Youth Competition Times

RRB JE

2nd Stage (CBT-II)

CAPSULE

ELECTRONICS & ALLIED ENGINEERING

Computer Science, Information Technology, Instrumentation & Control Engineering

Theory + MCQ's

Study Material and Question Bank

Chief Editor
A.K. Mahajan

Compiled & Written by
Er. Anil Kumar, Er. Ajeet Kumar, Er. Deepak Sharma

Computer Graphics by
Balkrishna, Charan Singh

Editorial Office
12, Church Lane Prayagraj-211002
9415650134
Email : yctap12@gmail.com
website : www.yctbooks.com/www.yctfastbook.com/www.yctbooksprime.com

Publisher Declaration
Edited and Published by A.K. Mahajan for YCT Publications Pvt. Ltd.
and printed by Luxmi Naryan Printing Press. In order to Publish the book,
full care has been taken by the Editor and the Publisher,
still your suggestions and queries are welcomed.
In the event of any dispute, the judicial area will be Prayagraj.

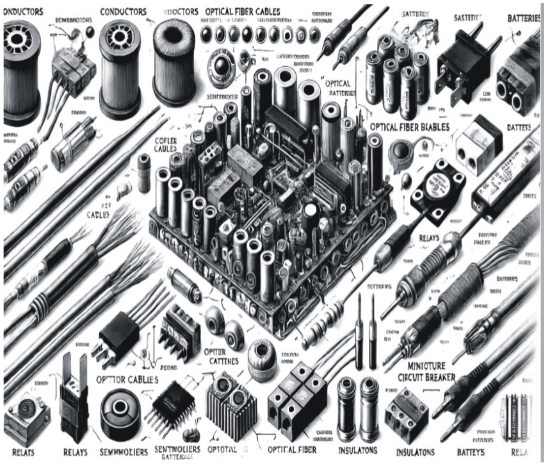
₹ : 695/-

INDEX

SYLLABUS

RRB JE CBT-2 Electronics Engineering

- **Electronic Components & Materials:** Conductors, Semiconductor& Insulators; magnetic materials; jointing & cleaning materials for U/G copper cable & OFC; Cells and Batteries (Chargeable and non chargeable); Relays, Switches, MCB & Connectors.
- **Electronic Devices and Circuits:** PN Junction diodes, thyristor; Diode and triode circuits; Junction Transistors: Amplifiers; Oscillator; multivibrator, counters; Rectifiers; Inverter and UPS.
- **Digital Electronics:** Number system and Binary codes; Boolean Algebra & Logic gates; Combinational & Sequential logic circuits; A/D & D/A Converter, counters, Memories.
- **Linear Integrated Circuit:** Introduction to operational Amplifier, Linear applications; Non-Linear applications, Voltage regulators, Timers; Phase lock loop.
- **Microprocessor and Microcontroller:** Introduction to microprocessor, 8085 microprocessor working; Assembly Language programming; Peripherals & other microprocessors; Microcontroller.
- **Electronic Measurements:** Measuring systems; Basic principles of measurement, Range Extension methods, Cathode ray oscilloscope, LCD, LED panel, Transducers.
- **Communication Engineering:** Introduction to communication; Modulation techniques; Multiplexing Techniques Wave propagation, Transmission line characteristic, OFC; Fundamentals of Public Address systems, Electronic exchange, Radar, Cellular and Satellite communication.
- **Data communication and Network:** Introduction to data communication, Hardware and interface; Introduction to Networks and Networking devices; Local Area Network and Wide area Network; Internet working.
- **Computer Programming:** Programming concepts; Fundamentals of 'C' and C^{++}; Operators in 'C' and C^{++}; Control Statements; Functions, Array String & Pointers, File Structure; Data Structure and DBMS.
- **Basic Electrical Engg:** DC Circuits; AC fundamentals; Magnetic, Thermal and Chemical effects of Electric current; Earthing-Installation, Maintenance, Testing.



1. Electronic Components and Materials

Content Detailed

■ Conductors, Semi conductor & Insulators ■ Magnetic materials; Jointing & Cleaning materials for U/G copper cable & OFC ■ Cells and Batteries (chargeable and non chargeable) ■ Relays, Switches, MCB & Connectors.

❒ Conductor

Materials with majority of free electrons are called conductors.

Conductors can be classified into three categories-

Solid conductor	Liquid conductor	Gaseous conductor
Solid conductors have a definite shape and size for example- gold, copper, iron etc are solid conductors.	Those conductors which are not stable in shape and have the property of flowing are called liquid conductors for example- Water (H_2O), Silver nitrate etc.	No gas is an ideal gas conductor. To make a gas a conductor, some amount of salt is added to it. So that it gets ionized and behaves like a good gaseous conductor. For example- Helium, Argon, Neon are gaseous conductors.

- **Properties of a good conductor:**

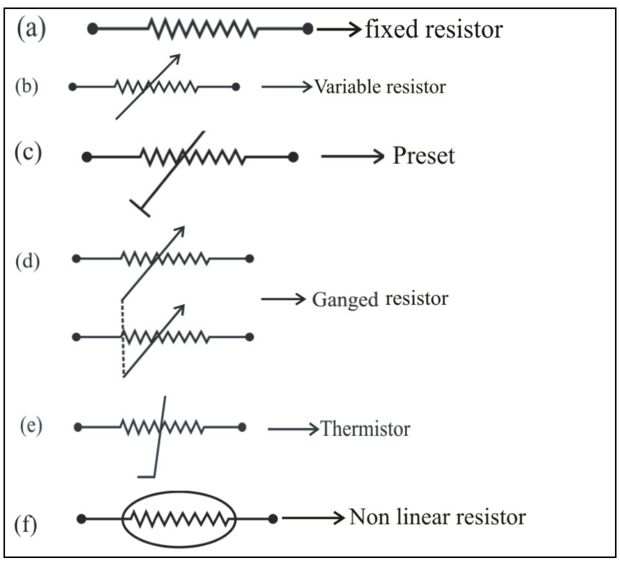
1. The conductor should be cheap and easily available.
2. The conductor should be ductile.
3. The conductor should be malleable.
4. The conductor should be unaffected by atmospheric influences.
5. The conductor material should have more conductivity and low resistivity.

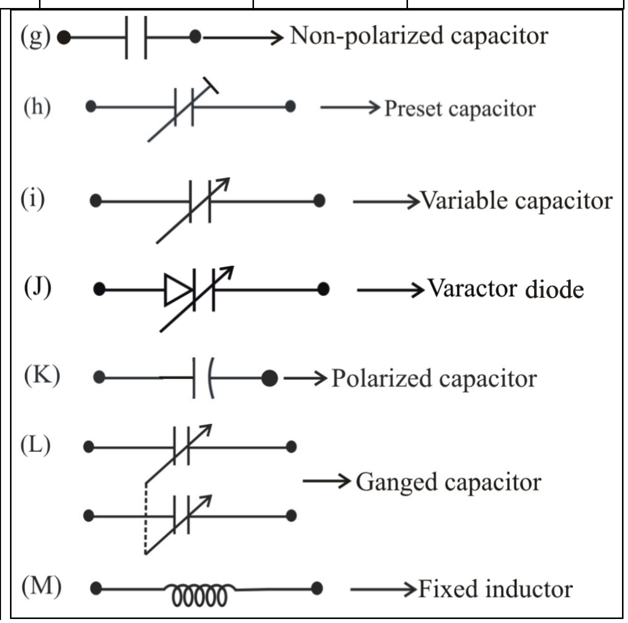
◻ Some types of conductors and their properties:

Sr. No.	Name of conductor	Colour or mixture	Resistivity (in ohm-meter (at 20^0C)	Conductivity (at 20^0C)	Melting point in ^{0}C	Temperature coefficient (at 20^0C) per ^{0}C
1.	Silver	White	1.59×10^{-8}	6.289×10^{7}	960	0.0038
2.	Copper	Dull red	1.72×10^{-8}	5.8×10^{7}	1084	0.00428
3.	Aluminium	White	2.82×10^{-8}	3.4×10^{7}	657	0.004013
4.	Gold	Golden yellow	2.44×10^{-8}	4.2×10^{7}	1063	0.0034
5.	Tungsten	Dark grey	5.6×10^{-8}	1.79×10^{7}	3422	0.0051
6.	Zinc	Blue grey	5.9×10^{-8}	1.69×10^{7}	420	0.0037
7.	Brass	Yellow (Cu + Zinc)	6.3×10^{-8}	1.59×10^{7}	930	0.0015
8.	Nickel	White	6.99×10^{-8}	1.43×10^{7}	1453	0.00537
9.	Iron	Silvery-grey	1.0×10^{-7}	1.0×10^{7}	1538	0.0069
10.	Tin	White	1.09×10^{-7}	9.17×10^{6}	232	0.0051

11.	German silver	Mixture Copper→60% Nickel→15% Zinc →25%	3.316×10^{-7}	3.015×10^{6}	960	0.0027
12.	Lead	Grey	2.2×10^{-7}	4.55×10^{6}	327	0.0043
13.	Manganin	Mixture Copper → 84%, Manganese→12% Nickel→4%	4.82×10^{-7}	2.0×10^{6}	960	0.00025
14.	Eureka	55% copper and 45% Nickel	5×10^{-7}	4.04×10^{6}	1270	+0.00001–0.004
15.	Platinum	White-grey	1.06×10^{-7}	9.43×10^{6}	1773	0.00367
16.	Mercury	Silver -White	9.8×10^{-7}	1.02×10^{6}	–38.9	0.0009
17.	Nichrome	80% Nickel + 20% Chromium	1.10×10^{-6}	9.09×10^{5}	1400	0.0014
18.	Carbon	–	3×10^{-5}	1.25 to 2×10^{4}	3500	-0.005

■ Electronics components symbol





☐ Comparison of different types of resisters-

Type of resistor	Resistive material	Range	Power rating	Tolerance	Cost	Noise	High frequency response	Temp. Coefficient
Carbon Composition	Carbon- Clay	upto 20MΩ	upto 2W	+5% to ± 20%	Moderate	Low	Better	Low
Carbon and metal film	carbon or thin layer of metal	upto20 MΩ	More than carbon composition	± 1% to ± 5%	Cheap	High	Normal	More than carbon composition
Wire wound	wire wrapped around an insulating core	upto100 kΩ	upto 200 W	± 1%	Costly	Very Low	Poor	Medium

☐ Comparison of Different types of capacitors-

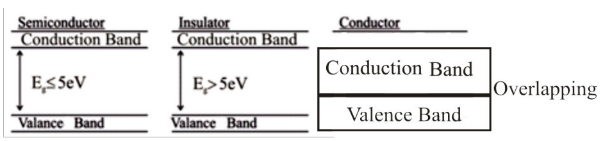
Type of Capacitor	Dielectric (Dielectric constant)	Range	Voltage Rating	Tolerance	Leakage current	Polarity	Application
Paper Capacitor	Impregnated paper (2-6)	0.0005 μF to 10 μF	100V to several thousand volts	± 10%	Low	No	AC, DC, High voltage and High Current
Polyester capacitor	Polyester (2.0)	0.0005μF to 10μF	upto 2000V	± 10%	Low	No	tuned circuit, Digital computer
Ceramic capacitor	Ceramic (80-1200)	3 pf to 2μF	3V to 6000V	± 10% to ± 20%	Low	No	Coupling capacitor, Bypass capacitor
Mica capacitor	Mica (3-8)	1 pf to 1 μF	500 V, 40kV at high frequency	± 0.5%	Low	No	Temperature varying
Electrolyte Capacitor	Aluminium Oxide (7)	1μF to several thousands μF	1V to 500V	± 10%	High	Yes	Filter circuit, coupling capacitor

☐ Energy Bandgap $\boxed{E_g = E_c - E_v}$

E_c = Energy level of conduction band

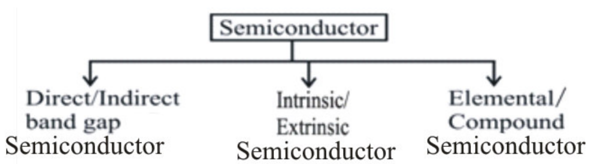
E_v = Energy level of valance band

E_g = Forbidden energy gap



- In metals the conduction band and valance band overlap with each other.
- In insulator energy band gap is very high.
- In semiconductor energy band gap is relatively small.
- Valance band can never be empty.
- 1eV = 1.6×10^{-19} Joule

☐ Semiconductor



☐ Elemental semiconductor

➢ only single element ➢ C, Si, Ge, Pb

☐ Compound semiconductor

➢ at least two elements ➢ GaAs, GaN

☐ Direct/Indirect Band gap Semiconductor:

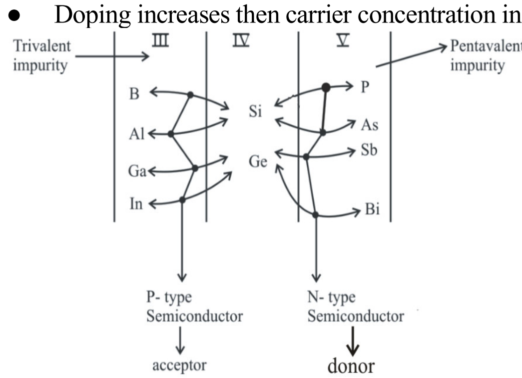
- Light is produced in the direct band gap.
- Heat is produced in the indirect band gap.
- Direct Band gap semiconductor- GaAs, GaN, GaSb, CdS, InGaAs, ZnS
- Indirect Band gap semiconductor- Si, Ge, AlAs, AlSb, PbSe, GaP.

☐ Comparison of intrinsic semiconductor and extrinsic semiconductor

Intrinsic semiconductor	Extrinsic semiconductor
It is pure semiconductor	It is impure semiconductor
Number of free electrons is equal to number of holes.	Number of free electrons and number of holes are unequal.
Conductivity is low.	Conductivity is high.
Conductivity depends only on temperature.	Conductivity depends both on temperature and impurity.
No impurity.	Trivalent and pentavalent impurity.
The order of current in milliamperes.	The order of current in microamperes.

☐ Doping - The process of adding of impurity into pure semiconductor.

- Doping increases then carrier concentration increases.



☐ Standard Doping Level

- $\boxed{\text{Moderate doping}} \Rightarrow 1:[10^6 \text{ to } 10^8] \rightarrow$ N and P type SC
- $\boxed{\text{Lightly doping}} \Rightarrow 1:10^{11} \rightarrow N^-$ and P^- type SC
- $\boxed{\text{Highly doping}} \Rightarrow 1:10^3 \rightarrow N^+$ and P^+ type SC

➢ Intrinsic SC $\xrightarrow{1:10^8}$ Extrinsic SC

- $1:10^6$ or 1 in 10^6 or $1/10^6$ is read as , 1 impurity atom in 10^6 atoms.
- Conductor ⟶ Metallic Bond
- Semiconductor ⟶ Covalent Bond
- Insulator ⟶ Ionic Bond

Comparison of N-type and P-type Semiconductor-

Parameter	N-type	P-type
Doping	Pentavalent impurities.	Trivalent impurities.
Conductivity	More	Less
Impurities	Extra electrons known as donor atoms.	Extra holes, known as acceptor atoms.
Charge carrier	Majority charge carrier are electrons and minority carrier are holes.	Majority carrier are holes and minority carrier are electrons.
Fermi level	Near to conduction band.	Near to valence band.

Fermi Level

- It indicates carrier concentration.
- Fermi level also gives the information that, at 0^0K above fermi level, all are empty and below fermi level all allowed energy levels are filled.

$$f(E)=\frac{1}{1+e^{[(E-E_F)/KT]}} \qquad K=1.38\times10^{-23}\,J/K$$

Where, E: given energy level
E_f: fermi-level
K: Boltzmann's constant
T: Absolute temperature

NOTE

f(E) doesn't gives:
(i) Number of electrons in a given energy level
(ii) Number of energy levels with electrons.
At T = 0K
case (i) : E << E_f:

$$f(E)=\frac{1}{1+e^{(E-E_f)/KT}}=\frac{1}{1+e^{-\infty}}=1\Rightarrow 100\%$$

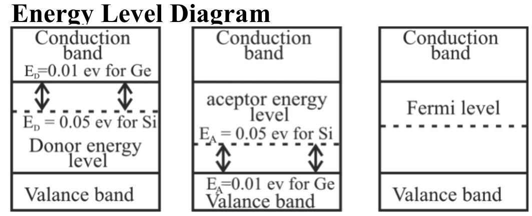
case (ii) : E = E_f: at $T\neq 0$

$$f(E)=\frac{1}{1+1}=\frac{1}{2}=0.5\Rightarrow 50\%$$

case (iii) : E >> E_f: at T = 0K

$$f(E)=\frac{1}{1+e^{(E-E_f)/KT}}=\frac{1}{1+e^{+\infty}}=0\Rightarrow 0\%$$

Energy Level Diagram



- The Fermi Level in intrinsic semiconductor lies center of the forbidden gap.
- The Fermi Level in P-type semiconductor lies above the valance band
- The Fermi Level in N-type semiconductor lies below the conduction band.

Effect of temperature on Fermi-level:

When temperature goes on increases extrinsic semiconductor gradually gets the intrinsic behaviour when thermally generated e^- concentration dominates the donor electrons, so that Fermi-level to the mid-gap.

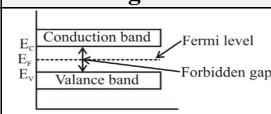
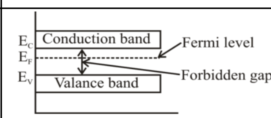
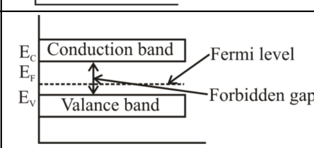
Fermi energy level: The Energy of the electron at 0K is called Fermi energy (Unit → eV)

$$\text{Fermi Energy} = \text{Maximum kinetic energy of electron}$$

$$E_F=\frac{1}{2}mv^2 \qquad V=\sqrt{\frac{2E_F}{m}}$$

- If the Fermi function is f(E) of any electron, then the Fermi function for the hole = 1–f(E)
- $E_g = KT\ell n\left(\frac{N_C.N_V}{n_i^2}\right)$

Fermi level in different type semiconductor

Semiconductor	Fermi formula	Fermi diagram
Intrinsic semiconductor	$E_F=\frac{E_C+E_V}{2}-\frac{KT}{2}\ln\left(\frac{N_C}{N_V}\right)$	
n-type semiconductor	$E_F=E_C-KT\,\ln\left(\frac{N_C}{N_D}\right)$	
p-type semiconductor	$E_F=E_V+KT\ln\left(\frac{N_V}{N_A}\right)$	

Remember

- A semiconductor at absolute zero temperature, behaves as a perfect insulator.
- In a intrinsic semiconductor the resistivity (inverse of conductivity) decreases as the temperature increases. Hence the semiconductors have negative temperature coefficient of resistance.

Electrical Neutrality

- n- type and p- type semiconductors are electrically Neutral.

$$N_D+p=N_A+n$$

Where. N_D → Donor, N_A → Acceptor
p → Positive charge, n → Negative charge.

Energy Band gap. (E_g): $E_g \propto \frac{1}{temp.}$

	Ge	Si	GaAs
E_{g0K}	0.785 eV	1.21 eV	1.52 eV
E_{g300K}	0.72eV	1.1 eV	1.42 eV

Mass Action Law: $n \cdot p = n_i^2$

Where, n = concentration of electron

p = Concentration of hole.

n_i = Intrinsic carrier concentration.

- Mass action law mostly used for extrinsic semiconductor to find minority carrier concentration.
- When temperature changes, n_i^2 also changes. So mass-action law not valid when temperature Changes.

$$\text{Minority carrier conc.} = \frac{n_i^2}{\text{majority carrier conc.}}$$

- Minority carriers depend on → Temperature
- Majority carriers depend on → Doping

$$\text{Minority carrier conc.} = \frac{n_i^2}{\text{Doping conc.}}$$

Thermal Voltage $V_T = \frac{KT}{q}$ $V_T = \frac{T}{11600}$

$V_T = 26mV$

Boltzman constant

$\bar{K} = 1.38 \times 10^{-23} J/^oK$ $K = 8.62 \times 10^{-5} eV/^oK$

Diffusion coefficient

Element	Formula	Ge (300K)	Si (300K)
Electron(e^-)	$D_n = \mu_n \times V_T$	99 cm^2/sec	34 cm^2/sec
Hole (H^+)	$D_p = \mu_p \times V_T$	47 cm^2/sec	13 cm^2/sec

$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = \frac{KT}{q} = V_T$ (Einstein relation)

Where,

D_n = diffusion coefficient of electron

D_p = diffusion coefficient of hole

μ_n = mobility of electron

μ_p = mobility of hole

V_T = thermal voltage

T = temperature

K = Boltzman constant

Conductivity

Element	Conductivity formula
Metal	$\sigma = q\mu n = \rho\mu = \frac{J}{E}$
Intrinsic semiconductor	$\sigma = n_i q \mu$
Extrinsic Semiconductor	$n-type \rightarrow \sigma = nq\mu_n$ $p-type \rightarrow \sigma = pq\mu_p$
Intrinsic Semiconductor	$\sigma = n_i q(\mu_n + \mu_p)$

For minimum conductivity

for P-type: $P = n_i\sqrt{\left(\frac{\mu_n}{\mu_p}\right)}$

for n-type: $n = n_i\sqrt{\left(\frac{\mu_p}{\mu_n}\right)}$

For minimum conductivity condition for p-type semiconductor is $\sigma_{min} = 2n_i\sqrt{\mu_n\mu_p}.q$

Where, σ = Conductivity, n_i = Carrier Concentration

μ_n = Mobility of electrons, μ_p = Mobility of Holes

q = Charge

- In metal when temperature increases mobility of charge carrier decreases therefore conductivity decreases with temperature.
- In metal free electron concentration is independent of temperature.
- In semiconductor conductivity mainly depends on carrier concentration.
- For 1ºC Ge → σ ↑ by 6% : Si σ↑ by 8%.

Electric field intensity

$E = \frac{|dV|}{dt} V/m$

Where,

dV = Change in voltage, dt = thickness of bar

- Anywhere of the semiconductor bar field intensity is same.

Mobility of charge Carriers

- It is drift velocity per unit electric field.
- unit $\rightarrow \frac{m^2}{V-s}$ or $\frac{cm^2}{V-s}$
- It defined how fast the charge carrier travels from one place to another and is given by - $\mu = \frac{V_d}{E}$

Where, V_d = drift velocity , E = Electric field

Mobility	Ge	Si	GaAs
e^- mobility (μ_n)	3800 cm^2/Vsec	1300 cm^2/Vsec	4600 cm^2/Vsec
hole mobility (μ_p)	1800 cm^2/Vsec	500 cm^2/Vsec	400 cm^2/Vsec

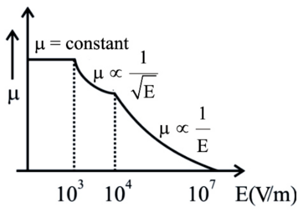
- Mobility of charge carriers decreases with increases temperature and varies as -: $\mu \propto T^{-m}$

  Where, m is constant

  $\text{In Ge} \rightarrow m = 1.66 \text{ for } e^{-} \text{ and } 2.33 \text{ for hole}$

  $\text{In Si} \rightarrow m = 2.5 \text{ for } e^{-} \text{ and } 2.7 \text{ for hole}$

- Mobility also varies with applied electric field



μ = constant	$E < 10^3 \text{ V/cm}$
$\mu \propto \frac{1}{\sqrt{E}}$	$10^3 < E < 10^4$ V/cm
$\mu \propto \frac{1}{E}$	$E < 10^4 \text{ V/cm}$

- At smaller electric field mobility is constant
- At very high electric field product of mobility and electric field becomes constant and is equal to saturation value of drift velocity.
- Overall mobility-

$$\frac{1}{\mu_T} = \frac{1}{\mu_1} + \frac{1}{\mu_2} + \frac{1}{\mu_3} + ...$$

Where, μ_T = overall mobility

$\mu_1, \mu_2, \mu_3 \rightarrow$ mobility corresponding to different scattering Mechanism.

- **Wave length of light (λ) -** $\lambda = \frac{1.24}{E_g(eV)} \mu m$

  E_g = Energy gap of the material in Electron Volt

  $\text{For visible light } \lambda = 0.38 \mu m \text{ to } 0.76 \mu m$

  $\text{For infrared } \lambda > 0.76 \mu m$

- **Important point related to Si**
- Si has better thermal stability.
- It is more suitable for used in switching application.
- High power handling capacity.
- Uses in high power device Ex. SCR. DIAC, TRIAC
- Low frequency application, ➢ Low leakage current (nA)
- Atomic Number $\rightarrow$ 14, ➢ atomic weight $\rightarrow$ 28.086
- **Important point related to Ge**
- It is higher conductivity due to large mobility.
- Relatively more suitable for high frequency applications.
- Higher leakage current (μA), ➢ atomic Number $\rightarrow$32
- atomic weight $\rightarrow$ 72.63
- Large conductivity than, Ge > Si
- **Important point related to GaAs**
- It is a direct band gap Semiconductor.
- Covalent bond present, ➢Switching time very small.
- Used in microwave device.
- **Used-** LED, LASER, Tunnel diode, varactor diode, PIN diode
- **Intrinsic Concentration (n_i)**

  $n = p = n_i$ $\quad n_i = \sqrt{A_0 T^{3/2} e^{\frac{-Eg}{2KT}}}$

  $n_i^2 \propto T^3$

  $n_i \propto T^{3/2}$ $\quad A_0$ = material constant

  Hence n_i varies non-linear with temp., At T= 300K

  $\text{Si-}n_i = 1.5 \times 10^{10} \text{ atom/cm}^3$ $\quad \text{Ge-}n_i = 2.5 \times 10^{13} \text{ atom/cm}^3$

Insulators

The substances in which the number of free electrons is negligible are called insulators.

Properties of Good Insulator

1. The value of dielectric strength should be high.
2. The specific resistance should be more than 10^{12} ohm centimeter
3. The material should be able to radiate heat.
4. The insulators should unaffected by moisture and water
5. The insulator material should be strong.

Classification of Insulators

Solid Insulator	Liquid Insulator	Gaseous Insulator
Solid dielectrics have definite shape, size and volume. For example- Ebonite, mica, Bakelite, porcelain, glass, marble, slate, dry wood, fiber etc.	Those dielectric which have the property of flowing and do not have any definite shape are called liquid dielectric. For example- mineral oil.	Those dielectric which do not have any definite shape or size are called gaseous dielectrics, For example dry air, nitrogen, hydrogen etc.

■ Different types of Insulators:

Sr. No.	Name of Insulator	Dielectric strength (kV/mm)	Characteristics
1.	Dry air	About 3 kV/mm	It is the best insulation material. Bare metallic wires are used in overhead lines and the air between them acts as a insulator.
2.	Vulcanized rubber	30-50 kV/mm	Vulcanized rubber is prepared by mixing sulphur and zinc oxide in ordinary rubber through heat process. It is used as a dielectric covering in various type of wires and cables.
3.	Polyvinyl chloride, (PVC)	About (14−20) kV/mm	It is good insulating material, which is more durable than vulcanized rubber. At present PVC is increasingly being used in place of rubber.
4.	Ebonite	30–40 kV/mm	It is hard, material-like rubber that starts burning at 180ºC. It is used to make lead acid, storage battery cover, panel boards, machine cover etc.
5.	Mica	20–60 kV/mm	It is only natural and mineral substance that is transparent and unaffected by fire and moisture. It is used as the base of heating elements of electrical heating devices.
6.	Micanite	20–40 kV/mm	Micanite paper or cloth is made by pasting very thin sheets of mica on cloth or paper with the help of varnish. It is used in armature winding work.
7.	Bakelite	17–21 kV/mm	It is used in making switches, Plugs, Tops, Sockets, Bulb holder, Celling roses etc.
8.	Learthroid paper	12–17 kV/mm	It is used as a insulation layer between coil and armature slots in the winding of electrical machines.
9.	Resin	12–14 kV/mm	It is a synthetic substance; it is used in making Bakelite.
10.	Mineral oil	10–16 kV/mm	Non-conductivity of mineral oil is very high. It is obtained from petroleum. It is used in transformer starters, switches with high current carrying capacity, capacitors etc.
11.	Porcelain	8–12 kV/mm	This is a special type of clay. It is used for making overhead lines, kit-kat fuses, switches plates for heating elements.
12.	Glass	8–12 kV/mm	It has property of brittleness, so it is not used in switches. It is used to make the cover of bulbs, fluorescent tube etc.
13.	Asbestos	4–6 kV/mm	It is a white coloured fibrous mineral. It is used as a insulator and heat barrier in electric iron and heater etc.
14.	Marble	2–6 kV/mm	It is a white coloured mineral stone. Its powder is used as a insulator in immersion heating element.
15.	Shellac (Varnish)	2–3 kV/mm	It is a chemical material, which prepared by dissolving it in methylated spirit. It is used in paper, cloth, wood winding etc.
16.	Paper	1–10 kV/mm	It is prepared from grass, cotton etc. It is used as a non-conducting layer in paper capacitors. Leatheroid paper and presspahn paper are two types of paper.

◻ Classification of insulator based on temperature

Class	Maximum safe Temperature	Insulating material
Y	90°C	Cotton, silk, normal paper, wood
A	105°C	Cotton, Silk, oil absorbed paper
E	120°C	Leatheroid paper, empire cloth, fiber
B	130°C	Mica, fiber glass, asbestos
F	155°C	Mica, fiber glass, Asbestos
H	180°C	Material made from mixture of Elastomer and mica, fiber glass, asbestos
C	More than 180ºC	Mica, porcelain, glass, quartz.

Magnetic Materials

Materials that can be magnetized are called magnetic materials. Net magnetic field produced by an electron at nucleus is zero.

> Magnetization means alignment of dipoles in the direction of applied magnetic field.

- **Magnetic Dipole :** Two unlike magnetic poles of equal pole strength at a very small distance is known as magnetic dipoles.
- **Example :** A small bar magnet, magnetic needle, a current carrying loop etc.
- **Magnetic Laws:** Magnetic Laws are following –
  - **Biot-savart Law–** $dB = \frac{\mu_0}{4\pi}\frac{Id\ell\sin\theta}{r^2}$

    B = Magnetic field, r = Distance , $d\ell$ = Differential length
  - **Ampere's circuital Law :**

    Ampere's law is analogous to Gauss's law in electrostatics.

    $H = \frac{I_{enc}}{2\pi r}$ also $\oint_C \vec{H}\cdot\vec{dl} = I_{enc}$
- **Magnetic Flux-**
  - The number of magnetic field lines which pass through a given cross-sectional Area (A).
  - SI unit -Weber
  - CGS unit- Maxwell
  - Formula - $\phi = B \times A$
  - 1 Weber = 10^8 Maxwell's
- **Magnetic flux density:**

  $B = \frac{\phi}{A} = \mu H$ (Wb/m^2 or Tesla)
- **Magnetic susceptibility(χ_m):** Magnetic susceptibility is the degree of magnetization of a material in response to an applied magnetic field.

  $\chi_m = \frac{M}{H}$ $\frac{\to \text{Magnetization}}{\to \text{Magnetic field intensity}}$

  It is unitless proportionality constant.
- **Magnetic Moment:** $m = I \times A$ in Amp-m^2

  m -Magnetic moment, I - Current, A → Area

  $\text{Magnetization}(M) = \frac{m_{net}}{V}$ $\frac{\to \text{Net magnetic moment}}{\to \text{Volume}}$

  $\therefore M = \frac{Am^2}{m^3} = A/m$
- **Magnetic Intensity :**

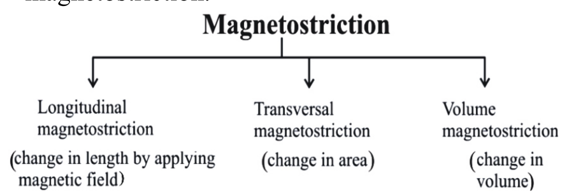
  $B = B_0 + B_m = \mu_0(H + M)$

  $B = \mu_0 H + \mu_0 M = \mu_0 H + \mu_0 \chi_m H$

  $= \mu_0 H(1 + \chi_m) = \mu_0 \mu_r H$ $[\because \mu_r = 1 + \chi_m]$

- **Bohr Magneton:** Smallest unit of magnetic moment is Bohr Magneton.

  $P_B = \frac{neh}{4\pi m}$ for n = 1, $P_B = 9.27 \times 10^{-24}$ Amp-m^2 or J/T
- **Magnetic Anisotropy:** Different magnetic properties exhibited by ferromagnetic materials in different directions is known as magnetic anisotropy.
- **Causes of magnetic anisotropy**
  - **Cold working:** when material is shaped without increasing temperature.
  - **Annealing :** Heat treatment of a material
  - **Quenching :-** Immediate cooling after heating.
- **Magnetostriction:** Change in dimension of a material when magnetic field is applied is called magnetostriction.

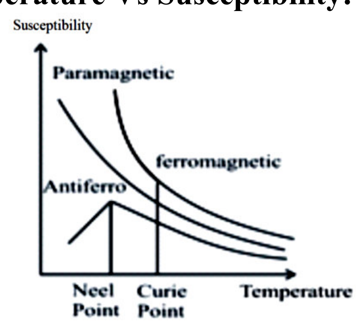


> erse of magnetostriction is called "Villari . "

- **Curie Temperature:** The temperature at which a ferromagnetic material becomes paramagnetic in nature. A magnetic material completely loses its magnetic property at curie's temperature.

  According to Curie's law-

  i.e. $\chi_m = \frac{C}{T}$ Where, C → Curie's constant
- **Temperature Vs Susceptibility:**

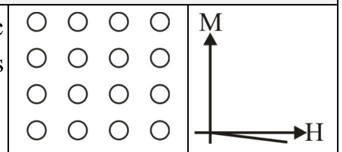
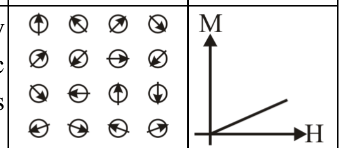
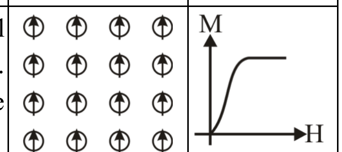
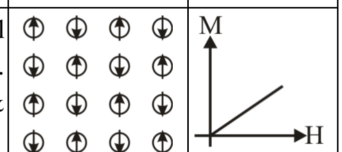
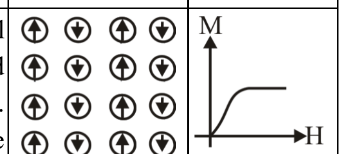


- **Paramagnetic –** Curie's law $\chi_m = \frac{C}{T}$
- **Ferromagnetic –** Curie- weiss law $\chi_m = \frac{C}{T-\theta}$

  θ- Curie's temperature, T > θ (ferro → para)
- **Anti ferromagnetic –** Curie – Weiss law

  $\chi_m = \frac{C}{T+\theta_n}$ $T > \theta_n$ (Neel's Temp)

■ Different types of magnetic materials and their properties :

Type	Example	Atomic/Magnetic Behaviour
Diamagnetic	Inert gases, many metals - Au, Cu, Hg, non-metallic elements - Bi, Si, P, S, many ions - Na^+, Cl^- & their salts, diatomic molecules - H_2, N_2, H_2O, most organic compounds, graphite	Atoms have no magnetic moment. Susceptibility is small & negative. 
Paramagnetic	Some metals - Al, some diatomic gases - O_2, NO, ions of transition metals and rare earth metals, and their salts, rare earth oxides.	Atoms have randomly oriented magnetic moments. Susceptibility is small & positive. 
Ferromagnetic	Transition metals Fe, CrO_2, Co, Ni, alloys of ferromagnetic elements, some alloys of Mn - MnBi, Cu_2MnAl.	Atoms have parallel aligned magnetic moments. Susceptibility is large (below T_C). 
Antiferromagnetic	Transition metals Mn, Cr & many of their compound - MnO, CO, NiO, Cr_2O_3, MnS, MnSe, CuC_2.	Atoms have antiparallel aligned magnetic moments. Susceptibility is small & positive. 
Ferrimagnetic	(Fe_3O_4-magnetite), (Fe_2O_3-maghemite), mixed oxides of iron and other elements such as Sr ferrite.	Atoms have mixed parallel and anti-parallel aligned magnetic moments. Susceptibility is large (below T_c). 

■ Important Terms Related to Magnetism –

Air gap	The distance between north and south poles of magnetic circuit.
Coercive force	The magnetic field required to reduce the residual magnetism to zero value.
Residual magnetism	Remaining magnetisation in the magnet after magnetic field intensity is zero.
Gauss	The unit of magnetic induction or magnetic flux density used to measure the magnetic field density (magnetic flux/cm^2).
MGO	Mega Gauss Oersted
Oersted	The unit of magnetic intensity in the CGS system that describes magnetic force.
Retentivity	The material's ability to retain the magnetization when magnetic field is removed after saturation.

■ Types of magnetic materials:

- **Soft magnetic materials :-** These are used in transformer, electric machines and magnetic memory.

☛ **Ex.** Iron, Iron-silicon alloys, Nickel-iron alloys.

- **Hard magnetic materials :-** These are also called permanent magnetic materials.

☛ **Ex.** Alnico, Chromium steel, Tungsten steel, Carbon steel etc.

❒ Cable

A wire with a insulation cover is called a cable. The thickness of insulation layer on the conductor of the cables depends on the voltage.

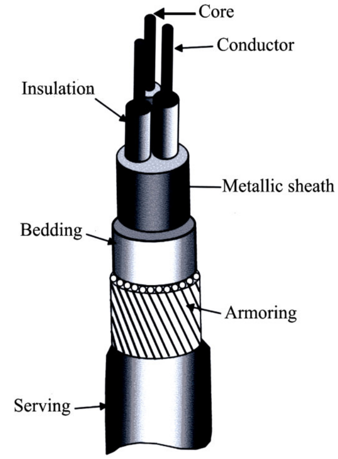
- **The structure of the cable mainly consists of the following parts:**

Layer over a cable is CIMBAS.

C→ Core of conductor, I → Insulation

M → Metallic sheath, B → Bedding,

A→ Armouring S→ Serving

Main part	Feature	Cable structure
Core	➲ Electric current flows through this part. ➲ In this aluminium or copper wires are used. ➲ Its thickness depends on the current carrying capacity.	
Insulation-covering	➲ Each core has a paper, fabric or varnished paper covering over it. ➲ The thickness of this insulation covering depends on the voltage carried by the cable.	
Metallic Sheath	➲ A layer of lead or lead-alloy is applied on the insulation cover. ➲ This metallic layer does not allow moisture to reach the core.	
Bedding	➲ A layer of fiber and paper material or jute or sackcloth dipped in bedding compound is applied on the metallic sheath. ➲ This layer protects the metallic layer from mechanical injuries, scratches etc.	
Armouring	➲ It is applied on the bedding. ➲ It is an sheath made of galvanized steel wire. ➲ It protects the cable from mechanical injuries, pressure etc.	
Serving	➲ This layer is applied on the armouring. So that the armouring can be protected. For this, fiber containing material or jute/sackcloth dipped in fiber compound is used.	

- The life of the underground cable is 40-50 year.
- In underground cable, losses are less as compare to overhead line.
- Maintenance cost is less in underground cable.
- Initial cost is more in underground cable while initial cost in overhead line is low.
- Surge Impedance of cable to 40 Ω-60Ω where as the surge impedance of overhead line is 400 Ω -600Ω.

Colour of different types of wire or cables :

Type	Colour Code
1ϕ−line	Red/Brown
1ϕ Neutral	Black / blue
Ground wire	Green
3-ϕ neutral	Black
Neutral wire Three core flexible cable	Blue

Cable Insulation

Based on the use, the following are the types of insulation material used in cable insulation −

1. Rubber	2. Vulcanized Indian rubber
3. Impregnated paper	4. Varnish cambric
5. Polyvinyl chloride	6. Vulcanized bitumen
7. Gutta Purcha	8. Asbestos
9. Silk and Cotton	10. Enamel insulation

Types of Cables:

Type of cable	Features	Uses
VIR (Vulcanized India Rubber)	This cable is usually of one core. It is covered with vulcanized Indian rubber (VIR) If required, it can be made of two or three cores.	It is used in casing capping, conduit pipe and temporary type of electrical wiring.
CTS (Cable Tyre Sheathed) Cable	It is made in one, two and three cores. It is also called T.R.S. or tough rubber sheathed cable.	It is used in electrical wiring in moisture places.
PVC cable	This cable is covered with poly-vinyl chloride. It is made in one, two three and four cores.	It is used in electrical wiring. It is used at normal temperature.
Lead Sheathed Cable	It is prepared by covering it with vulcanized Indian rubber and then a protective covering of a metal called lead. It is made in one, two, three and four cores.	It is used in electrical wiring of chemical industries and other machines.
Weather-Proof cable	This cable is similar to VIR cable. It is made weather-proof by dipping in a liquid that can with stand atmospheric changes. It is made in, one, two and three or four cores.	It is used in open spaces in domestic and industrial electrical wiring.

Tropodure Cable	It is prepared by coating a thermo plastic compound on PVC cable. It is made in one, two three or four cores.	It is used in wiring of railway signals and power equipment
Flexible cable	It is made by collecting may thin wires in the form of a group and coating a insulation coating on it.	It is used where they need to withstand motion and flexing.
Ordinary flexible cable	The diameter of these wires is generally 0.193 mm and SWG number is 36.	They are used for general purposes example- temporary electrical wiring, connecting loudspeakers to amplifiers etc.
Cotton or Silk covered flexible cable	These cables are prepared by coating vulcanized Indian rubber on 23 or 40 wires of 36 SWG number of copper. These are usually 3 cores.	These are used as main leed in electrical thermal equipment example- electric Iron, electric toaster etc.
Workshop flexible cable	It is made in the form of 3 or 4 cores with current carrying capacity up to 25A.	It is used as the main leed of mobile machines in the workshop.
Armoured cable	This type of cable is made by coating a insulation layer of polyethylene on a single stranded copper wire.	It is used as an underground cable for power supply.

- **Classification of cables based on voltage grade which are used in electrical equipment/wiring:**

Classification	Rating	Type of cable
Low Voltage Cable	For domestic light, fan and power load up to 250V.	VIR, PVC, CTS, weather proof and flexible type are used.
Medium voltage cable	For domestic and industrial power load up to 650V	VIR, PVC, CTS, weather-proof, lead sheathed, tropodure and flexible type are used.
High voltage cable	Used in power distribution system up to 22,000 V or 22 kV.	Armoured type cables are used in this.
Extra high voltage cable	Voltage above 22,000V or 22 kV	

- **Classification of Underground Cables :**

Based on number of core	Based on voltage	Based on insulation material	Based on area	Based on state of insulation material
1. Single core cable	1. Low tension cable (upto 1 kV)	1. (MI cable) mineral insulated cable	1. Electronic cable	1. Solid cable
2. Two core cable	2. High-tension cable (1 kV to 11 kV)	2. (XLPE) cross linked poly ethylene cable	2. Electric power cable	2. Liquid cable
3. Three core cable	3. Super-tension cable (11 kV to 33 kV)	3. (PVC) Poly vinyl chloride cable		3. Gas cable
4. N - core cable	4. Extra-high tension (33 kV to 66 kV)			
	5. Oil filled and gas pressure cables (66 kV to 132 kV)			

☐ Classification of cable based on structure :

Cable	Voltage
General cable	Below 11 kV
Belted cable	11kV to 22kV
Screened cable	22kV to 66kV
Pressure cable- 1. Oil pressure cable 2. Gas pressure cable	Above 66kV 132kV to 220kV Above 220kV

☐ Types of Underground Cable for 3-phase Supply

Type of underground cable for 3-ϕ	Rating and features
1. Belted cable	➲ In normal conditions it can be used upto 11 kV but in abnormal conditions it can be used up to 22 kV. ➲ It is used for low and medium voltage. In this each core is jointly insulated by paper strips.
2. Shielded cable	➲ This type of cable is used for high voltage generally 22 kV to 66kV
(i) Shielded or H cable	➲ It is used to 66kV. In this after applying a insulated layer on each core, a perforated metallic sheath is applied on it.
(ii) SL Cable (Separate lead cable)	➲ In this type of cable, a insulated layer, metallic cover, bedding and armouring are applied on each.
(iii) HSO cable	➲ The cross-section of this cable is triangular. Due to which its weight and thermal resistance are reduced.
(iv) PILC cable (Paper insulated lead cover cable)	➲ It is suitable for low (250V) and medium (650V) voltage. This is a normal type of paper insulated, belted type cable.
(v) PILCSTA cable (Paper insulated lead covered single tapped armouring cable	➲ It is used up to 11 kV. ➲ This is also a type of belted cable.
(vi) PILCDTA cable (Paper insulated lead covered double tapped armored cable)	➲ It is used up to 33 kV. ➲ It is a belted cable with double armouring.
(vii) PVC cable (Poly Vinyle Chloride cable)	➲ These are used up to 11 kV. ➲ Each core of this cable is separately insulated with PVC.
(viii) $3\frac{1}{2}$ core PILCDTA cable	➲ This is a 4 core belted cable with double armouring. ➲ In this, three cores are of normal thickness and the fourth core is half the other three cores. ➲ The fourth core is used as neutral. It is used in industries upto medium voltage (650V).
3. Pressure cable	➲ This is a PILCDTA type cable in which transformer oil is filled inside the lead covering instead of fiber/jute material. ➲ It is used from 66 kV to 220kV.

❒ Types of joints in optical fiber-

These are the special joints used for fiber optical cables only and can be classified based on their characteristics as follows-

1. Splice

(i) Mechanical splice

(ii) Fusion splice

2. Connector

(i) DNP connector (Dry No Polish)

(ii) SMA connector (Sub Miniature type A)

3. Coupler

(i) T-coupler

(ii) Star

(iii) Three port coupler

Splice -

• It is used to connect the two ends of fiber optic cables permanently.

• This method is commonly used for signal transmission over a long distance.

(i) Mechanical splice - This joint uses a technique designed to hold two fiber ends in a position such that light passes through two fiber cables.

(ii) Fusion Splice-

• It is most reliable joint between two cables.

• This joint uses an electric are to pass a high-voltage signal so that the maximum output is received at the end.

Mechanical splicing	Fusion splicing
(i) Mechanical splicing does not use any other thing to connect two cables.	(i) Fusion splicing uses heat or an electric are to joint two cables.
(ii) Mechanical splicing holds two cables together using its own assembly	(ii) Fusion splicing uses two cables into are single cable.
(iii) It is comparatively less expensive	(iii) It is more expensive than mechanical splicing
(iv) Average signal loss is more because of variability in the type of connector used.	(iv) Average signal loss is less because they offer very high quality signal transmission.

Connector - Fiber optics connectors are joints that are reusable and they to attach and detach at any point in time.

• The connector is of two types-

(i) DNP connector - Dry No Polish connector are pre-assembled connectors that do not require field polishing and assembling.

(ii) SMA connector -It is a sub miniature type A coaxial connector that is used for high - frequency devices like a microwave, mobile signal antenna, wi-fi antenna etc.

DNP Connector	SMA connector
1. DNP is Dry No Polish connector	1. SMA is sub Miniature type A connector
2. It is a pre-assembled design.	2. It is a screw - type coupling design
3. Installation is fast	3. Installation is slower that the DNP connector

Coupler - It is a device that divides one input signal into two output signals.

• Coupler can also be used for dividing two inputs into one output. In such cases, it is called a combiner.

Different types of couples are-

T-coupler - The T-coupler is used split one incoming signal into output signals using a grin lens and beam splitter.

Star coupler- The star coupler in used to split one incoming signal into many output signals.

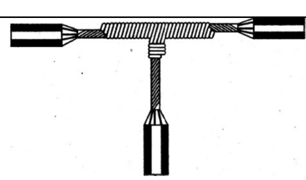
Three ports coupler – The three port coupler splits one input signal into two output signals without using grin lens and beam splitter.

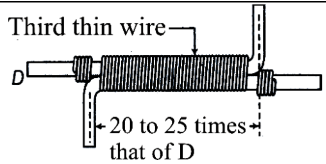
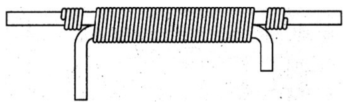
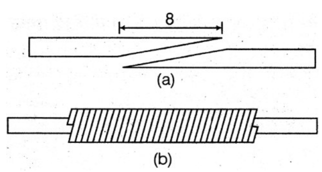
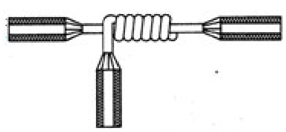
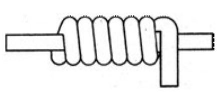
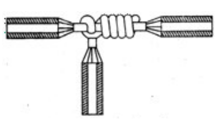
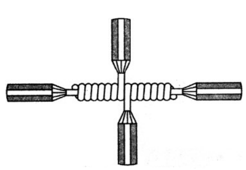
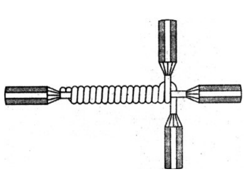
Difference between T-coupler and Star coupler-

T-Coupler	Star Coupler
1. T-coupler has one input and two outputs.	1. A star coupler has one input
2. The output power of the two ports is not evenly distributed.	2. The output power is equally distributed
3. It is used in bus type of networks and small networks	3. It is used in large network.
4. It anyone coupler in the network gets disconnected, all other terminals will also get disconnected.	4. If any one-star coupler terminal gets disconnected, it won't impact other terminals in that network.

❒ Joints in Electrical Conductors

The following types joints are common in overhead wiring and domestic wiring.

Sr.No.	Type of joint	Symbol	Characteristics	Uses
1.	Twisted Joint		➲ In this joint, the end of the wires are twisted together and their terminating ends are bent towards the joint. ➲ It is also called pig-tail joint or rat-tail joint.	It is used on insulators installed on the pole of the overhead line and not in the middle of the line.
2.	Married Joint		In this joint, after twisting the conductor together once or twice, the terminating ends are wrapped in opposite directions.	➲ It can be used in a straight line. ➲ It is also called a straight joint
3.	T-Joint		In this type of joint, only the insulation of the main cable is stripped and the conductor of the other cables are wrapped on both sides of the joint	This joint is used to take branch lines from the main power supply line.

4.	Britannia Joint		In this joint the conductors are kept parallel and adjacent to each other and the terminal end are bend at right angles. Now a third wire wrap is made on both wires to from a joint.	It is used only where the tensile pressure is high.
6.	Britannia T-Joint		Its features are similar to Britannia joint.	This joint is used in overhead lines for the inner exitance of electrical energy perpendicular to the service line.
7.	Western-Union joint		It is a joint that can bear high tensile pressure. In, this the wires are tightly wrapped over each other.	It is used at the ends of overhead lines.
8.	Scarfed joint		It is a lapped joint between two pieces of wood. In this, the ends of two pieces of wood are sharpened and joined by tightening or sticking them together.	It is used in single conductors that bear low tensile pressure. It is used in earth conductors in the wiring inside buildings.
9.	Tap Joint		This joints is made in single conductors up to 2 mm thick without any third wire	
(i)	General tap joint		This joint can be prepared quickly this joint becomes even better after soldering	This joint is used where tensile stress is present.
(ii)	Aerial tap joint		In this type of joints the end of the cable or conductors are wrapped together and one terminal end is left open.	This type joint is mostly used in short current circuits.
(iii)	Knotted tap joint		Its structure is similar to a normal tap joint. But a knot is put at one of the terminal ends.	Knotted tap joint is used where the tensile stress in the conductor is high.
10.	Cross-double-duplex joint		In this joint, A third wire is wrapped over the wires to be joined and a double knot is tied at the terminating ends.	
(i)	Cross-double duplex joint		This joint is a combination of two normal tap joints, in which two other conductors are connected and taken through the middle of the conductor	
(ii)	Duplex cross tap joint			This joint is used where two conductor wires are taken out simultaneously.