insulating Gases

3.4.1 Introduction.

3.4.2 Commonly used insulating gases

4. **Dielectric Materials:**

4.1 Introduction

4.2 Dielectric Constant of Permittivity

4.3 Polarization

4.4 Dielectric Loss

4.5 Electric Conductivity of Dielectrics and their Break Down

4.6 Properties of Dielectrics.

4.7 Applications of Dielectrics.

5. **Magnetic Materials:**

5.1 Introduction

5.2 Classification

5.2.1 Diamagnetism

5.2.2 Para magnetism

5.2.3 Ferromagnetism

5.3 Magnetization Curve

5.4 Hysteresis

5.5 Eddy Currents

5.6 Curie Point

5.7 Magneto-striction

5.8 Soft and Hard magnetic Materials

5.8.1 Soft magnetic materials

5.8.2 Hard magnetic materials

6. **Materials for Special Purposes**

6.1 Introduction

6.2 Structural Materials

6.3 Protective Materials

6.3.1 Lead

6.3.2 Steel tapes, wires and strips

6.4 Other Materials

6.4.1 Thermocouple materials

6.4.2 Bimetals

6.4.3 Soldering Materials

6.4.4 Fuse and Fuse materials.

6.4.5 Dehydrating material.

Syllabus coverage up to Internal assessment

Chapters: 1, 2 and 3.

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(CHAPTER - 1)
(CONDUCTING MATERIALS)

* Conducting Materials :-

A conductor is an object or type of materials that allow the flow of an electric current in one or more direction.

(OR)

The material which are used for conduction of electricity is known as conducting material.

Example:- Gold, silver, Aluminium, copper.

* Non-Conducting Material :-

The material which are used for prevention of electricity is known as non-conducting material.

(OR)

The material which are not allow the flow of any electric current is known as non-conducting material.

Example:- wood, Rubber, Glass, Mica, paper.

* Resistivity and Factors affecting Resistivity:-

→ Ohm's Law:-

According to ohm's law the current flowing in a conductor is directly proportional to the potential difference between two ends of a conductor at constant temperature.

$$I \propto V$$

$$\rightarrow \boxed{I = \frac{V}{R}} \rightarrow V = IR$$

where, V = voltage between two terminals of a conductor.
I = Current flowing through the conductor
R = Resistance of conductor.

* Resistance :-
It is the property of a material which opposes the flow of current

* Law of Resistance :-

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

$$\rightarrow \boxed{R = \rho \frac{L}{A}}$$

where,
R = Resistance → ohm's (Ω)
L = length of Resistance.
A = Area of crossection of conductor → $(m)^2$
ρ = Resistivity / specific Resistance → Ω meter (ohm meter)

1st law → $R \propto L$
2nd law → $R \propto \frac{L}{A}$

$\therefore R \propto \frac{L}{A}$

$\rightarrow R = \rho \frac{L}{A}$

$\rightarrow R.A = \rho L$

$\rightarrow \frac{R.A}{L} = \rho$

$\rightarrow \rho = \frac{R.A}{L}$

$= \frac{ohm.m^2}{m}$

$= ohm.m$

$\rightarrow \rho = \Omega m$ (ohm meter)

→ Resistance depends on following factors :-
(i) Length of conductor (L)
(ii) Area of cross-section (A)
(iii) Type of conductor material.

*** Resistivity :- (ρ) [Row]**

Resistivity is the resistance of a material for unit length and unit cross-section area of the material.

If, $L = 1m$, $A = 1m^2$

→ $\boxed{\rho = R}$

→ Resistivity is always constant for a particular material.

*** Dimension of Resistivity :-**

$\rho = \frac{R \cdot A}{L}$

$= \frac{[ML^2T^{-3}A^{-2}][L^2]}{[L]}$

$\therefore \rho = [ML^3T^{-3}A^{-2}]$

$\because$ Acceleration (a) = $\frac{\text{velocity}}{t}$

$= \frac{d/t}{t}$

$= \frac{d}{t^2}$

$= \frac{L}{[T^2]}$

→ $a = [LT^{-2}]$

*** Dimension of Resistance**

$R = V/I$

$= \frac{\text{work}/\text{charge}}{I}$

$= \frac{W/q}{I}$

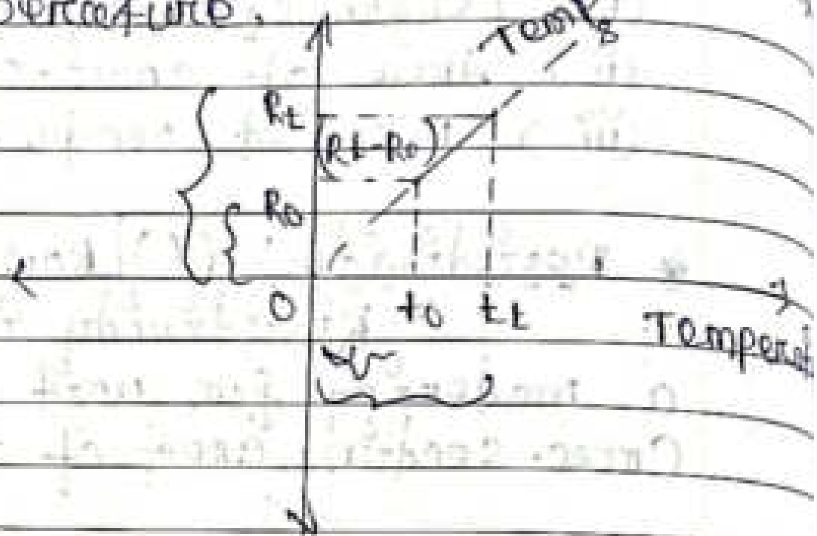
$= \frac{F \cdot d}{q I}$

$= \frac{ma \cdot [L]}{It \cdot [A]}$

$= \frac{[M][LT^{-2}] \cdot [L]}{[A][T][A]}$

$\therefore R = [ML^{+2}T^{-3}A^{-2}]$

→ Resistance of pure metal increase with increase a temperature.



$R_0 \rightarrow$ Resistance at t_0 temp

$(t_t-t_0) \rightarrow$ change in temper. $R_t \rightarrow$ Resistance at t_t temp

$(R_t-R_0) \propto R_0$ —— (i)

$\propto t$ —— (ii)

$\rightarrow$ $\boxed{R_t - R_0 = \alpha R_0 t}$

α - Temperature co-efficient at $0°C$

$R_t = \alpha R_0 t + R_0$

$\rightarrow$ $\boxed{R_t = R_0(\alpha t + 1)}$

→ change in resistance $(R_t - R_0)$ depends on R_0 and also depends on change in temperature $(T_t - T_0)$.

* Factors affecting resistivity :-

→ Temperature
→ Alloying
→ Mechanical stressing.

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Effect of Temperature on Resistivity :-

→ The resistance of most of the conducting material increases with temperature

→ The change in resistance of a material per ohm, per degree change in temperature is called as the temperature coefficient of resistance of that material.

→ The resistance of a conductor changes with temperature according to the law,

$$R_t = R_0(\alpha t + 1) \quad \text{———} \quad (i)$$

→ If the resistance of the same material at any other temperature t_1 degree t_1 is R_{t_1}.

So eqn (i) → $R_{t_1} = R_0 \cdot (\alpha t_1 + 1)$ ——— (ii)

Diving eqn (ii) By (i)

$$\frac{R_{t_1}}{R_t} = \frac{R_0(\alpha t_1 + 1)}{R_0(\alpha t + 1)}$$

$$\Rightarrow \frac{R_{t_1}}{R_t} = \frac{\alpha t_1 + 1}{\alpha t + 1}$$

$$\Rightarrow \frac{R_{t_1}}{R_t} = \frac{\alpha t_1 + 1 + \alpha t - \alpha t}{(\alpha t + 1)}$$

$$\Rightarrow \frac{R_{t_1}}{R_t} = \frac{(\alpha t + 1) + (\alpha t_1 - \alpha t)}{\alpha t + 1}$$

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$= \frac{(\alpha t + 1)}{(\alpha t + 1)} + \frac{\alpha(t_1 - t)}{(\alpha t + 1)}$

$$R_{t_1} = R_t \left[1 + \frac{\alpha(t_1 - t)}{(\alpha t + 1)}\right] \quad \text{------ (iii)}$$

→ From eq^n (iii) we got that the resistance at any temprature t_1 degree can be calculated if the resistance at t degree is known.

→ Also the designer of electrical equipment to determine by calculation the I^2R loss in the winding of equipment like motor, Generator, transformer etc.

→ R_1, R_2, R_3 are resistances at temprature t_1, t_2, t_3 respectively.

$$R_2 = R_1 [1 + \alpha_1 (t_2 - t_1)] \quad \text{---- (iv)}$$
$$R_3 = R_1 [1 + \alpha_1 (t_3 - t_1)] \quad \text{---- (v)}$$
$$R_3 = R_2 [1 + \alpha_2 (t_3 - t_2)] \quad \text{---- (vi)}$$

→ $$\frac{R_3}{R_2} = 1 + \alpha_2 (t_3 - t_2) \quad \text{---- (vii)}$$

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→ Diving eqⁿ (v) by (iv)

$$\frac{R_3}{R_2} = \frac{R_1[1+\alpha_1(t_3-t_1)]}{R_1[1+\alpha_1(t_2-t_1)]}$$

$$\boxed{\frac{R_3}{R_2} = \frac{1+\alpha_1(t_3-t_1)}{1+\alpha_1(t_2-t_1)}} \quad \text{---- (viii)}$$

→ comparing eqⁿ (vii) & (viii)

$$1+\alpha_2(t_3-t_2) = \frac{1+\alpha_1(t_3-t_1)}{1+\alpha_1(t_2-t_1)}$$

$$\Rightarrow \alpha_2(t_3-t_2) = \frac{1+\alpha_1(t_3-t_1)}{1+\alpha_1(t_2-t_1)} - 1$$

$$= \frac{1+\alpha_1(t_3-t_1) - 1 - \alpha_1(t_2-t_1)}{1+\alpha_1(t_2-t_1)}$$

$$= \frac{\alpha_1(t_3 - t_1 - t_2 + t_1)}{1+\alpha_1(t_2-t_1)}$$

$$= \frac{\alpha_1(t_3-t_2)}{1+\alpha_1(t_2-t_1)}$$

$$\boxed{\alpha_2 = \frac{\alpha_1}{1+\alpha_1(t_2-t_1)}} \quad \text{---- (ix)}$$

→ Eqⁿ (ix) is the relationship between temperature co-efficient of resistance with change in temperature.

Temperature co-efficient of Resistance (α):-

$R_t = R_0(1+\alpha t)$

$\Rightarrow \frac{R_t}{R_0} = 1+\alpha t$

$\Rightarrow \left(\frac{R_t}{R_0} - 1\right) = \alpha t \Rightarrow \boxed{\alpha = \frac{1}{t}\frac{(R_t - R_0)}{R_0}}$

$\alpha = \frac{R_t - R_0}{R_0 t}$

Alloying :-

Brass → Cu + Zn
(60-80%) (40-20%)

* Adding some impurities to a metal it is a combination of metal and non-metal.

* Alloying of a metal always increases its resistivity and decreases its conductivity.

* Examples of some alloy are.
Brass → Cu + Zn
Bronze → Cu + tin
Alnico → Al + Ni + Cu

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Nichrome → Ni + Cr.
steel → iron + carbon.

* Alloys have higher resistivity than a pure metal.

* But tensile strength of brass is much more than copper & therefore may be used for making structural products such as rods, shafts, bearing plates, plug points socket outlets etc.

* with increase in resistivity other properties like hardness and ~~tensile~~ tensile strength also increases.

(iii) Effect of mechanical stressing on resistivity :-

Mechanical stressing increases the resistivity of a material and decrease in conductivity by heat treatment process or by influence of mechanical treatment.

* with increasing in resistivity tensile strength also increasing.

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2.3. Classification of conducting materials

- Low resistivity materials
  - Example
    - silver
    - copper
    - Gold
    - Aluminium
    - steel
- High resistivity materials
  - Example
    - Tungsten
    - Carbon
    - platinum
    - Mercury

Low resistivity material :-

These are use in house wiring conductors for power distribution in the winding of Transmission and transformer, motors, Generator etc.

* It should have following properties.

(i) Low temperature co-efficient.
(ii) Sufficient Mechanical strength
(iii) Ductility
(iv) Resistance to corrosion.
(v) Long services life
(vi) Low cost
(vii) Easily available in market.
(viii) solderability
(ix) Low power loss & voltage drop.

High resistivity Materials :-

These materials are used for making resistance elements for heating device and where a large value of resistance is required.

* It should have following properties :-
(i) Low temperature co-efficient.
(ii) High melting point
(iii) No tendency for oxidation.
(iv) High mechanical strength.

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(CONDUCTING MATERIAL)

Conducting materials :-

The materials which are use for conduction of electricity known as conducting materials.

Example :-

Silver, copper, Gold, Aluminium etc.

Non-conducting materials :-

The materials which are not allow the flow of electric current is known as non-conducting materials.

Example :-

wood, Rubber, glass, paper etc.

Resistivity and Factor's affecting Resistivity :-

Ohm's law :-

Ohm's law state that the current flow in a conductor is directly proportional to the potential difference between two ends of a conductor at constant temperature.

$$I \propto V$$

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

R = Resistance

I = Current

V = voltage.

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Resistance :-

Resistance is the property of material which opposes the flow of current.

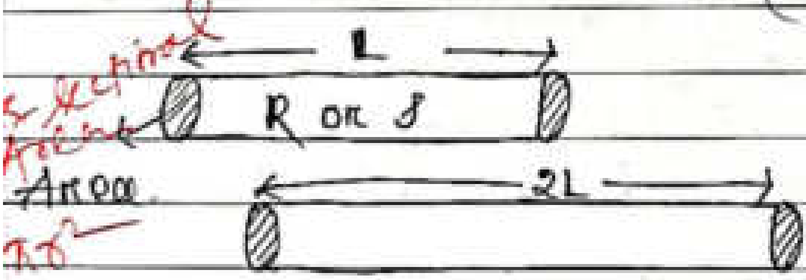
1st law : $R \propto L$

2nd law : $R \propto \frac{1}{A}$

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

$$\boxed{R = \rho \frac{L}{A}}$$

where, A = Crossectional Area
L = Length of conductor
ρ = Resistivity of Material.
(Depended on material)



$R \to 2R$

Resistance depends on two factors :-
(i) Length of conductors ($\uparrow R \propto L \uparrow$)
(ii) cross-sectional Area of conductor.

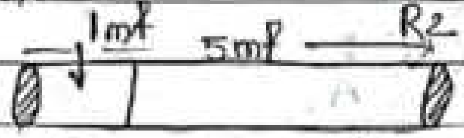
$R = \rho \frac{L}{A}$ $\quad$ ($\downarrow R \propto \frac{1}{A} \uparrow$)

$\rho = R \frac{A}{L}$ $\quad$ Area = 1 unit
Length = 1 unit.

$\boxed{\rho = R}$ → Resistance depends upon Area and Length.

ρ is always constant for a particular material ~~one~~ is change with in change Area and where length.

* Example



$A = 1\,m^2$

$\rho = 3\ \text{ohm}$

$$\boxed{R = \rho \frac{L}{A}}$$

$R_1 = 3 \frac{1}{1}$

$= 3\ \text{ohm}$

$R_2 = 3 \frac{5}{1}$

$= \frac{15}{1}$

$= 15\ \text{ohm}$

Resistivity unit (specific Resistivity Resistance)

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

$\therefore \rho = \frac{RA}{L} = \frac{\text{ohm} \cdot m^2}{m}$

$= \text{ohm} \cdot m$

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Dimension of specific Resistivity :-

Dimension of Resistance

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

$V = \frac{W}{q}$ → work
→ charge.

$q = it$

$$R = \frac{W}{qI} = \frac{W}{i^2t} = \frac{[ML^2T^{-2}]}{[A^2T]} = \frac{ML^2T^{-2}}{[A^2T]}$$

$$= ML^2T^{-3}A^{-2}$$

∴ Resistance of Dimension (R)
or, Dimension of specific Resistance :-

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

$$\rho = \frac{RA}{L} = \frac{[ML^2T^{-3}A^{-2}][L^2]}{[L]}$$

$$\rho = [ML^3T^{-3}A^{-2}]$$

Resistance of pure metal with in in temperature :-

Let is measurement the Resistance of metallic conductor also record the temperature at the time of Resistance measurement.

R_0 = Initial Resistance
T_0 = Initial Temperature.

- Then heat of conductor for some time and measure the temperature and Resistance.

R_1 = Final Resistance
t_1 = Final Temperature

→ Due to change in temperature how much resistance will be change - depends on actual temp of initial Resistance.

$$\boxed{R_t - R_0 \propto R_0} \quad \text{-----} \ (i)$$

- If various temperature is more than change in Resistance is more and vice-versa.

$$R_t - R_0 \ (t_t - t_0) \text{----} (ii)$$
$$\rightarrow R_t - R_0 \propto t \uparrow$$

Combine eqn (i) and (ii), we get :-

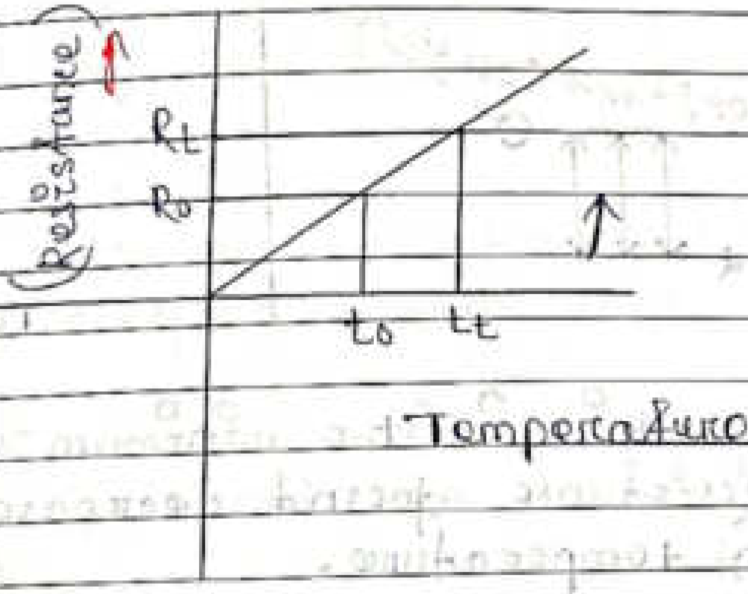
$$R_t - R_0 \propto R_0 t$$
$$R_t - R_0 = \alpha R_0 t$$

$$\rightarrow R_t = \alpha R_0 t + R_0$$

$$\rightarrow \boxed{R_t = R_0(1 + \alpha t)}$$ Temperature co-efficient

→ From the above equation we got temperature of material depends on Resistance.

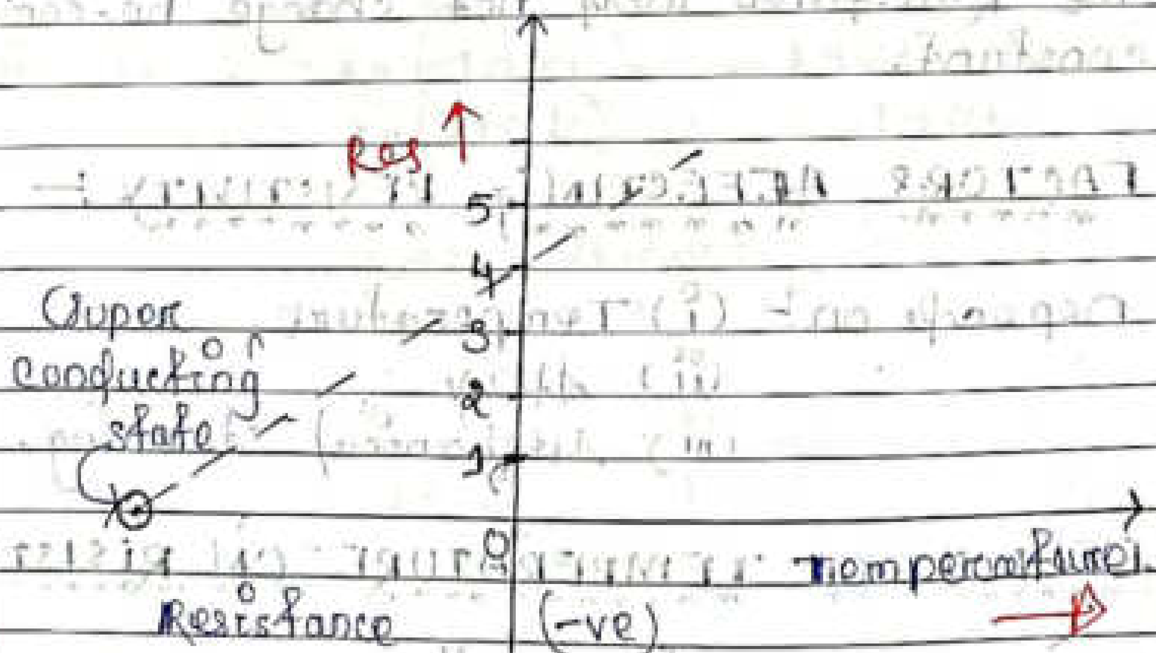
Diagram.

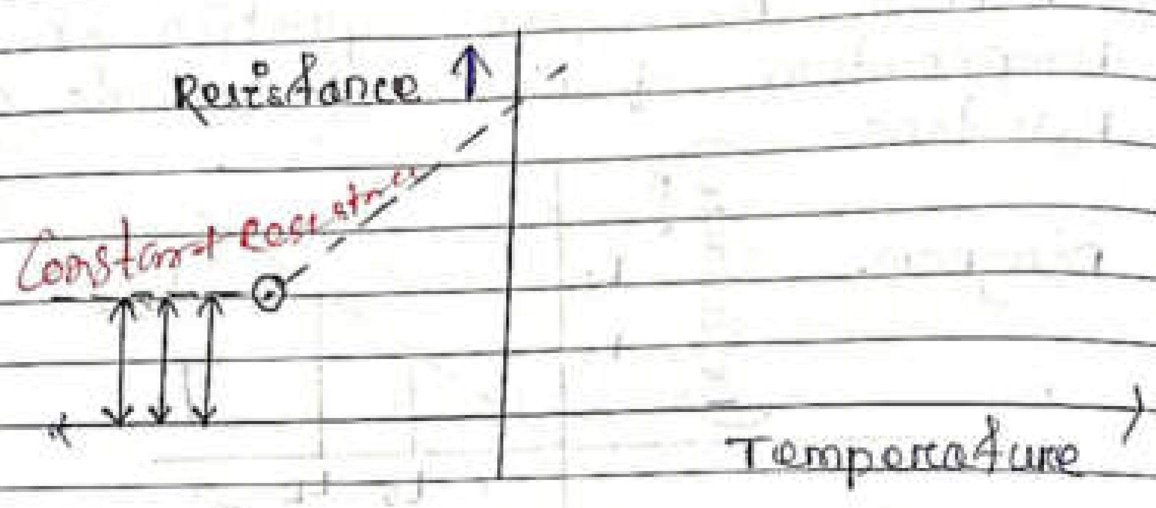


Super conductor :-

→ conductor having zero Resistance.

→ Super conductor is practically impossible.





→ This is the minimum point where resistance doesn't decrease with decrease in temperature.

→ With decreasing temp. the resistance always constant from a definite point.

→ After a certain minimum temperature the resistance will not change be-comes constant.

FACTORS AFFECTING RESISTIVITY :-

Depends on :- (i) Temperature
(ii) Alloy
(iii) Mechanical stressing.

EFFECT OF TEMPERATURE ON RESISTIVITY :-

$$R_t = R_0 [1 + \alpha t]$$

$$\Rightarrow \rho_t \frac{L}{A} = \rho_0 \frac{L}{A} (1 + \alpha t)$$

$$\Rightarrow \rho_t = \rho_0 (1 + \alpha t)$$

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-) the change in Resistance of most of conducting material per ohm per degree change in temperature is called Temperature co-efficient of Resistance of the material.

-) The resistance of a conductor changes with temp according to the law:

$$R_t = R_0 (1 + \alpha t)$$

R_0 Resistance at temp $0°C$

R_t " " " $t°C$

$$R_t = R_0 (1 + \alpha ( ))$$

R_{t_1} at temp t_1

$$R_{t_1} = R_0 (1 + \alpha t_1) \text{ --- (ii)}$$

(ii) $$\frac{R_{t_1}}{R_t} = \frac{R_0 (1 + \alpha t_1)}{R_0 (1 + \alpha t)} = \frac{1 + \alpha t_1 + \alpha t - \alpha t}{1 + \alpha t}$$

$$= \frac{1 + \alpha t + \alpha t_1 - \alpha t}{1 + \alpha t}$$

$$= \frac{1 + \alpha t}{1 + \alpha t} + \frac{\alpha t_1 - \alpha t}{1 + \alpha t} = \frac{1 + \alpha t_1 + \alpha t}{1 + \alpha t}$$

$$= 1 + \frac{\alpha (t_1 - t)}{1 + \alpha t}$$

From above eqn we get the Resistance

-) $$\frac{R_{t_1}}{R_t} = \frac{1 + \alpha (t_1 - t)}{1 + \alpha t}$$ -) $$\boxed{R_{t_1} = R_t \frac{1 + \alpha (t_1 - t)}{1 + \alpha t}}$$

* The Relationship between temp. co-efficient of Resistance with change in temperature can also be found or by following ways.

∴ α - temperature co-efficient

Let R_1, R_2, R_3 are resistance at temperature t_1, t_2, t_3.

$$R_2 = R_1 [1+\alpha_1 (t_2 - t_1)] \text{ ------ (i)}$$

$$R_3 = R_1 [1+\alpha_1 (t_3 - t_1)] \text{ ------ (ii)}$$

$$R_3 = R_2 [1+\alpha_2 (t_3 - t_2)] \text{ ------ (iii)}$$

$$\rightarrow R_3/R_2 = 1+[\alpha_2 (t_3 - t_2)] \text{ ------ (iv)}$$

$$R_t = R_1 (1+\alpha t)$$

$$\rightarrow R_t = (R_0 + R_1 \alpha t)$$

$$\rightarrow R_t - R_0 = R_0 \alpha t$$

$$\rightarrow \boxed{\alpha = \frac{R_t - R_0}{R_0 t}}$$

Deviding eqn (2) by (1)

$$\frac{R_3}{R_2} = \frac{1+\alpha_1 (t_3 - t_1)}{1+\alpha_1 (t_2 - t_1)}$$

$$= \frac{1+\alpha_1 (t_3 - t_1) + \alpha_1 (t_2 - t_1) - \alpha_1 (t_2 - t_1)}{1+\alpha_1 (t_2 - t_1)}$$

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$$= \frac{1+\alpha_1(t_2-t_1)}{1+\alpha_1(t_2-t_1)} + \frac{\alpha_1(t_3-t_1) - \alpha_1(t_2-t_1)}{1+\alpha_1(t_2-t_1)}$$

$$= \frac{1+\alpha_1(t_3-t_1-t_2+t_1)}{1+\alpha_1(t_2-t_1)} \quad \text{--- (5)}$$

$$= \frac{1+\alpha_1(t_3-t_2)}{1+\alpha_1(t_2-t_1)}$$

comparing equ^n (4) with equ^n (5)

$$\Rightarrow \left(1+\alpha_2(t_3-t_2)\right) = \frac{1+\alpha_1(t_3-t_1)}{1+\alpha_1(t_2-t_1)}$$

$$= \alpha_2 = \frac{\alpha_1}{1+\alpha_1(t_2-t_1)}$$

$$= \boxed{\alpha_2 = \frac{1}{\alpha_1 + (t_2-t_1)}} \quad \text{--- (6)}$$

- From equ^n (6) we got that, the temp. co-efficient of Resistance 'α' is not constant with change in Resistance & also changed with Respect to temp.

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Q. The Resistance of a conductor is 5Ω at 50°C and 7Ω at 100°C then the mean temp co-efficient of Resistivity of the material is ?

Given, t_0 50° $R_0 = 5\Omega$

t_1 100°C $R_1 = 7\Omega$

$$R_t = R_0(1+\alpha t) \quad (\alpha\Delta T) \qquad \Delta t = t_t - t_0$$

$\Rightarrow 7 = 5(1+\alpha(100-50))$

$\Rightarrow 7 = 5(1+50\alpha)$

$\Rightarrow 7 = 5 + 250\alpha$

$\Rightarrow 7-5 = 250\alpha$

$\Rightarrow 2 = 250\alpha$

$= \alpha = \frac{2}{250}$

$= 0.008\ ^{\circ}C$

temp. co-efficient of Resistivity unit = °C

Temp co-efficient of Resistance :

$R_t = R_0(1+\alpha t)$, where $t = t_t - t_0$

$\Rightarrow R_t = R_0 + R_0\alpha t$

$\Rightarrow R_t - R_0 = R_0\alpha t$

$\Rightarrow \alpha t = \frac{R_t - R_0}{R_0}$

$\Rightarrow \alpha = \frac{R_t - R_0}{R_0 t} \Rightarrow \boxed{\alpha = \frac{R_t - R_0}{R_0(t_1 - t_0)}}$ (Formula)

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Q. If 2.2M long conductor has a cross-sectional area of $0.025m^2$ and resistance of 5Ω. Find its Resistivity.

(a) 0.072 ohm.m
(b) 0.67 $ohm^{-1}.m^{-1}$
(c) 0.057 ohm.m
(d) 0.057 $ohm^{-1}.m^{-1}$

$$R = \rho\frac{L}{A} = \rho = \frac{AR}{L}$$

$$= \frac{5\Omega \times 0.025m^2}{2.2m}$$

$$= 0.057 \text{ ohm.m}$$

Effect of temp on Resistivity :-

(collision less)

10 collision

→ Temp ↑ ∝ Resistivity ↑

→ (collision more)

15 collision

→ tem ↑ Thermal Energy ↑ (kinetic)
Randomness ↑ collision ↑↑ τ_c ↓
↓
Time of collision between two electron.

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→ ↓ conductivity ∝ T_c ↓

Minimum amount of flow current.

→ conductivity ↓ ∝ $\frac{1}{\text{Resistivity}}$ ↑

tem ↑ ∝ Resistivity ↑

Q. Determine the temp co-efficient of resistance of a resistor at 0°C, when the resistor has a resistance of 20 ohms, at 0°C and 40 Ω at 60°C

Soln

$R_0 = 20$ ohm
$R_t = 40$ ohms
$T_0 = 0°$
$T_t = 60°C$
$\alpha = ?$

$\alpha = \frac{R_t - R_0}{R_0(t_t - t_0)}$ $\alpha = \frac{40-20}{20(60-0)}$

$= \frac{20}{20(60)}$

$= \frac{20}{1200}$

$= 0.01666$

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By Sudhanshu

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Alloying :-

Alloying is a solid solution of two or more metals.

→ Alloying of metals is used to achive some electrical and Mechanical properties.

→ Alloying of metals always increases the resistivity and decreases its conductivity.

→ With increasing resistivity other properties like hardness, mechanical strength also increases.

→ The atomic structure of a solid solution is irregular as compare to pure metal due to which the electrical Resistivity of a solid solution increases more rapidly with increase in alloy content.

→ Resistivity ↑ conductivity ↓

Depend → crystal structure

Resistivity depend on → Residual component
→ thermal component

Depend (Temp)

→ ~~Electrolysis~~

~~process~~ ~~Rest~~

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Thermal components :-

→ At any temp. thermal energy lattice forces lattice atoms to vibrate of their own possition which caused hindrance to the flow of electrons.

thermal components
(it become to 0 at t = 0°k)

→ Residual components :-

It is due to impurity in the material due to cristal imperfection.

→ Due to crystal imperfection it is exist even at 0°k temp

Mechanical stressing :-

Mechanical stressing of the crystal structure of material developed the localised strains in the material crystal structure

→ This localised strains disturbe the movement of free electrons through the material which result in an increasing on resistivity of the material.

strain

Q. At $20^\circ C$ aluminium wire has a resistance of 30Ω. The temp. coefficient of resistance is 0.00305 per degree celsius what is the approximate resistance of the wire (in Ω) at $30^\circ C$.

Soln

Given,

$\alpha = 0.00305$

$R_0 = 30\Omega$

$T_0 = 20^\circ C$

$T_t = 30^\circ C$

$R_t = ?$

$R_t = R_0(1+\alpha\Delta t)$

$= 30(1+0.00305(t_t - t_0))$

$= 30(1+0.00305(30-20))$

$= 30(1+0.00305(10))$

$= 30(1+0.0305)$

$= 30+0.915$

$= 30.915$ (Ans)

Q. Find the resistivity of a material (in ohm-cm) of wire whose resistance is 5 ohm (Assume length of the wire is 15M, diameter of wire is 0.15CM.

Given, R = 5 ohm

L = 15m

Diameter of wire = 0.15CM

ρ = ?

$\rho = \frac{RA}{L}$

$A = \pi r^2$

$= 3.14 \left(\frac{0.15}{2}\right)^2$

$= 3.14 \times (0.075)^2$

$= 3.14 (0.005625)$

$= 0.01766$

length = 15m converted in cm.

$= \frac{15}{100}$ M

L = 0.15 c.m

$\rho = \frac{RA}{L}$

$= \frac{5 \times 0.01766}{0.15}$

$= \frac{0.0883}{0.15}$

= 0.58866

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Classification of conducting Material :-

→ Low Resistive Material (Resistance ↓)
→ High Resistive Material (~~constructive~~)

Low Resistive Material :- (High conductivity)

Material having low Resistive or high conductivity are very useful in electrical Engg for manufacturing electrical enggenering Machines or equipment.

→ This material used as conductors for all ~~king~~ kind of winding in all electrical Machine

→ This Material are also used was conductors in transmission and distribution of electrical enggenering.

Example :- silver, copper, Gold, Aluminium and steel etc.

Properties of low Resistivity Material :-

→ Highest possible conductivity !
(Ideally Resistivity = 0)

→ Least possible temp. co-efficient of Resistance.
(temp ↑, Resistance ↑) Loss ↑

→ High Melting point. (tem ↑)

→ High Mechanical strength.

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→ High ductility.
→ High corrosion Resistance
→ Solder ability
→ Low cost.
→ Long life
→ High flexibility

(a) Low temp. coefficient.
↳ Low temp. coefficient means the change of Resistance with change in the temp should be low.

→ 1 avoid the variation in voltage drop and power low with change in temp.

Example :-
In summer session the Resistance of transmission line which are very long will increase Resistance due to increase in temp. It in increase the voltage drop and power ~~low~~ loss in transmission line.

The winding of electrical machine and apparatus ~~becomes~~ becomes hot and when loaded this increases the temp in winding. So that voltage drop and power loss in the winding increases if the material is high temp. co-efficiently.

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(b) Sufficient mechanical strength :-

Generally the overhead transmission and distribution line are subjected to mechanical stress due to wind and their own weight.

-> So it is very important to make the mechanical strength high to with stand the mechanical ~~strong~~ stress.

-> The conductive materials used for the winding of transformer, motors, and generators develop mechanical forces when loaded. which become very large if a ~~due to~~ high current flow due to short circuit on that condition ~~materials~~ conducting materials is subjected mechanical stress.

(c) Ductility :-

Ductility is that property of a material which allow it to be drawn out into a wire. so conducting materials should be ductile enough to be drawn into different shape and size.

-> (Wires are used for different application. in some case round wire section is used. where in some case rectangular wire are also used.)

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(d) Solderability :—

Solderability provide minimum contact resistance during joining of two conductor, as compare to a simple joint. So solderability is needed while choosing a conducting material.

(e) Resistance to corrosion :—

All conducting material should possess the resistance to corrosion property. Otherwise the conductive capacity of the metal will decrease when used in out-door atmosphere.

Note :—

The reader should not lead himself to believe that all conducting materials should possess all the above mentioned properties. Depending upon the applications an appropriate material should be chosen which may not have all the above properties but those which the particular application calls for.

Table 2.1 values of resistivity temperature coefficient, density and melting point for different materials.

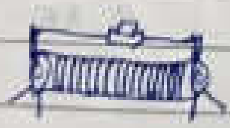
Material	Resistivity (ohm-m) at 20°C × 10^{-8}	Temperature co-efficient per degree C at 20°C × 10^{-4}	Density	Melting Point (degree c)
Aluminium (cast soft)	2.8	35	2.68	655
Aluminium (Hard drawn)	2.9	35	2.71	630
Carbon	400 to 1200	-12 to -60	1.9 to 2.3	3450
Copper (annealed)	1.72	39	8.89	1084.
Copper (hard drawn)	1.77	39	8.89	1084
Iron (cast)	75 to 98	–	7.80	1500 to 1530
Lead	21	41	11.40	327
Nickel (commercial)	10.5	40	8.85	1450
Silver	1.60	40	10.50	960
Tin	11.50	46	7.30	232
Tungsten	5.50	50	18.80	3300

Silicon steel	50 to 60	—	7.70	—
Carbon steel (High carbon)	15 to 45	2 to 40	—	—
Carbon steel (up to 0.4% carbon)	10 to 14	40 to 50	7.80	1350
Nichrome	100	4.4	8.15	1538
Brass	7	15 to 20	8.40 to 8.70	—
Manganin	48	0.5	8.40	102
Constantan	52	0.25 to 05	8.90	—

High Resistivity Material :- (↑R conductance)

High Resistivity Material are used in such application where large value of Resistance is required.

Example :-



- Starter for electrical
- Loading Resistance
- Rheostat
- Filament incandescent lamp.
- Resistance element for heating device
- Resistance used in precision measuring instrument.

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→ If low Resistivity material wire used for such application, then the length of wire would be to large which would increases the size of equipment.
example:-

Nichrome (R ↑) Copper (R ↓)

Nichrome (R ↑)	Copper (R ↓)
$\rho = 100 \times 10^{-8}$ ohm-m	$\rho = 1.732 \times 10^{-8}$ ohm-m
$a = 12.6 \times 10^{-8}$ m²	$a = 12.6 \times 10^{-8}$ m²
$R = 40\Omega$	$R = 40\Omega$
$l = ?$	$l = ?$

Nichrome:

$$l = \frac{RA}{\rho}$$

$$= \frac{40 \times 12.6 \times 10^{-8}}{100 \times 10^{-8}}$$

$$= \frac{40 \times 12.6}{100}$$

$$= \frac{504}{100}$$

$$= 5.04 \text{ M}$$

Copper:

$$l = \frac{RA}{\rho}$$

$$= \frac{40 \times 12.6 \times 10^{-8}}{1.732 \times 10^{-8}}$$

$$= \frac{40 \times 12.6}{1.732}$$

$$= \frac{504}{1.732}$$

$$= 290.99 \text{ M.}$$

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→ From above Example when the element of copper 290 M length required. When the Element is Nicrome only 5.04 meter length meter Required.

→ A high resistivity materials besides possessing High value of Resistivity should also possessing the following additional properties.

(i) Low temperature co-efficient
(ii) High melting point.

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Problems:

Q: What is resistivity (in ohm-mtr) of a 2ohm cylinder wire when the length & the diameter of the wire are 10 meter & 0.4 meter respectively.

Sol^n Given,

$R = 2$ ohm

$l = 10$ m

diameter $= 0.4$ m

$\rho = ?$

$$\rho = \frac{RA}{L}$$

$$A = \pi r^2$$
$$= 3.14 \left(\frac{0.4}{2}\right)^2$$
$$= 3.14 (0.2)^2$$
$$= 3.14 (0.04)$$
$$= 0.1256$$

$$\rho = \frac{RA}{l}$$
$$= \frac{2 \times 0.1256}{10}$$
$$= \frac{0.2512}{10}$$
$$= 0.02512 \text{ ohm-m}$$ (Ans)

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Accuracy :-

It is the degree of close-ness with which, an instrument reading approaches the true value of the quantity being measured, i.e conformity to the truth.

→ It indicates the closeness b/w measure value and true value. This closeness must be high, then the accuracy will high.

A_T	A_m
50	49.7
	49.8
	49.9 (more accuracy)

Precision :-

It is the degree of closeness b/w the measured when same i/p value measured no. of times.

10 V → 9.995 → High accuracy.
9.999
9.997
9.998
} High precision

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Additional properties :-

(a) Low temperature co-efficient :-

For precision application of material the temperature co-efficient of resistance must be low otherwise, the accuracy of measurement will be reduced.

Example:-
→ Resistance box
→ precision Resistance.

(b) High melting point :-

The ~~melting~~ melting point of material should be high inorder to resist the high temperature for a long period.

Example
→ Rheostat
→ starter for electric motor
→ Room heater
→ Furnaces.

(3) No Tendency for oxidation :-

High tendency :-
High temperature oxidation of a metal is a corrosion process involving the reaction b/w the metal and the atmospheric oxygen at elevated temperature.

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→ Material used as high resistance elements in heating appliances should be able to withstand high temperature for a long time without oxidation. Because if an oxide layer is formed on the heating elements the amount of heat radiation will reduce.

Low Resistivity Materials :-

Copper :-

→ Copper has high conductivity (low resistivity) and it is non-magnetic (non-Ferrous) in nature.

→ It has remarkable physical, chemical and electrical properties.

→ Copper is reddish in colour and can be available in hard drawn or annealed form.

→ Mechanical properties are different for hard drawn and annealed copper. Hard drawn copper becomes soft after annealing.

→ Annealed copper are soft with low tensile strength, high flexible, high conductivity and are obtained by heating at specific temperature and then cooling.

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→ Hard drawn coppers are hard with good tensile strength, low conductivity and are obtained by drawing copper bars or rods in cold condition.

→ When it is exposed to atmosphere, copper-oxide layer is formed on its surface which acts as a protective layer and prevents corrosion.

→ Density and melting point of annealed copper are 8.89 and 1084 degrees centigrade and for hard drawn copper 8.93 and 1084°C respectively.

→ The tensile strength of copper varies from 8.15 to 4.72 tonnes/cm²

→ Copper has good solderability and welding characteristic with minimum contact resistance.

→ The most important application of hard drawn copper are in overhead conductors, high-voltage underground cables and bus-bars because of its high mechanical strength.

→ Annealed copper is used conductors in low voltage power cables, winding coils for electrical machines and transformers.

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-> Due to scarcity of copper, it is not used in transmission and distribution line.

-> pure form of copper is not used as an electrical contact material. it becomes harder and cheaper when 10 to 30% of Nickle is mixed with it.

-> Due to it's high electrical and thermal conductivity it is commonly used as a contact material for control relays, motor starter switches and tap changer.

-> it has poor resistance to oxidation which lower it's efficiency.

Silver :-

-> pure silver has high electrical conductivity and corrosion resistance.

-> when 15% of copper is added with pure silver it becomes more harder.

-> When 40% of copper is mixed with pure silver it makes more hard which is used in commutator segment of small DC motor.

-> For Brushes and collector rings of DC Motor, silver graphite alloy is used.

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Gold :-

-> Gold is the best known electrical conductors but it is not found sufficiently and also it is costly.

-> It's density is 19.3 times more that water, melting point is 1063°C and boiling point in 2100°C.

-> It's good corrosion resistance makes it's alloy very much useful as contact material, so, it's alloy is corrosion resistance brazing material.

Brazing :-
Used to join two similar or dis-similar metal just like welding.

Aluminium :-

-> After copper aluminium is the best conductor for transmission line.

-> Resistivity of aluminium is 2.8×10^{-8} (1.6 time more than copper) ohm-m and it's density is 2.68 (1/3 of copper) and it's Melting point is 655°C.

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→ Aluminium is the soft metal but when alloyed with magnesium, silicon and iron it acquires higher mechanical strength and mostly used in over head transmission line.

→ Like copper oxide layer aluminium oxide layer is formed over it's surface when it exposed to atmosphere and that layer prevent from oxidation and acts as a resistance layer to corrosion.

→ when aluminium oxide layer is formed on the surface it acts as a insulator because aluminium oxide has relatively higher resistivity.

→ It is quite extensively used for flexible wires, overhead transmission lines, bus bars, squirrel cage induction motor rotor bars.

Q. Why Aluminium can't be substitude in place of copper for the application of winding of electrical Machine & TF ?

disadvantages:-

(i) Aluminium wire have low tensile stress as compare to copper (0.95 to 1.57 tones/cm²) which results the breaking of the wire under tension conditions developing knicks (~~twist~~) (Twist)

→ Since Aluminium Resistivity is higher than copper. The wire has to have a thicker ~~proportion~~ cross-section to keep the I^2R losses low.

Those winding occupies more space and the machine size increases.

Advantages:-

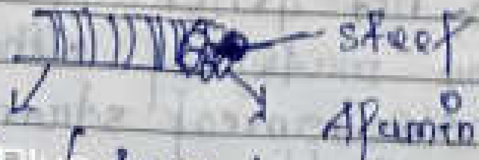
→ Because of lower density of aluminium as compared to copper Aluminium wound machine less weight.

→ Aluminium weights about 1/35th time as much has copper its resistance per unit weight is less than that of copper. although the resistivity is higher.

→ For economic Reason Aluminium has replaced copper in many field

→ over head transmission line are now all made of Aluminium conductor with steel Reinforced (ACSR) → (provides Higher strength to overhead line)

→ ACSR provides higher strength to over at line.



(ACSR)

AAC

All Aluminium conductor.

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Steel :-

→ steel is alloy of iron with small percentage of carbon.

→ when carbon is added with iron, it acquires a good mechanical property

→ with addition of a small percentage of carbon tensile strength of steel increases but at the same time its ductility decreases.

* (If the % of carbon addition increases the steel is brittle)

→ steels are classified ~~carbon about~~ follows

(i) Mild steel containing carbon about 0.25%

(ii) Medium steel containing carbon about 0.45%.

(iii) The High carbon steel containing carbon of about 0.70% and above.

→ The resistivity of steel is 8 to 9 times higher than that of copper. So that it is not generally used as a conducting material although it has high Mechanical strength and is easily available.

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→ steel is easily corroded when exposed to moisture. so to avoid this a zinc coating is provided over it's surface (galvanizing).

→ Galvanised steels wires are used as overhead telephone wires and as earth wires.

STRANDED CONDUCTORS.

Formulae: $N = 3x^2 - 3x + 1$, $D = (2x-1)d$

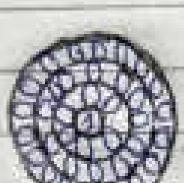
→ when a single conductors of large cross-section is used, it becomes rigid in construction and is liable to kinks and breaks while handling.

→ To avoid this conductors are made of a number of thin wires, bunched to-gether, called stranded conductors.

→ stranding makes the conductors flexible and eliminate to a large risk of it's breaking during handling or operation.

* A stranded conductor is made by twisting the wire (strands) together to form layers.

* generally stranding is done in opposite direction for successive layer. This means if the wire of one layer are twisted in left-hand direction. the next layer of wires will be twisted in the right hand direction and soon.



1 → 1 conductors (centre)
2 → 6 conductors (1st layer)
3 → 12 ,, (2nd layer)
4 → 18 ,, (3rd layer)
5 → 24 conductors (4th layer)

The No of layer to be provided will depends upon the number of wires to be provided.

Formula is given for a number of wires for a particular layer, the total No. of wire in a particular stranded conductor and the diameter of the stranded conductor.

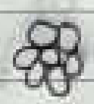
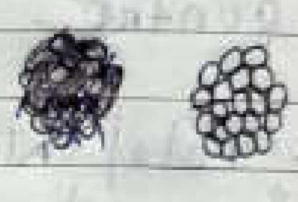
Table

The No. of wires in different layers, total number of wires and over-all ~~dia.~~ diameter of stranded conductors.

No. of wires in the centre	1 wire	3 wires	4 wires
→ No. of wires in the n^{th} layer from centre	$6n$	$3+6n$	$4+6n$
→ Total No. of wires in a stranded conductor having n layer	$1+3n(1+n)$	$3(1+n)^2$	$(4+3n)(1+n)$
→ Diameter over the n^{th} layer in centimeters where d indicates the diameter of each wire in centimeters.	$(1+2n)d$	$(2.155+2n)d$	$(2.414+2n)d$

Formula - $N = 3x^2 - 3x + 1$
$D = (2x - 1) d$

Table

Sl No.	No of layer (x)	Total No. of st (N)	Diameter of conductor (D)	Cross-sectional
1	1	1	d	
2	2	7	3d	
3	3	19	5d	
4	4	37	7d	
5	5	61	9d	

Bundled conductor :-

Corona loss :- → charge particle

AC
Skin effect

High voltage pass.

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Corona loss :-

Electric field surface on conductor is greter than of dielectric strength then air around the conductor ionizes.

-) Due to corona there is a hissing sound and ~~proper~~ purple glow around the conductor.

-) Due to light and sound the energy is dissipated called as corona loss.

-) Minimize the corona loss :-

(i) voltage
(2) GMD & GMR.

-) To reduce corona loss we need to reduce electric field which can be term by following method,

(a) Reduce operating voltage.
(b) increase GMD & GMR
(Geometry Mean Distance, Mean radius)

-) Increasing GMD required increasing distance between conductor. which is lead to increasing cross arm and increasing in size of tower. Hence increase the cost

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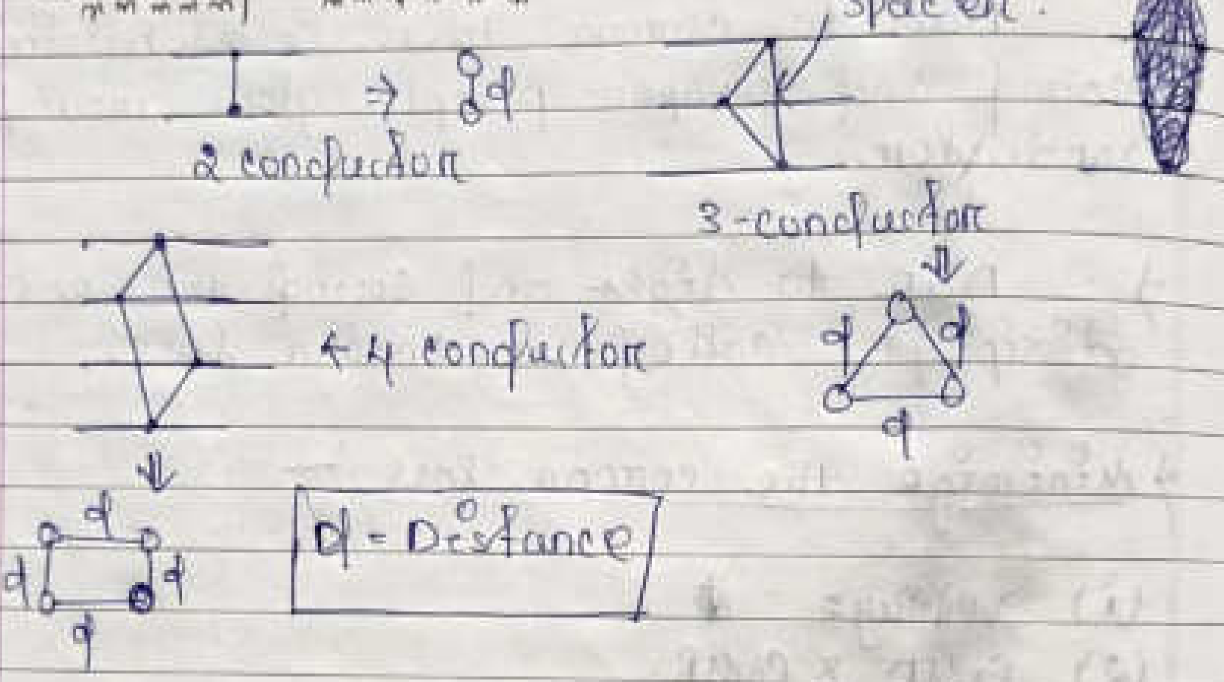
Implic

→ Increasing GMR

Bundled conductor :-



→ A Bundled conductor is a conductor made up off two or more Sub-conductor and is use as one fase - conductor.

→ For voltage greater than 220kV it is preferable to use more than one conductor for fase which is known as Bundled conductore.

Advantages :-

(i) Current carrying capacity increases.
(ii) Reduce losses.
(iii) Increase Efficiency $\eta = \frac{o/p}{i/p}$

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(iv) Improvement in voltage Regulation

$$\text{formula} = V.R = \frac{V_{N.L} - V_{F.L}}{V_{F.L}}$$

(v) Reduced corona loss.
(vi) Line is less liable to cause radio-
interference.

Low Resistivity copper alloys :-

1. Brass :-
→ copper + zinc (Tensile strength ↑)
60% 40%

→ when copper is alloyed with zinc (60% copper 40% zinc) it is called as brass.

→ Brass has high tensile strength but has lower conductivity than copper.

→ It is weldable and solderable and fairly resistant to corrosion.

→ Due to all these reasons, Brass can be used as current carrying and structural material in plug-points, socket-outlets, switches, lamp holders, fuse holders, knife switches, sliding contacts for starter and rheostats etc.

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2. Bronze :-

→ Copper when alloyed with tin (80% - 16%) and a very small percentage of a 3rd element like cadmium, Beryllium, phosphorous, silicon etc. is called as Bronze.

Copper + tin + small percentage of a 3rd elements { cadmium, Beryllium, phosphorous, silicon
↓ 80%, ↓ 16%, ↓ 4%

→ When copper and tin alloyed with cadmium it is known as cadmium bronze.

→ When the third element is phosphorous, the alloy is called phosphorous bronze (slip rings)

→ When the third element is silicon, the alloy is called silicon bronze.

→ All bronzes possess high mechanical strength as compare to copper and bronzes are more free from corrosion than brasses.

cadmium bronze → contacting conductor and commutator segment

Beryllium bronze → current carrying spring sliding contacts, knife switch blades, etc.

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3. Beryllium copper alloy :—

→ When copper alloy contain a small % of beryllium then it is called bronze.
(copper + small % of beryllium)

→ It has high conductivity and mechanical strength.

USES:
→ current carrying springs
→ brush holders,
→ bellows,
→ coil springs, sliding contacts and knife switch blades.

High Resistive Material & Their Application

→ heating Device. → stater.
→ Rheostat
→ Measuring instrument.

High Resistive material are used for making resistance element for heating device stator for electric motor, Resistance for measuring instrument, loading Resistance, (Rheostat) filament lamp for incandescent lamp etc.

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→ High Resistive materials are generally made by alloy of different metal.

MANGANIN :-

↳ Copper + Manganese + Nickle
86% 12% 2%

→ Manganin is an alloy of copper (86%) Manganese (12%) and Nickle (2%)

→ The melting point of manganin is 102°C and it can easily be drawn into a thin wire.

Application :-

* coils for precision electrical measuring Instrument.
* Resistance boxe.

Constantan :-

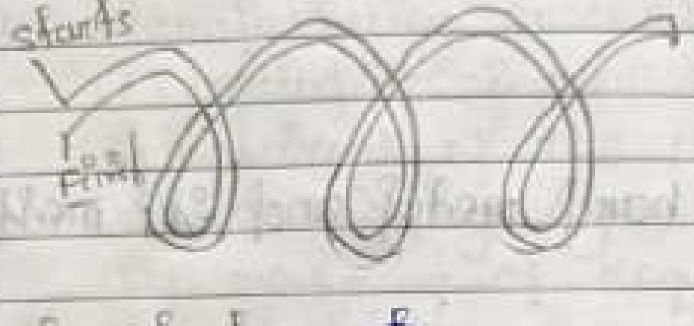
→ It is a copper Nickle alloy
(60%) (40%)

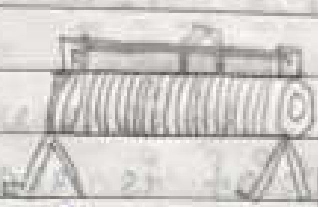
→ The maximum permissible working temp. is about 500°C, and it can be drawn into thin wires.

Application :-

→ For making, resistance elements for items line loading ~~starter and~~ Rheostats and starter for electric motors

* To make the rheostat purely resistive, the wire is wound first clockwise in the forward direction and then anticlock wise in the reverse direction as shown in fig.





S - start
F - Finish

(Rheostat)

(Laboratory type rheostat using constantan wire)

NICROME

→ Nicrome is an alloy of manganese (1.5%) Nickle (75.7) and cromium (20-23%) and a little % of iron.

→ It can be drawn into thin wires and is mechanically strong and its working temperature is 1100°c.

→ It has high resistivity, i.e 100×10^{-8} Ω mt. at 20°c which is twice that of manganin and constantan.

Date / /

Application :-

For making heating element for electric irons, electric ovens, room heaters, electric ~~iron~~ furnaces etc.

TUNGSTEN :-

→ It is a very hard metal and it's melting point is 3300°C

→ It can be drawn into very thin wires required for making filaments.

Application :-

→ Filament for incandescent lamp.
→ Heater in electron tube.

* It oxidises very quickly in the presence of oxygen even at temperature of few hundred degree centigrade.

* In the atmosphere of inert gas (Nitrogen, Argon etc) or in vacuum, ~~tung~~ tungsten can reliably work at temperature like 2000°C and even higher.

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CARBON :—

→ It is manufactured from graphite and other form of carbon like, coal etc.

→ Manufacturing process :—
(i) grinding of raw carbon materials.
(ii) Mixing of the powder of carbon with a binding agent (coal-tar)
(iii) moulding of requisite component.
(iv) Baking.

→ It's conductivity can be increase by addition of copper or bronze powder with carbon moulding compound.

Application :—

→ Current carrying element Ex - Brushes in electrical M/c apparatus, ~~elem~~ electrodes for electric-arc furnaces, non-wire resistance, carbon pile resistances, membranes and other components for telecommunication equipments, battery cell element, arc lamps arc weldings.

CHARACTERSTICS :—

→ It has very high value of resistance/ resistivity. ($\alpha \uparrow R$)
→ Negative temperature co-efficient of resistance. ($\alpha \uparrow R$)

→ pressure sensitive (electrical resistance of the carbon contact decreases as the pressure increases) (P↑ R↓)

→ Low surface-friction. (

~~[struck-out word]~~

PLATINUM :—

→ platinum is greyish white metal which is non-corroding.

→ It is malleable and ductile and is resistance to most chemicals.

→ platinum is a heavy metal having specific weight of 21.4 gm/cm³

→ It's melting point is 1775°C. The resistance of platinum is 0.9×10^{-6} Ω-mt and it's temperature co-efficient is 0.00307 per °C.

→ platinum can be drawn into thin wires and strips. It does not oxidize in air and has no tendency to arc.

Application :—

→ Heating element in laboratory ovens and furnaces.

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→ platinum - Rhodium thermocouple is used for measurement of temperature upto 1600°c

→ platinum is also used as electrical contact materials and as material for grids in special purpose vacum tube.

* contact Materials
materials used for making contacts have to withstand arcing and spark-over whenever contacts are separated. (Make and break operations)

* Due to frequent operation,
* The property deteriorate with time because of ① corrosion ② erosion.

① corrosion cause a film of oxide to be deposited on the contacts, reducing the conductivity of the conduct.

② erosion is caused due to fusing and wear of the working surface of the contacts during operation.

platinum being highly resistant to corrosion and having a high melting point is often used for making lightly loaded contacts (current not exceeding 1A)

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Mercury :—

- It's a silver white metal.
- It's specific weight is 13.55 gm/cm^2.
- It is the only metal which is in liquid state in room temperature.
- It's Boiling point is 357°C.
- It's resistivity is 0.95×10^{-6} Ω-m and temperature co-efficient of resistance is 0.00027 per °C.
- Mercury is poisonous.

Application :—

- Mercury arc rectifier.
- Gas filled tubes (Mercury vapour lamp)
- As liquid contact material in electrical switchs.

Example :—

It is used for making and breaking contact in Buchholz relay for T/F protection.

Mercury arc Rectifier :—

- It is a type of electrical rectifier used for converting high voltage or high current (AC) into DC.

- It is used to provide power for industrial motors, electric railways, streetcars and electric locomotives as well as for radio transmission and for high-voltage direct current (HV.DC) power transmission.

→ But mercury arc rectifier is replaced by semiconductor rectifiers, such as diodes, thyristors, GTO, etc.

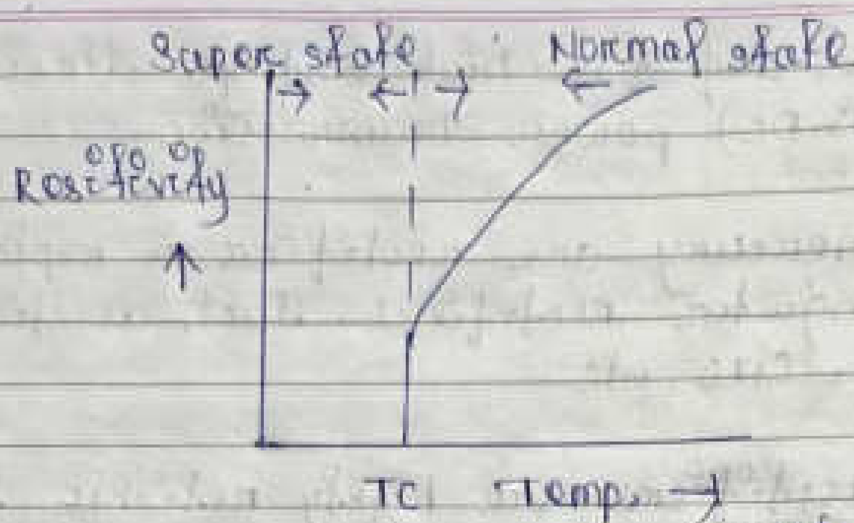
→ This rectifiers are highly reliable, lower cost and maintenance and lower environmental risk.

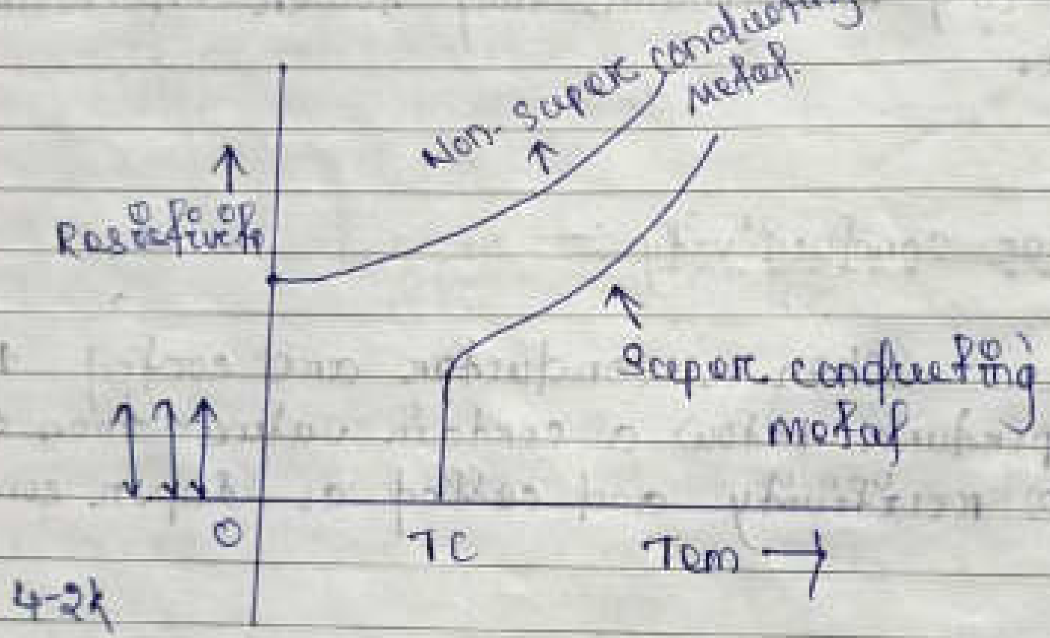
Super conductivity :—

when a conductor are cooled to a temperature below a certain value then they lose resistivity and called as Super conductivity

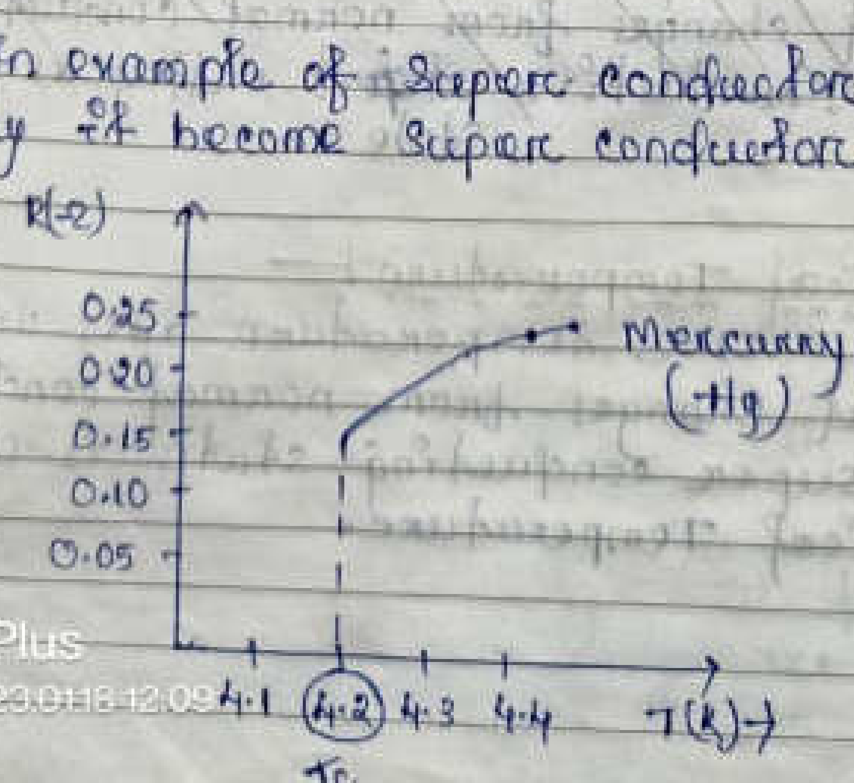
~~The temperature at are which the metal changes from normal conducting state to Super conductive state is called as~~

Critical Temperature :—
The temperature are which the metal changes from normal conducting state to super conducting state is called as Critical Temperature.



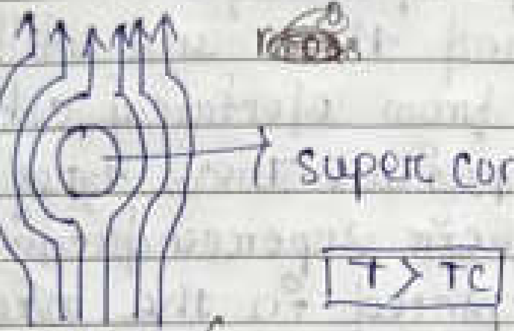


→ An example of super conductor is mercury it become super conductor 4.2 Kelvin



Properties of Super conductor :-

1. Zero electric Resistance
2. Meissner effect :- Expulsion of magnetic field.
3. Critical temperature.
4. Critical Magnetic field.



(Meissner effect)

Meissner effect :-

As a super conductor in a magnetic field is cooled to the temperature at which it abruptly losses electrical resistance, all or part of the magnetic field within the material is expelled.

Critical Magnetic field :-

The minimum applied magnetic field needed to destroy super conductivity in a material is called critical Magnetic field.

Super conductor are Divided into two types.
(1) Type-1 Super conductor
(2) Type-2 Super conductor.

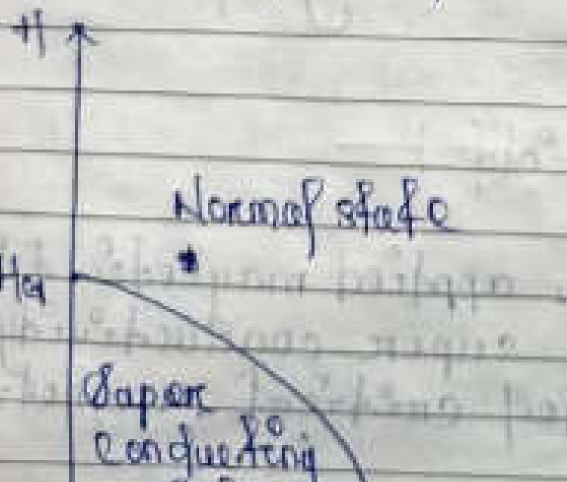
(1) Type-1 Super conductor :-

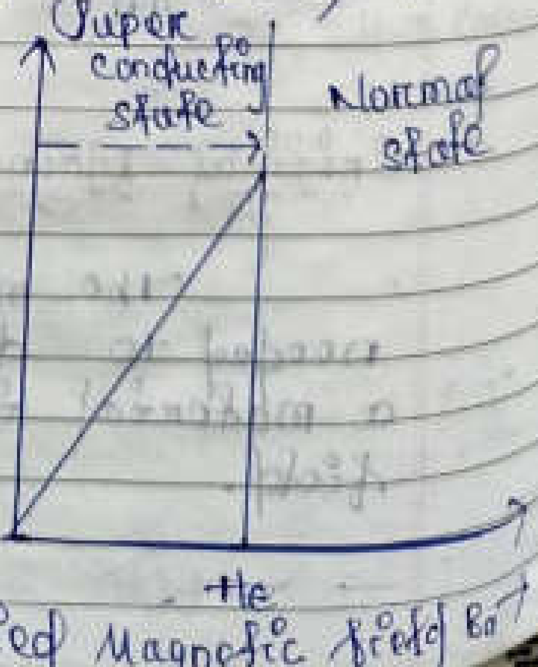
→ This kind of superconductor includes basic conductive parts and these are utilized in different fields from electrical cabling to microchips on computer. These types of Super-conductors lose their superconductivity very simply when it is placed in the magnetic field at the critical magnetic field (Hc) After that, it will become like a conductor.

→ These types of Superconductors are also named as soft Superconductor due to the reason of loss of Superconductivity.

→ These superconductors obey the Meissner effect completely.

→ The Superconductor examples are Zinc & Aluminum





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Type-II Superconductor :-

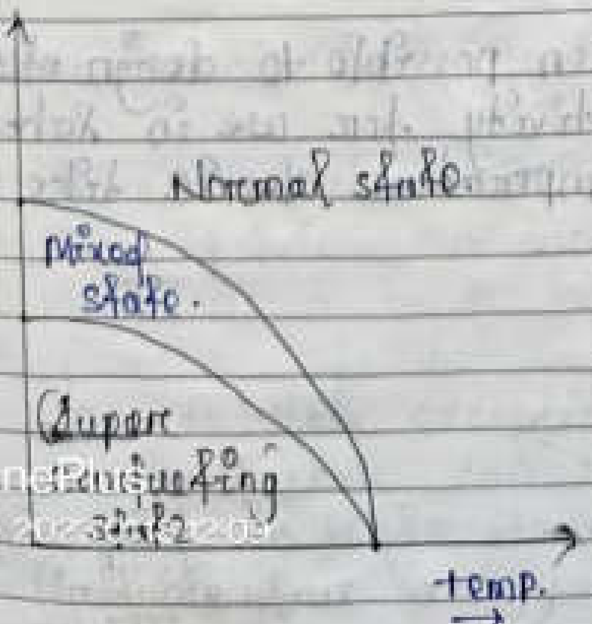
→ This kind of semiconductors will start to lose their superconductivity on the less significant magnetic field & totally drop their super-conductivity at the higher critical magnetic field.

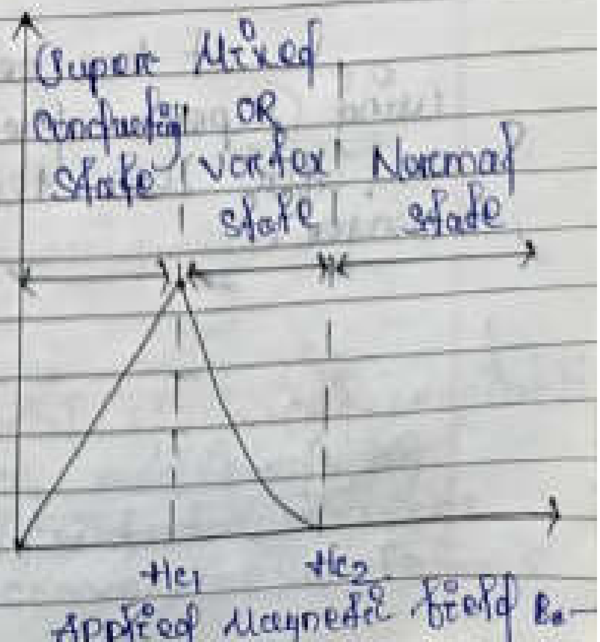
→ The condition between the slighter critical magnetic field & higher critical magnetic field is called an intermediate state otherwise vortex state.

→ This type of semiconductor is also named as hard superconductors due to the reason they lose their superconductivity slowly but not simply.

→ These semiconductors will obey the effect of meissner but not total".

→ The best examples of these are NbN and Babi3





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Application of Superconductor Materials :-

① Electrical Machines :-

→ Efforts are being made at present to develop electrical Machines and transformers utilizing Superconductivity.

→ If we could use superconductors as conducting materials, it is possible to manufacture electrical generators and transformers in exceptionally small size having an efficieny as high as 99.99%

② Power cables :-

If we use Superconducting materials as a power cables for long-distance there is very less ~~power~~ power loss and voltage drop

③ Electromagnet :-

It has been possible to design electromagnets using Superconductivity for use in laboratories and for low temperature device like the maser.

(CHAPTER-2)
(Semiconducting Materials)

Semiconducting Materials :-

Semiconductor are the materials which have a conductivity lies between conductors (Generally metal) and non-conductor or insulator (Such as ceramic)

→ Semiconductor can be compounds such as gallium Arsenide or pure metals such as germanium silicon.

$\uparrow \sigma \propto$ concentration of free charge
↑
(conductivity)

Insulator | Semi conductors | Conductors

$10^5 e^{-1}/m^3$ $10^{21} e^{-1}/m^3$ → No. of electrons/volume.

Properties of Semiconductor :-

1. Semi-conductor acts like an insulator at zero kelvin. On increasing the temp. it works as a conductor.

2. Due to their exceptional electrical properties, semiconductor can be modified by doping to make semiconductor devices suitable for energy conversion, switches & amplifier.