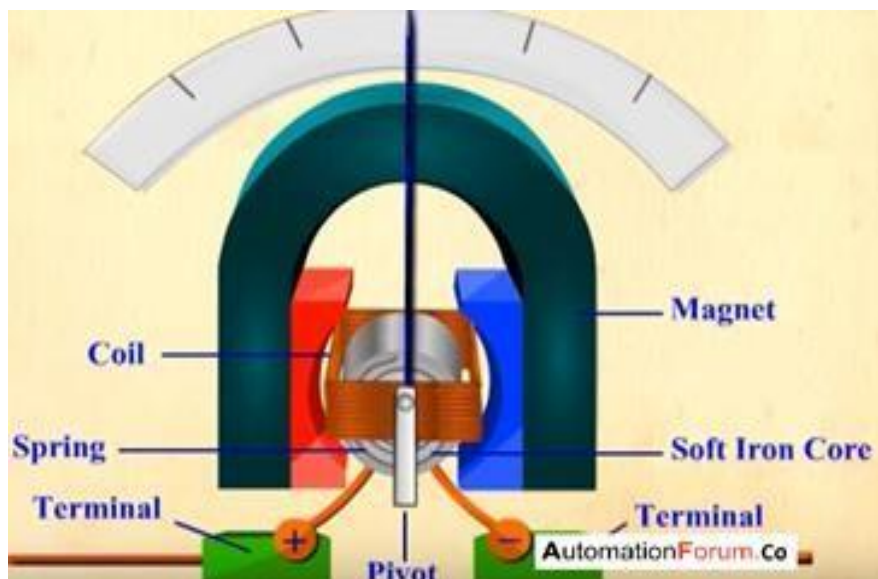




GANESH INSTITUTE OF ENGINEERING AND TECHNOLOGY

# Electrical Engineering Material (Th- 04)

(As per the 2019-20 syllabus of the SCTE&VT,  
Bhubaneswar, Odisha)



## Third Semester

Electrical Engg.

**Prepared By:**

**N.P BALIARSINGH**

**ELECTRICAL ENGINEERING MATERIAL**

**CHAPTER-WISE DISTRIBUTION OF PERIODS & MARKS**

<b>Sl. No.</b>	<b>Chapter/ Unit No.</b>	<b>Name of The Chapter/ Unit</b>	<b>Periods as per Syllabus</b>	<b>Expected Marks</b>
01	01	Conducting materials	16	20
02	02	Semiconducting materials	10	20
03	03	Insulating materials	09	15
04	04	Dielectric materials	08	10
05	05	Magnetic materials	08	20
06	06	Material for special purposes	09	15
<b>TOTAL</b>			<b>60</b>	<b>110</b>

# CHAPTER-1

## Conducting Materials

### Learning Objectives:

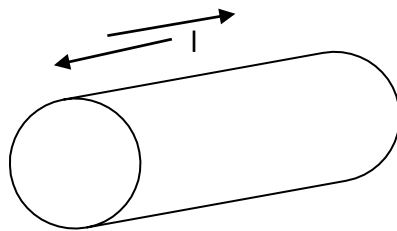
- 1 . 1 Introduction
- 1 . 2 Resistivity, factors affecting resistivity
- 1 . 3 Classification of conducting materials into low-resistivity and high resistivity materials
- 1 . 4 Low Resistivity Materials and their Applications. (Copper, Silver, Gold, Aluminum, Steel)
- 1 . 5 Stranded conductors
- 1 . 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

### 1 . 1 Introduction :

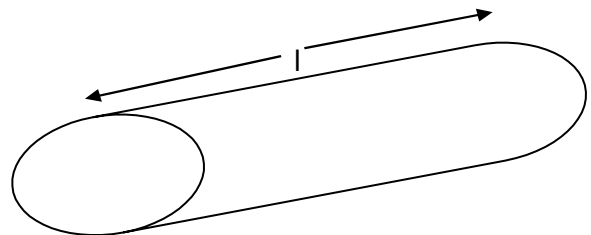
Conducting materials which must be good conductors of electricity, characterized by a large electrical conductivity and a small electrical resistance serve to carry current in electrical equipment. Conducting materials can further be divided into two groups namely materials of low resistivity and materials of high resistivity.

### Resistivity, factors affecting resistivity:-

The resistance R offered by a conductor depends on following factors.



Smaller l  
Larger A  
Low R



Larger l  
Smaller A  
Greater R

- i) Varies directly as its length l
- ii) Varies inversely as the cross section A of the conductor.
- iii) It depends on the nature of the material.
- iv) It also depends on temperature of the conduction.

mathematically –  $R \propto l/A$  or  $R = \rho l/A$  Where  $\rho$  is a constant and is known as its specific resistance or resistivity.

The factor in the resistance which takes into account the nature of the material is the resistivity.

The factors affecting resistivity are

- i) Nature of the material
- ii) Temperature

If temperature increases, resistivity of pure metals also increases. But resistivity of insulators decreases. Hence insulators are said to possess a negative temperature coefficient of resistance.

## Classification of Conducting materials in to Low-Resistivity and High Resistivity material :-

Low resistivity materials are employed for making conductors for all kinds of windings required in electrical machines, apparatus and devices, as well as for transmission and distribution of electrical energy. The fundamental requirements to be met by low resistivity materials are

- i) The least possible temp coefficient of resistance
- ii) Adequate mechanical strength in particular, high tensile strength.

Low resistivity conducting materials are Copper and its alloys like cadmium copper, chromium copper, Brass, Bronze and its alloy like phosphorus Bronze, Beryllium Bronze etc. Low resistivity conducting materials are also like Duraluminium, Hindaluminium, magnaluminium

High resistivity materials have properties like the low temperature coefficient of resistance, high melting point and no tendency for oxidation. They must be ductile and should have high mechanical strength. High resistivity materials consist of Manganin, constantan or Eureka, platinum, nichrome, tungsten, carbon and Mercury.

### Low Resistivity materials and their applications-

**Copper:-** Due to its high conductivity and reasonable cost, copper is most widely used metal for electrical purposes. It is non ferrous, non magnetic (diamagnetic) metal. It possesses several advantageous properties such as given below:-

1. It is a ductile metal. It can be easily drawn into thin bars and wires. Hence it is very useful for making cables, strands and conductors.
2. Its ultimate tensile strength is high enough which makes it substantially strong to sustain mechanical loads.
3. Its melting point is sufficiently high that makes it suitable for use at high temperature also.
4. When exposed to atmospheric environment, it forms a protective layer of Copper Oxide (CuO). Thus the Copper is highly resistant to corrosion which is a desired property for bare/open overhead conductors.

**Types of Copper:-** Copper is available in two distinct forms. These are

- 1) Annealed Copper
- 2) Hard drawn Copper

Annealed Copper is more ductile than the hard drawn copper. It is used as power cables, Winding wires for electrical machines and transformers.

Hard drawn copper possesses high mechanical strength. It is suitable for overhead transmission wires and bus bars etc.

**Silver:-** It is a diamagnetic material. It possesses the highest electrical conductivity of any element and the highest thermal conductivity of any metal. The metal occurs naturally in its pure, free form, as an alloy with gold and other metals. Silver metal is used industrially in electrical contacts and conductors. Silver is very ductile, malleable (slightly harder than gold). Its greater cost has prevented it from being widely used in place of copper for electrical purposes. In radio frequency engineering,

particularly at UHF and higher frequencies, where silver plating is used to improve electrical conductivity of parts.

Silver is the best conductor of heat and electricity of any metal in the periodic table. It is used in currency, Jewellery & silverware, Dentistry (Dental filling), Photography and electronic, mirrors and optics. Silver and silver alloys are used in the construction of high quality musical wind instruments of many types. Silver is used to make solder and brazing alloys. The medical use of silver includes its incorporation into wound dressings and its use as an antibiotic coating in medical devices. It is used in clothing or shoes.

**Gold:-** Symbol of Gold is Au and its atomic number is 79. It is a diamagnetic material. It is a dense, soft, malleable and ductile material. It is a dense, soft, malleable and ductile material with a bright yellow colour. Beside its wide spread monetary and symbolic functions, gold has many practical uses in dentistry, electronics and other fields. Its high malleability, ductility, resistance to corrosion and most other chemical reactions, and conductivity of electricity has led to many uses, including electric wiring, coloured glass production etc. Gold readily creates alloys with many other metals. These alloys can be produced to modify the hardness and other metallurgical properties. Gold is a good conductor of heat and electricity and reflects infrared radiation strongly. Chemically it is unaffected by air, moisture and most corrosive reagents and is therefore well suited for use in coins and jewellery and as a protective coating on other more reactive metal. However it is not chemically inert. Gold is yellow colour. It is used in monetary exchange, investment, jewellery, medicine, industry, electronics & commercial Chemistry.

**Aluminium:-** Its conductivity is lower than that of copper, but it is cheaper than copper. It is nonferrous, weak magnetic (Paramagnetic) metal of white colour.

- It is a lightweight metal
- It is a ductile metal by virtue of which it can be easily drawn into thin bars and wires. Therefore aluminium is very useful for making cables, strands and conductors.
- Its ultimate tensile strength is sufficiently high which is lower than copper. Therefore it does not find favour in making winding for transformers, motors.
- Under atmospheric exposure, it forms a protective layer over its surface. This layer is of aluminium oxide that makes aluminium corrosion resistant.
- It can be easily soldered which is an essential requirement in wiring and other connections.
- Pure aluminium is a very soft metal. But when alloyed with alloying elements like Si, Mg, Ni, Co etc, it becomes hard and tough.

**Types of aluminium:-**

1. Rolled aluminium
  - (i) Hot rolled
  - (ii) Cold rolled
2. Hard drawn aluminium

**Application:-**

- 1) Overhead transmission line
- 2) Domestic wiring
- 3) Bus bars
- 4) Rotor bars of sq. Large induction motor

**Steel:** - Steel is an alloy of Iron and other elements including carbon. The following elements are always present in steel: carbon, manganese, Phosphorus, Sulphur, Silicon and traces of Oxygen, nitrogen and aluminium. Steel with increased carbon content can be made harder and stronger than iron, but such steel is also less ductile than iron. Steel is also distinguishable from wrought iron, which can contain a small amount of carbon, but it is included in the form of slag inclusion. To inhibit corrosion, at least 11% chromium is added to steel so that a hard oxide forms on the metal surface, this is known as Stainless steel. Iron and steel are widely used in the construction of roads, railways, other infrastructures, appliance and buildings. Even those with a concrete structure employ steel for reinforcing. In addition, it sees wide spread use in major appliances and car. Despite growth in usage of aluminum, it is still the main material for car bodies. Steel is used in a variety of other construction

materials such as bolts, nail and screws. Other common applications including ship building, pipeline transport, mining, offshore construction, aerospace, white goods, heavy equipment etc.

**Stranded Conductors:-** Stranded conductors are made by twisting the thin wires of smaller cross-section. Wires of each layer are then laid helically around the wires of other layer. This process is called stranding. Stranding is done in opposite directions for successive layers i.e. if the wires of one layer are twisted in C.W. direction then the wires of next layer are twisted in A.C.W. direction. In this way stranding is done for different layers. Stranded conductors can be of two different designs

- 1) Circular stranded conductor
- 2) Compact circular stranded conductor

In the former type the strands are circular in cross section, while in the latter type it is elliptical. Circular stranded conductors are generally used for single phase applications. The Compact circular stranded conductors are used for  $3\phi$  applications and in making core cables. The compact circular stranded conductors are made by compacting the circular stand by means of pressing them through a set of dies and rollers.

**Specifications:** - Stranded conductors are specified as 19/2.50, 37/2.06 etc. First numbers 19, 37 etc. Indicate the total number of wires in a stranded conductor, and the second numbers 2.50, 2.06 etc. Indicate the diameter of each wire in millimeter.

**BUNDLE CONDUCTORS:-** A bundle conductor is a conductor made up of two or more conductors called the sub conductor per phase in close proximity compared with the spacing between phases. The sub conductors of a bundle conductor are separated from each other by a constant distance varying from 0.2m to 0.6m depending upon designed voltage and surrounding condition throughout the length of the line with the help of spacers. It has several advantages such as

- a. Reduced corona loss and radio interference.
- b. Reduced losses thereby giving higher transmission efficiency.
- c. Higher charging current
- d. Lesser Inductance per phase
- e. Higher capacitance resulting in increase in the maximum power transfer capacity.

These conductors are used in 400KV tower.

**LOW RESISTIVITY COPPER ALLOYS:-** Several alloys of copper also fall in the category of low resistivity conducting materials. Main among them is brass and bronze. Brass is basically an alloy of copper and zinc, while bronze is an alloy of copper and tin. But they are prepared with the addition of other elements also.

**BRASS:** -It is an alloy of copper containing 40% Zn. Its conductivity is lower than that of copper. It has high tensile strength and is fairly resistant to corrosion. It can be easily pressed a desired shape and size, can be drawn into wires, and can be easily brazed. Brasses are widely used in following application.

- |                                       |    |                |
|---------------------------------------|----|----------------|
| <input type="checkbox"/> Plug points  | -> | Socket outlet  |
| <input type="checkbox"/> Lamp holders | -> | Fuse holder    |
| <input type="checkbox"/> Switches     | -> | Knife switches |

**BRONZE:** - It has a composition of 10% Sn in 90% Cu. Its conductivity is lower than that of pure copper. Bronze components are generally made by forging process. It is corrosion resistant and possesses high strength. Different types of bronze are generally used in following applications.

- Phosphor bronze for making springs, bushings etc.
- Cadmium bronze for making commentator segments.

### **HIGH RESISTIVITY MATERIALS AND THEIR APPICATION: -**

High resistivity materials can be divided into 3 groups. The first group consists of materials employed in electrical measuring instruments(standard,substandard etc)and in making standard resistances and resistance boxes. The second group consists of materials from which resistance elements are made for all kinds of rheostats and similar control devices. In the third group are materials suitable for making high temperature elements for electric furnaces, heating devices and loading rheostats. All these materials should have high resistivity, low temp. Co-efficient of resistance, high melting point, high ductility, high mechanical strength and no tendency for oxidation e.g. manganin, constantan, nichrome, Tungsten, carbon etc.

**TUNGSTEN:-** I) Hard steel W74 -> Transition metal

II) Resistivity twice that of aluminium

III) Can be drawn into very thin wires for making filaments

IV) In the atmosphere of inert gas (Nitrogen, argon etc) or in vacuum, tungsten can be readily worked at temperature like 2000° C and even higher.

It is paramagnetic

Uses-

- This material is used in electronic and vaccun engineering used as filament in incandescent lamps such as the electrodes, heaters, spring etc.
- The tungsten filament is made in straight, coiled or coiled coil form.
- It is extremely resistant to the destructive acting forces.

**CARBON:-** It is a diamagnetic material. There are several allotropes of carbon of which the best known are graphite, diamond and amorphous carbon, Diamond is highly transparent, while graphite is Opaque and black. Diamond has a very low electrical conductivity, while graphite is a very good conductor. In the human body carbon is the second most abundant element by mass after Oxygen. Carbon remains solid at higher temperatures than the highest melting point metals such as tungsten.  
Uses:-

Carbon is used in automatic voltage regulators for making the pressure sensitive pile resistors. It is used in the manufacture of welding electrodes, fixed and variable resistors for light currents and contacts of certain classes of d.c. switch gear which are subjected to arcing.

**PLATINUM (Pt<sub>78</sub>):-** It is a paramagnetic material

It is a dense, malleable, ductile, precious, gray white transition metal. Transition metals are ductile and malleable platinum is more ductile than gold, silver and copper, thus being the most ductile of pure metals.

But gold is still more malleable than platinum. It does not oxidise at any temperature. Pure platinum is slightly harder than pure iron. The metal has an excellent resistant to corrosion and high temperature and has stable electrical properties. All of these characteristics have been used for industrial applications.

**USES:-**

- 1) The most common use of platinum is as a catalyst in chemical reactions.
- 2) It is used as a precious metal. Platinum finds use in jewellery.
- 3) In the laboratory, platinum wire is used for electrodes; platinum pans. Platinum based anodes are used in ships, pipelines.

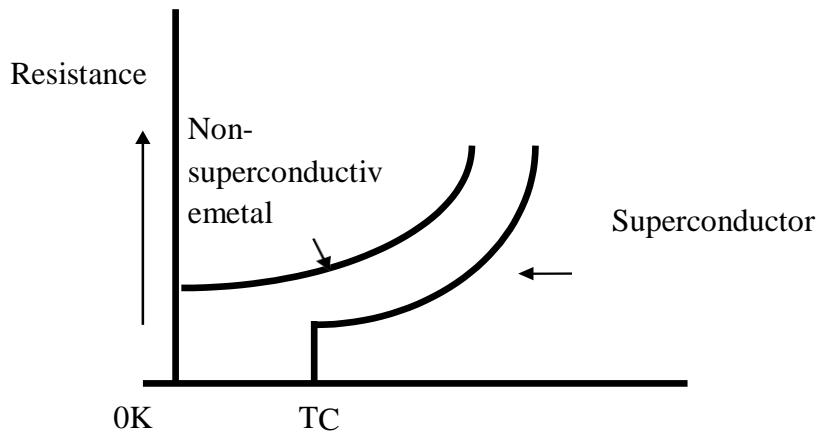
**MERCURY: - Hg<sub>80</sub>**

It is diamagnetic material. Mercury is the only metal that is liquid at standard conditions for temperature and pressure. It is a heavy, silvery white metal. As compared to other metals, it is a poor conductor of heat, but a fair conductor of electricity. Mercury does not react with most acids such as dilute sulphuric acid. Mercury finds use in the following main applications.

- i. Gas filled tubes
- ii. Mercury arc rectifiers
- iii. Thermometers
- iv. Extraction of Precious metals
- v. As liquid contact material in electrical switches.

**SUPERCONDUCTIVITY :-**

There are some metals and chemical compounds whose resistivity becomes zero when their temperature is brought near 0<sup>0</sup>k(-273<sup>0</sup>C).At this stage such metals or compounds are said to have attained super conductivity. E.g. Mercury becomes superconducting at approx. 4.5<sup>0</sup>k(-268.5<sup>0</sup>C). The transition from normal conductivity to superconductivity takes place abruptly, it occurs over a very narrow range of temperature about 0.05<sup>0</sup>k. The temperature at which the transition takes place from the state of normal conductivity to that of the super conductivity is called the transition temperature



## SUPERCONDUCTING MATERIALS:-

Superconductors are classified into the following categories.

1. On the basis of working temperature
  - I. Low temperature superconductors(LTS)
  - II. High temperature superconductors(HTS)
  
2. On the basis of kind of material
  - I. Metallic superconductors (MS)
  - II. Inter metallic compound superconductors.
  - III. Ceramic superconductors.(CS)
  - IV. Alloy superconductors.
  
3. On the basis of application
  - I. Magnetic grade superconductors.
  - II. NON magnetic grade superconductors.
  
4. On the basis of penetration of magnetic lines of force.
  - I. Type I or ideal superconductors.
  - II. Type II or hard superconductors.

## APLLICATION OF SUPERCONDUCTORS MATERIALS:-

Currently superconductors are used in the following important applications.

1. Switching elements.
2. Flip flop devices.
3. Small cryotrons.
4. Very strong magnets.
5. Magnetic detectors.
6. Resonance imaging etc.

## **SHORT QUESTIONS WITH ANSWER**

Q 1 What is Brass? ,W-16

Ans-Brass is an alloy made up of Copper & Zinc

Q 2. What happens to the resistivity if temperature increases? 2019(S)BP

Ans. If temperature increases, resistivity of pure metal also increase

Q3. Which material possesses the highest electrical conductivity of any element?

Ans. Silver possesses the highest electrical conductivity of any element

Q4. What is ACSR? Where is it used ?,2019(S),2020(W) old

Ans-ACSR is aluminium conductor steel reinforced.

It is used in transmission line.

Q5. What are the advantage of using bundle conductor in EHT line?2019W/N

Ans. I Current carrying capacity increases

ii Corona loss is less

iii. Less radio interference occurs

Q6. What is stranding?

Ans. Stranded conductors are made by twisting the thin wires of smaller cross-section. Wires of each layer are then laid helically around the wires of other layer.

## **Long questions**

Q1. State the advantage and disadvantage of aluminium as compared to copper when used as conductor of electricity? 2015,2019(S)BP

Q2. Describe briefly about stranded conductor?

Q3. Write short note on bundle conductor?

Q4. Which are the materials of high resistivity and their application? 2020(W)

Q5. Write the classification of superconducting material and its application ?2018(N)

## CHAPTER-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
  - Rectifiers
  - Temperature-sensitive resistors or thermistors
  - Photoconductive cells
  - Photovoltaic cells
  - Varistors
  - Transistors
  - Hall effect generators
  - Solar power

#### Introduction:-

Semiconductors are those materials whose conductivity lies between conductor and insulator.

#### Semiconductor:-

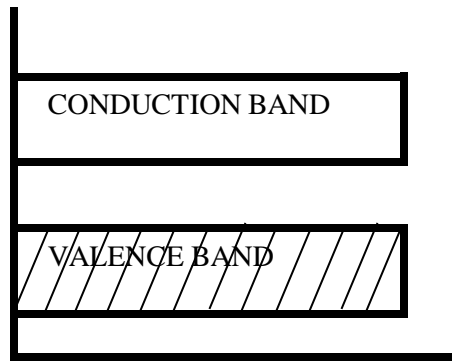
In semiconductor valency band is filled and conduction band is empty. Semiconductors are substances with properties somewhere between them. ICs (Integrated circuit) and electronic discrete components such as diodes and transistors are made of semiconductors. Common elemental semiconductors are Silicon and Germanium. Semiconductors become essential for many electronic appliances as well as for social infrastructure that support our everyday life.

#### Electron Energy & Energy band theory-

Electrical engineering Materials are classified into four categories i.e.

- i. Insulator
- ii. Conductor
- iii. Semiconductor
- iv. Magnetic Materials

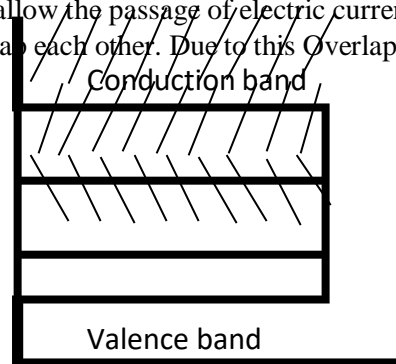
- i. Insulator:-



Insulators are those substances which do not allow the Passage of electric Current through them. In terms of energy band, the valence band is full while the conduction band is empty. Further the energy gap between valence and conduction band is very large.  $\sim 15\text{eV}$ .

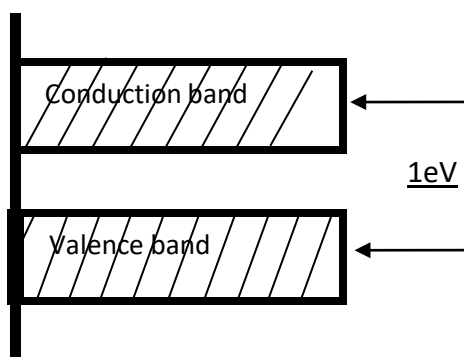
For this reason, the electrical conductivity of such materials is extremely small and may be regarded as nil under ordinary conditions.

- ii. **Conductors:-** Conductors are those substances which easily allow the passage of electric current through them. In terms of energy band, the valence and conduction bands overlap each other. Due to this overlapping, a slight p.d. across a conductor causes the free electrons to constitute electric current.



- iii. **Semiconductors:-**

Semiconductors are those substances whose electrical Conductivity lies in between conductors and insulators. In terms Of energy band, conduction band is almost empty. Further the energy gap between Valence and conduction band is very small. Therefore comparatively Smaller electric field is required to push the electrons from the Valence band to conduction band. In short a semiconductor has



- Almost full valence band
- Almost empty conduction band.
- Small energy gap between valence & conduction bands.

## Excitation of atom -

Excitation, in physics, the addition of a discrete amount of energy (called excitation energy) to a system such as an atomic nucleus, an atom or a molecule. When that results in its alteration ordinarily from the condition of lowest energy to that of higher energy.

## Insulators, Semiconductor and conductor-

The substance in which current does not flow is called insulator. Insulators are negative coefficient of resistance. It means that when temperature increases, resistance decreases.

The substance whose conductivity lies between conductor and insulator is called semiconductor. Semiconductors are negative coefficient of resistance.

The substance in which current flows easily is called conductor. Conductors are positive temperature coefficient of resistance. It means when temperature increases, resistance increases.

## Semiconducting materials :-

<u>Sl.No.</u>	<u>Element</u>	<u>Symobl</u>	<u>Atomic No.</u>
1	Boron	B	5
2	Carbon	C	6
3	Silicon	Si	14
4	Germanium	Ge	32
5	Phosphorus	P	15
6	Arsenic	As	33
7	Antimony	Sb	51
8	Sulphur	S	16
9	Selenium	Se	34
10	Tellurium	Te	52
11	Iodine	I	53

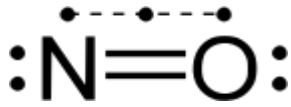
## 2.7 Covalent Bonds:-

A covalent bond is a chemical bond that involves the sharing of electron pairs between atoms. These electron pairs are known as shared pairs or bonding pairs, and the stable balance of attractive and repulsive forces between atoms, when they share electrons, is known as covalent bonding. For many molecules, the sharing of electrons allows each atom to attain the equivalent of a full valence shell, corresponding to a stable electronic configuration. In organic chemistry, covalent bonds are much more common than ionic bonds.

Atomic orbitals (except for s orbitals) have specific directional properties leading to different

types of covalent bonds. Sigma ( $\sigma$ ) bonds are the strongest covalent bonds and are due to head-on overlapping of orbitals on two different atoms. A single bond is usually a  $\sigma$  bond. Pi ( $\pi$ ) bonds are weaker and are due to lateral overlap between p (or d) orbital's. A double bond between two given atoms consists of one  $\sigma$  and one  $\pi$  bond, and a triple bond is one  $\sigma$  and two  $\pi$  bonds.

Covalent bonds are also affected by the electro negativity of the connected atoms which determines the chemical polarity of the bond. Two atoms with equal electro negativity will make no polar covalent bonds such as H–H. An unequal relationship creates a polar covalent bond such as with H–Cl. However polarity also requires geometric asymmetry, or else dipoles may cancel out resulting in a non-polar molecule.



Modified Lewis structures with 3e bonds

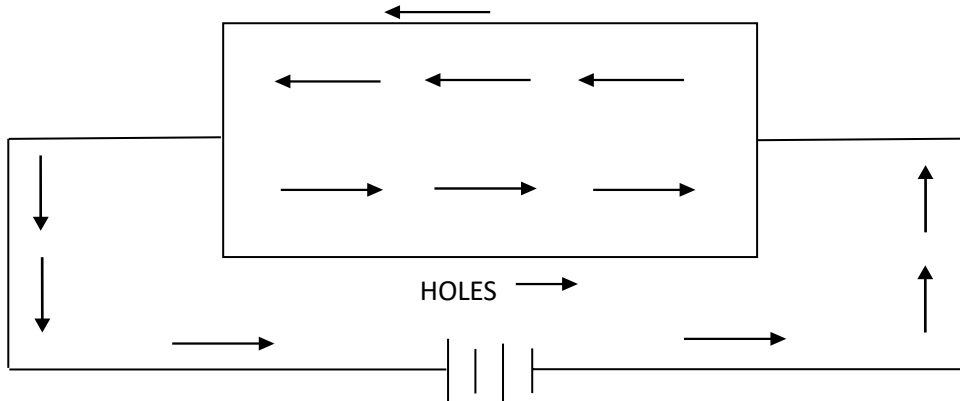
Nitric oxide

Dioxygen

## Intrinsic Semiconductors :-

A semiconductor in an extremely pure form is known as an intrinsic semiconductor.

### FREE ELECTRONS



When an electric field is applied across an intrinsic semiconductor, the current conduction takes place by two processes in parallel: by free electrons and holes as shown in the figure. Free electrons are produced due to the breaking up of some covalent bonds by thermal energy. At the same time, holes are created in the covalent bond under the influence of the electric field. Conduction through the semiconductor is by both free electrons and holes. Therefore, the total current inside the semiconductor is the sum of currents due to free electrons and holes. Current in the external wire is fully electronic. Referring to the figure, holes being positively charged move towards the negative terminal of the supply. As the holes reach the negative terminal, electrons enter the semiconductor crystal near the terminal and combine with holes, thus cancelling them. At the same time, the loosely held electrons near the positive terminal are attracted away from their atoms into the positive terminals.

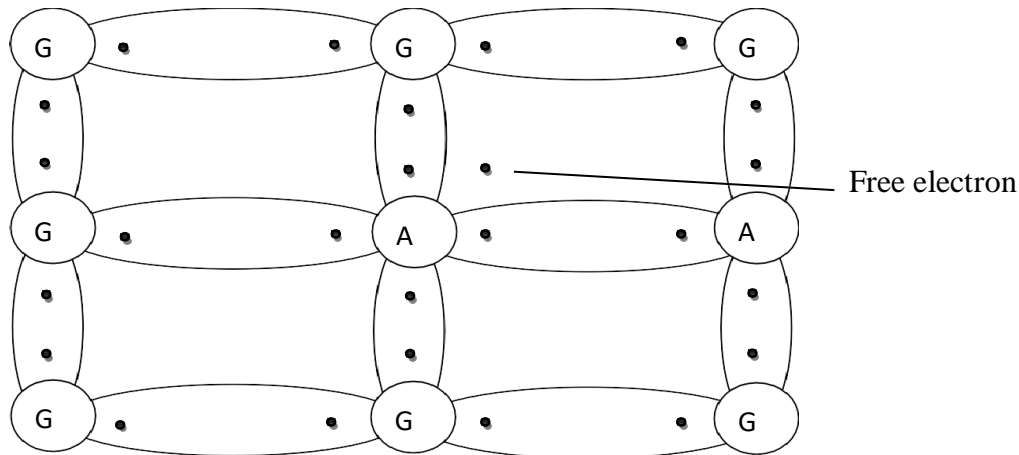
## Extrinsic Semiconductor :-

When a small amount of suitable impurity is added to a semiconductor, it is then called an impurity or extrinsic semiconductor. The process of adding impurity is known as doping. The process of adding impurity is to increase either the number of free electrons or holes in the semiconductor crystal. If a pentavalent impurity (having 5 valence electrons) is added to the semiconductor, a large number of free electrons are produced in the semiconductor. On the other hand, the addition of trivalent impurity (having 3 valence electrons) creates a large number of holes in the semiconductor crystal. Depending upon the type of impurity added, extrinsic semiconductors are classified into

1. N-type semiconductor
2. P-type semiconductor

## N-Type Semiconductor:-

When a small amount of pentavalent impurity is added to a pure semiconductor, it is known as n-type semiconductor. Such impurities which produce n-type semiconductor are known as donor impurities because they donate or provide free electrons to the semiconductor crystal.

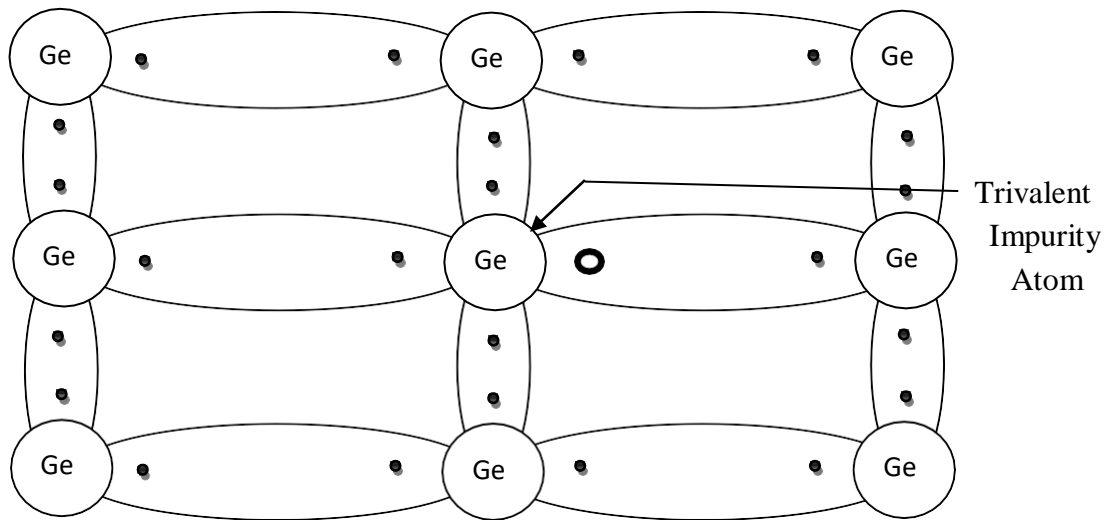


To explain the formation of n-type semiconductor, consider a pure germanium crystal. We know that Germanium atom has four valence electrons. when a small amount of pentavalent impurity like arsenic is added to germanium crystal, a large no. of free electrons become available in the crystal. Arsenic is pentavalent. Its atom has five valence electrons. An arsenic atom fits in the germanium crystal in such a way that its four valence electrons form covalent bonds with four germanium atoms. The fifth valence electron of arsenic atom finds no place in covalent bonds and is thus free. Therefore for each arsenic atom added, one free electron will be available in germanium crystal. Though each arsenic atom provides enough atoms to supply millions of free electrons. It is this predominance of electrons over holes that it is called n-type semiconductor. N stands for negative.

## P- type semiconductor :-

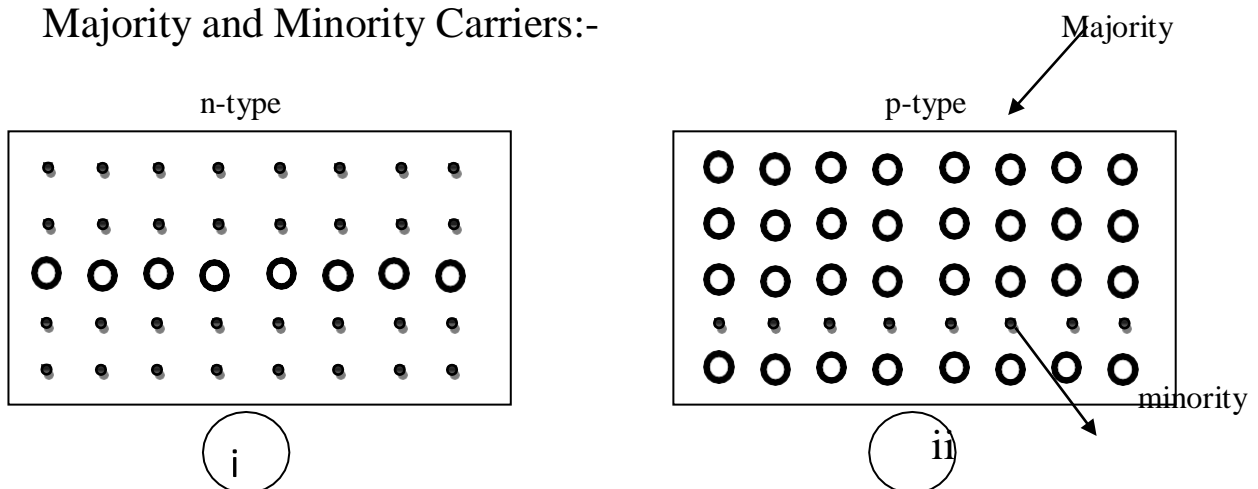
When a small amount of trivalent impurity is added to a pure semiconductor, it is called p-type semiconductor. Trivalent impurities are gallium and indium. Such impurities which produce p-type semiconductor are known as acceptor impurities because the holes created can accept the electrons.

To explain the formation of p-type semiconductor, consider a pure germanium crystal . When a small amount of trivalent impurity like gallium is added to germanium crystal , there exists a large number of holes in the crystal. Gallium is trivalent i.e. its atom has three valence electrons. Each atom of gallium fits into germanium crystal but now only three covalent bonds can be formed . It is because three valence electrons gallium atom can form only three single covalent bonds with three germanium atoms. In the fourth covalent bond, only germanium atom contributes one valence electron while gallium has no valence electron to contribute as all the three valence electrons are already engaged in the co-valent bonds with neighbouring germanium atoms. In other words , fourth bond is incomplete being short of one electron.



This missing electron is called a hole. Therefore for each gallium atom added, one hole is created. A small amount of gallium provides millions of holes. It is due to the predominance of holes over free electrons that it is called p-type semiconductor (p-stands for positive).

### Majority and Minority Carriers:-



An n-type material has a large number of free electrons and a small number of holes as shown in figure. The free electrons in this case are considered majority carriers-since the majority portion of current in n- type material is by the flow of free electrons and the holes are minority carriers.

Similarly in a p-type material, holes outnumber the free electrons as shown in figure. Therefore holes are the majority carriers and free electrons are the minority carriers.

## Semiconducting materials :-

<u>Sl.No.</u>	<u>Element</u>	<u>Symobl</u>	<u>Atomic No,</u>
1	Boron	B	5
2	Carbon	C	6
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4	Germanium	Ge	32
5	Phosphorus	P	15
6	Arsenic	As	33
7	Antimony	Sb	51
8	Sulphur	S	16
9	Sellenirium	Se	34
10	Tellurium	Te	52
11	Iodine	I	53

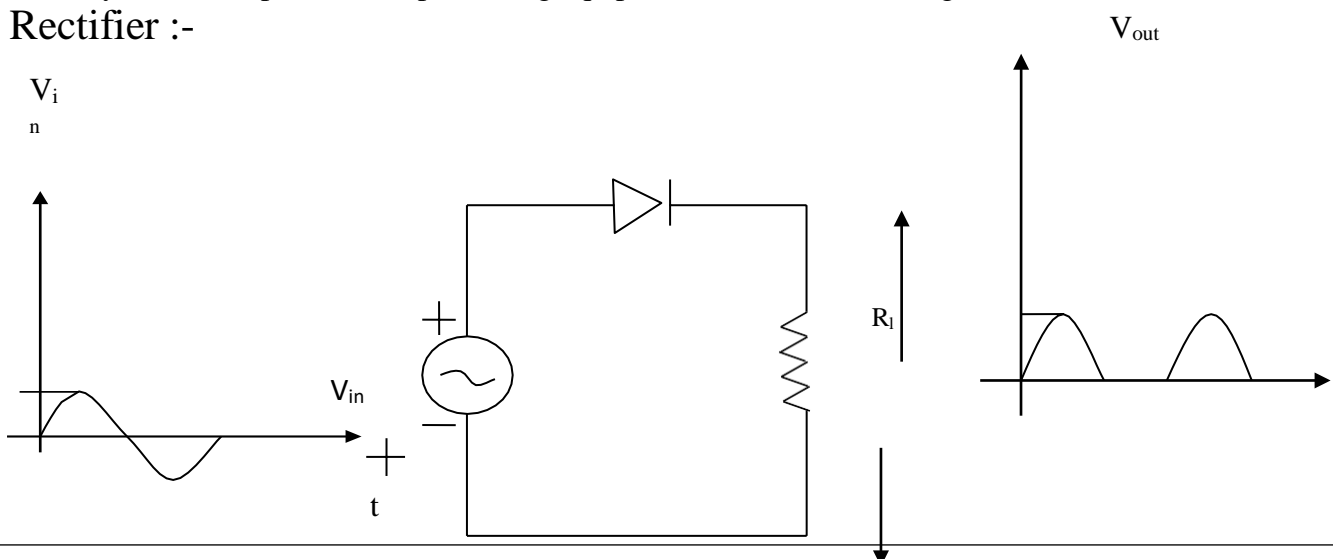
## Application of semiconductor materials:-

Semiconductor materials are applied in devices like transistors and lasers. Power semiconductor devices are discrete devices or integrated circuits intended for high current or high voltage applications. Power integrated circuits combine IC technology with power semiconductor technology; these are sometimes referred to as smart power devices. Some of the most important semiconductor devices are diodes, transistors and thyristors. Semiconductors find wide applications because of their compactness, reliability and low cost. They can handle a wide range of current and voltage. Semiconductor devices are around us. They can be found in just every commercial product we touch, from the family car to the pocket calculator Semiconductor.

Laser is the acronym for Light amplification by stimulated emission of radiation.

Semiconductor devices are contained in television sets, portable radios, stereo equipment and much more. Industrial control systems (such as those used to manufacture automobiles) and automatic telephone exchanges also use semiconductors. Even today heavy duty versions of the solid state rectifier diode are being used to convert large amounts of power for electric railroads of many different applications for solid state devices, space systems, computers, data processing equipment are some of the largest consumers.

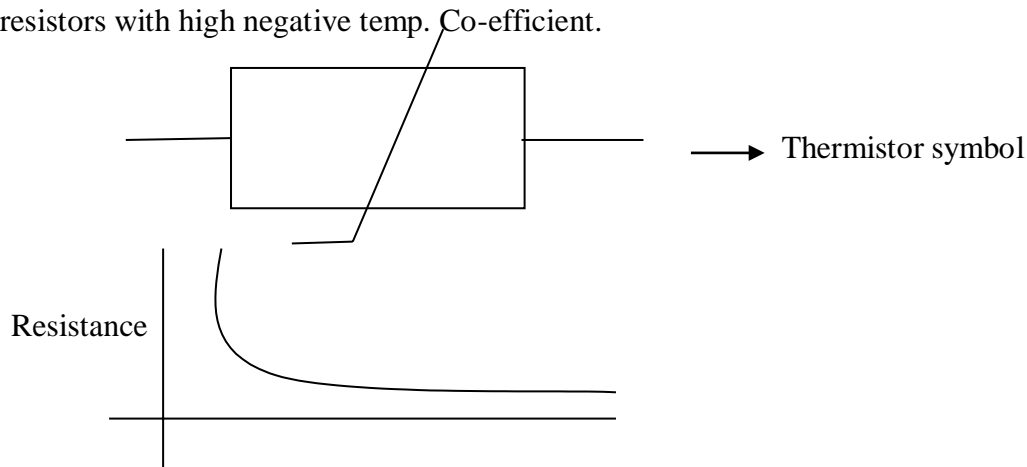
## Rectifier :-



The a.c. input voltage to be rectified; the diode and load  $R_L$  are connected in series. The d.c. output is obtained across the load. During the positive half cycle of a.c. input voltage, diode is forward biased and conducts current in the circuit. The result is that positive half cycle of input voltage appears across  $R_L$ . However during the negative half cycle of input a.c. voltage, the diode becomes reverse biased. Therefore diode does not conduct and no voltage appears across load  $R_L$ . The result is that output consists of positive half cycles of input a.c. voltage while the negative half cycles are suppressed. In this way, crystal diode has been able to do rectification i.e. change a.c. into d.c.

### Temp. Sensitive resistors or thermistors:-

Thermistors are also called the thermal resistors as the resistance of a thermistor varies as a function of temperature. Thermistors are essentially semiconductor devices that behave as resistors with high negative temp. Co-efficient.

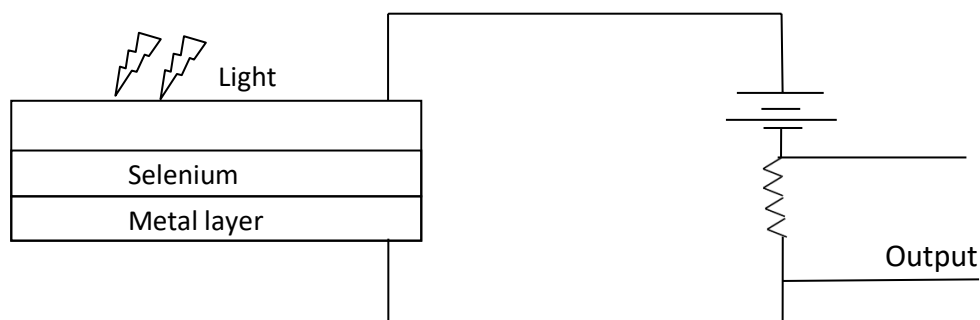


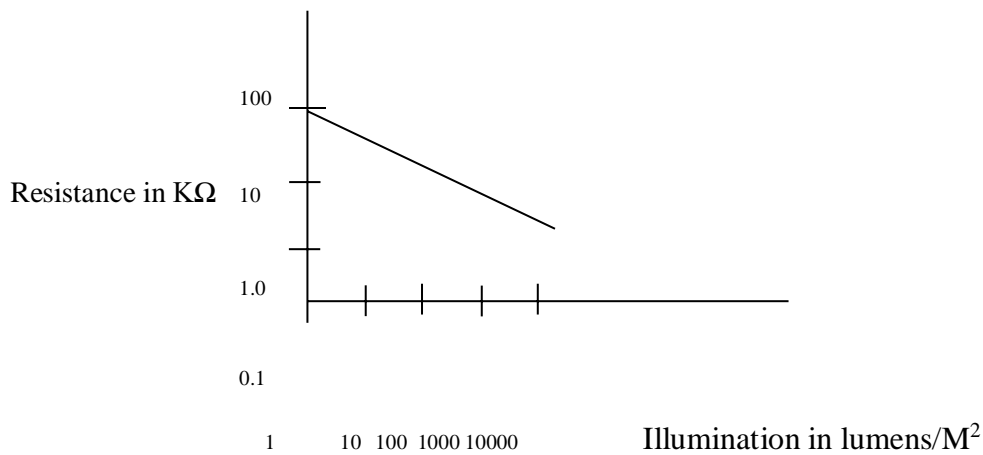
**Applications :-** These are cheaper in cost and highly sensitive devices. It is used in

- i. Measurement of temperature
- ii. Measurement of difference of two temperature
- iii. Control of temperature
- iv. Temperature compensation
- v. Thermal conductivity measurement
- vi. Measurement of gas composition
- vii. Measurement of flow

### Photoconductive cells:-

A Photo conductive cell is a device whose resistance decreases with increasing incident light intensity. The device works when light falls on it at high intensity making electrons to jump into the conduction band thus causing it to conduct electricity.





The electrical resistance of a semiconductor depends on the intensity of the incident light . A photoconductive cell works on the above principle.

A Photoconductive cell Consists of a thin transparent surface film of some metal, Which is placed on thin layer of semiconductor like selenium, which in turn is placed over a metal layer of iron. A high p.d. is applied across surface film and iron layer when light of suitable frequency falls on the transparent film, the electrical resistance of selenium layer decreases. This changes the current flowing inthe circuit. Photo conductive cells are also called photo resistors.

#### Applications:-

- I. Camera exposure control
- II. Density meter
- III. Automatic headlight dimmer
- IV. Night light control
- V. Street light control

### Photovoltaic Cells :-

A Photovoltaic cell (also called solar cell) is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. It is a form of photoelectric cell ( in that its electrical characteristics – e.g. current voltage, or resistance – vary when light is incident upon it ) which, when exposed to light, can generate and support an electric current without being attached to any external voltage source. The operation of a photovoltaic cell requires three basic attributes.

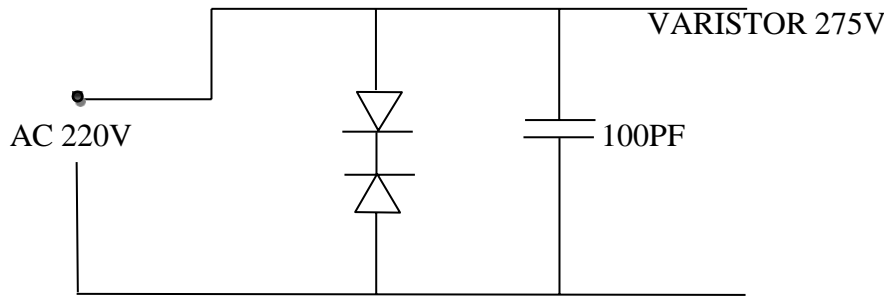
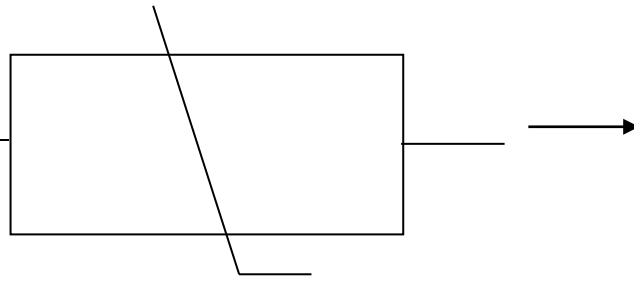
- 1) The absorption of light, generating either electron-hole pairs .
- 2) The separation of charge carriers of opposite types
- 3) The separate extraction of those carries to an external circuit. When light shines on the cell, it creates an electric field across the layers.

The solar cells work in three steps.

- 1) Photos in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon. Photons striking the cell pass through the thin p-doped upper layer and are absorbed by electrons in the lower N-layer causing formation of conduction electrons and holes. The depletion zone potential of PN junction then separates these conduction holes and electrons causing a difference of potential to develop across the junction.
- 2) Electrons (negatively charged) are knocked loose from their atoms, causing an electric p.d. current starts flowing through the material to cancel the potential and this electricity is captured. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction.
- 3) An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.

## Varistor

Symbol of varistor



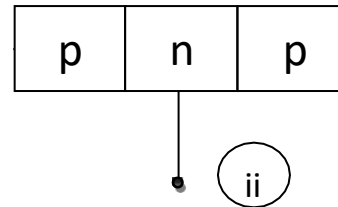
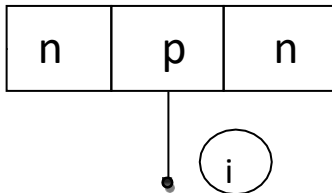
A varistor is an electronic component with a diode like non linear current voltage characteristic. The name is a portmanteau of variable resistor. Varistors are often used to protect circuits against excessive transient voltages. A varistor is also known as voltage dependent resistor. A varistor's function is to conduct significantly increased current when voltage is excessive. Only non ohmic variable resistors are usually called varistors. Other ohm types of variable resistor include the potentiometer and the rheostat. Their resistance decreases when the voltage increases. In case of excessive voltage increases, their resistance drops dramatically.

### Applications :-

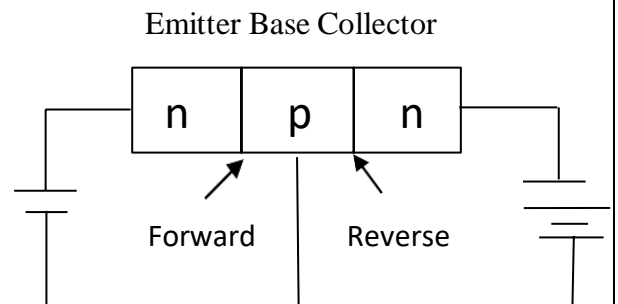
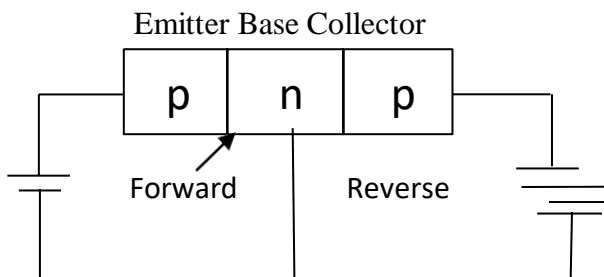
- i. Telephone and other communication line protection
- ii. Power supply protection
- iii. Electronics equipment protection

**Transistor** :- A transistor consists of two PN Junctions and three terminal device. Accordingly there are two types of transistors, namely

- n-p-n transistor
- p-n-p transistor



Naming the transistor terminals----

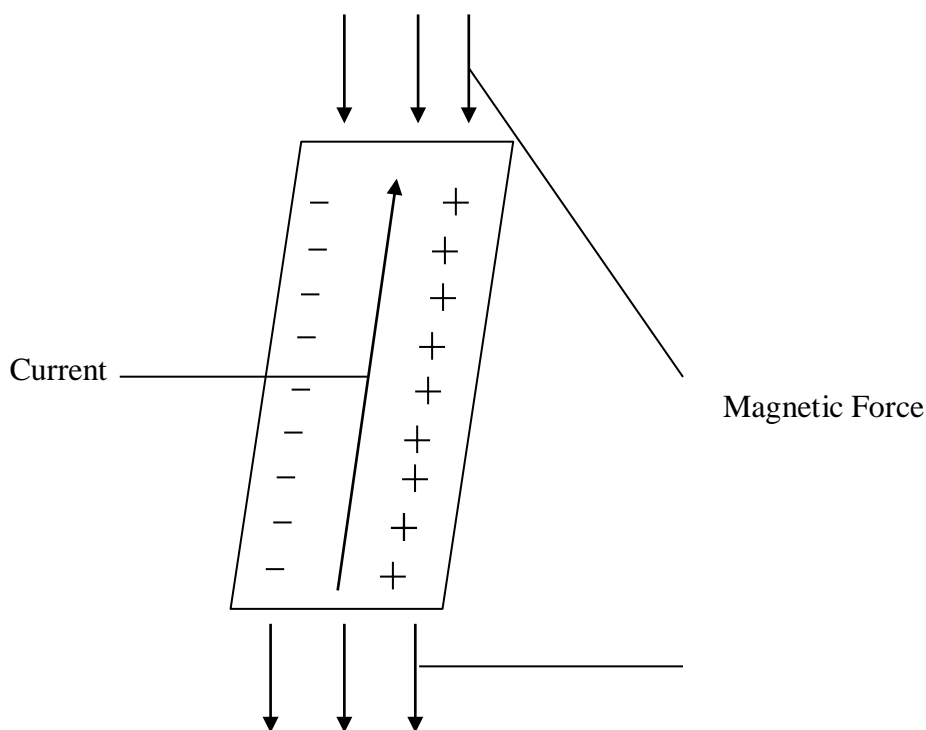


- I. **Emitter :-** The section on one side that supplies charge carriers is called the emitter. The emitter is always forward biased w.r.t. base so that it can supply a large no. of majority carriers. The emitter p-type of pnp transistor is forward biased and supplies hole charges to its junction with the base. Similarly n-type of npn transistor has a forward bias and supplies free electrons to its junction with the base.
- II. **Collector:-** The section on the other side that collects the charge is called the collector. The collector is always reverse biased. The collector p-type of pnp transistor has a reverse bias.

III **Base:-** The middle section which forms two p-n junctions between the emitter and collector is called base. The base –emitter junction is forward biased allowing low resistance for the emitter circuit. The base collector junction is reverse biased provides high resistance in collector circuit.

### Hall Effect generator:-

When a current carrying electrical conductor is placed in a magnetic field, a voltage sometimes develops between one side of the conductor and the other. For this to happen, the magnetic lines of force must be perpendicular, or nearly perpendicular to the line containing the conductor. The voltage then appears at right angles to the magnetic lines of force. If the conductor is a strip and the magnetic lines of force perpendicular to the strip, then the voltage will appear between opposite edges of the strip. This is called Hall Effect.



The electric field intensity given as  $e$  is described by the formula

$$e = K i m$$

Where “ $i$ ” is the current,  $m$  is magnetic field strength, and  $k$  is hall constant.

**Solar power:-** Solar power is the conversion of sunlight into electricity . This is done by using solar panels, which are large flat panels made up of many individual solar cells. It is most often used in remote locations. Every day light hits your roof's solar panels with photons (particles of sunlight). The solar panel converts those photons into electrons of direct current electricity. The electrons flow out of the solar panel and into an inverter and other electrical safety devices. The inverter converts that DC power (commonly used in batteries) into alternating current or AC power.

Solar cells are small, square shaped panel semiconductor made from silicon and other conductive materials. When sunlight strikes a solar cell, chemical reactions release electrons, generating electric current. Solar cells are called photovoltaic cells or PV cells.

Merits of Semiconductor electrical engineering:-

1. Semiconductor devices are very compact and portable. Therefore circuits using semiconductor devices are very compact and are portable.
2. The devices are operated with relatively low voltages, therefore power consumption is less.  
Ductility is a solid material's ability to deform under tensile stress, this is often characterized by the material's ability to be stretched into a wire malleability, a similar property is a material's ability to deform under compressive stress; this is often characterized by the material's ability to form a thin sheet (without breaking) by hammering.
3. These devices have almost unlimited life unless they are subjected to wrong voltages.
4. Transistors can withstand mechanical shocks as they are solid crystals.
5. Semiconductor devices are low priced.

## Short Questions with answer

Q1. What is intrinsic semiconductor? 2020(N)old

Ans. A semiconductor in an extremely pure form is known as intrinsic semiconductor

Q2. What is extrinsic semiconductor? 2019(S)BP,2019(S) new

Ans. When a small amount of suitable impurity is added to a pure semiconductor, it is then called impurity or extrinsic semiconductor.

Q3. What is a photovoltaic cell(PV Cell) ?W-17,2020(W)

Ans. A photovoltaic cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect

Q4. What is thermistor? 2016,w-17,2019(S)new

Ans. Thermistors are also called the thermal resistors as the resistance of a thermistor varies as a function of temperature.

Q5. What is photoconductive cells?

Ans. A photoconductive cell is a device whose resistance decreases with increasing incident light intensity.

Q6. What is Varistor? w-18,2020(W)old

Ans. A varistor is an electronic component with a diode like non linear current voltage characteristic.

### Long question

Q1. Explain N-type semiconductor & P-type semiconductor ? 2018(old),2019 W/N

Q3. Explain photovoltaic cell?

Q4. Briefly describe Hall effect generator? ,2018(S)

Q5. Differentiate between intrinsic & extrinsic semiconductor.2020(W)

## Chapter :-3

# INSULATING MATERIAL

3 . 1 Introduction

3 . 2 General properties of Insulating Materials

Electrical properties

Visual properties

Mechanical properties

Thermal properties

Chemical properties

Ageing

Insulating Materials – Classification, properties, applications

Introduction

Classification of insulating materials on the basis physical and chemical structure

Insulating Gases

Introduction

Commonly used insulating gases

### **Introduction:-**

Insulating materials are those materials in which current does not flow.

### **General properties of insulating material :-**

The general properties are

- i Electrical properties
- ii Visual properties
- iii. Mechanical properties
- iv. Thermal properties
- v. Chemical properties

### **Electrical properties-**

i- Insulation resistance

ii -Dielectric strength(Breakdown voltage)

iii - Dielectric constant

iv- Dielectric loss

Insulation resistance:- The resistance offered to the flow of electric current through the material is called insulation resistance. It is of two types

i-Volume insulation resistance

ii-Surface insulation resistance

Factors affecting insulation resistance:

**Temperature-**As the temperature of the insulating material rises ,its insulation resistance keeps on falling.

**Moisture-**Insulation resistance is reduced if the material absorbs moisture .so insulating material should be non hygroscopic.

**Applied voltage-** Applied voltage also affects insulation resistance.

**Dielectric strength-**Dielectric strength is the minimum voltage which when applied to an insulating material will result in the destruction of its insulating properties .Electrical appliances are designed to operate with in a defined range of voltage .If the operating voltage is increased gradually at some value of voltage ,the breakdown of insulating material will occur. The property which attributes to such type of breakdown is called the dielectric strength .Dielectric strength of mica is 80kv/mm. It means if the voltage applied across 1mm thick sheet of mica becomes 80kv,mica will loose its insulating properties.

Factors affecting breakdown voltage-:Temperature, moisture ,thickness of insulator

**Dielectric constant-**The ratio of capacity of storing the electric charge by an insulating material to that of air is called dielectric constant of the material.

Every insulating material has the property of storing electric charge  $Q$  when a voltage  $v$  is applied across it. The charge is proportional to the voltage applied and we get  $Q=CV$ . Where  $C$  is the capacitance of the capacitor .

**Dielectric loss-**Electrical energy absorbed by the insulating material and dissipated in the form of heat when an alternating voltage is applied across it is called dielectric loss. When a perfect insulation is subjected to alternating voltage it is like applying like alternating voltage to a perfect capacitor .In such a case there is no consumption of power. Factors affecting dielectric loss-: Temperature ,Moisture, voltage applied.

**Visual properties-**The following are the visual properties of insulating materials which are not of much importance as regarding the performance but come handy for distinguishing of cables.

Appearance and colour

### **Mechanical properties-:**

**Density-** Electrical insulations are used on the basis of volume and not weight.Insulating material of low density is especially suitable for small portable equipment.

**Viscosity-**It is of importance in liquid dielectric.Uniform viscosity provides uniform electrical and thermal properties

**Moisture absorption-**Water lowers the electrical resistance and dielectric strength.With its absorption certain chemical and mechanical effects may result.

e.g. Swelling,corrosion

Hardness of surface:-Hardness of surface enables the dielectric to resist surface scratching and abrasion

Surface tension:-In liquid dielectric low surface tension is desirable as it causes greater wetting of the electrical components and thus gives better cooling.

Uniformity:-Dielectric should be uniform throughout as it keeps the electrical losses as low as possible and electric stresses uniform under high voltage differences.

### **Thermal properties:-**

Heat resistance:-This is the general property of insulating material to withstand temp. variation within desirable limits without damaging its other important properties. If an insulator has favourable properties at ambient temperature but if it is not able to retain these, it is not a good insulator. The insulator which is capable of withstanding higher temp. without deterioration of its other properties can be used for operation for such higher temp.

Permissible temperature rise:- There is always some recommended operating temperature for an insulator. The operating temp. has a bearing on the life of the concerned apparatus.

Effect of overloading on the life of an electrical appliance:-Insulators can withstand overloading within permissible limits for short period of time. Continuous overloading ultimately results in the breakdown of insulating material. If the involved insulating material is able to withstand the higher voltages, the change will cause increase of dielectric loss that will increase heat generation.

Thermal conductivity:-Heat generated due to losses and dielectric losses will be dissipated through the insulator itself. How effectively this flow of heat takes place depends on the thermal conductivity of the insulator. An insulator with better thermal conductivity will not allow temp. rise because of effective heat transfer through it to the atmosphere

### **Chemical properties:-**

Resistance to external chemical effects:- Insulating materials should be resistant to oils or liquids, acids. The materials should not undergo oxidation and hydrolysis even under adverse condition  
Resistance to chemicals in soils:- Cables laid in the soil can deteriorate by the action of chemicals in soils. So it should be resistant to chemicals in soils

Effect of water and tropical tests:- Water directly lowers electrical properties such as electrical resistance and dielectric strength. The water may be transmitted through an outside coating and cause damage inside, it may be directly absorbed by an insulating material, it may cause a chemical change of insulation itself, or it may drastically lower the surface resistance of insulator.

**Ageing:-** Ageing reduces the insulation resistance. As age of insulating material is increased, the insulation resistance decreases. Ageing reduces the dielectric strength of the insulating material.

## Essential properties of insulating materials-

An ideal insulating material should possess

- i. Dielectric strength as good as that of mica
- ii. Mechanical strength as good as that of steel
- iii. Crushing resistance as good as that of granite
- iv. Fire proofing qualities as good as that of silica
- v. Chemical inertness equal to that of platinum.
- vi. Surface finish like that of ebonite
- vii. Low dielectric loss
- viii. Viscosity
- ix. Porosity
- x. Solubility
- xi. High melting point
- xii. High flash point
- xiii. High thermal conductivity
- xiv. Non volatility
- xv. Low thermal expansion
- xvi. High resistance to heat

## Classification of insulating material :-

- i. Fibrous materials-Wood,paper,textile industry
- ii. Insulating liquids-Mineral insulating oils,vegetable oils
- iii. Not resinous material-Asphalts and waxes
- iv. Impregnated fibrous material-impregnated paper
- v. Ceramics-Porcelain,alumina
- vi. Mica and its products
- vii. Asbestos and its products
- viii. Glass-fibre glass
- ix. Insulating resins and their products
- x. Laminates and adhesives

Enamels and varnishes

## APPLICATION OF INSULATING

### **MATERIAL** -Insulating material for transformer

#### Part to be insulated

Air cooled and oil cooled transformer

For tapping the coil of air cooled transformer  
Insulation between core and coils and also between  
Primary and secondary winding

#### Insulating Material

Fibrous Material

Cotton or oil cambric  
Synthetic resin

## Insulating material for machines

### Part to be insulated

1. DC and ac motor and generator for industrial Installations
2. Insulation of commutators
3. For insulating terminals of h.v. machines

### Insulating material

Laminated wool,  
Varnished paper  
Mica  
Porcelain

### Insulating materials for electronic equipment

#### Equipment

1. T.v and radio receiver
2. Medical electronics
3. Computer

### Insulating material

Synthetic resin,  
Paper,press board  
Synthetic resin,  
Paper and oil  
Synthetic resin  
Paper  
Bonded paper

## Introduction:-

In Insulating material current does not flow easily.

### **Classification of insulating materials on the basis of physical and chemical structure :-**

Insulating material on the basis of their physical and chemical structure may be classified in various categories

- i. Fibrous material
- ii. Impregnated fibrous materials
- iii. Non resinous materials
- iv. Insulating liquids
- v. Ceramics
- vi. Mica and mica products
- vii. Asbestos and asbestos products
- viii. Glass
- ix. Natural and synthetic rubbers
- x. Insulating resins and their products
- xi. Laminates, adhesives, enamels and varnishes

### **Insulating gases:-**

**Introduction:-** Insulating gases are used both as an insulant and heat transfer medium. The major problem they entail are

- i. Temperature instability
- ii. Abnormalities in dielectric behavior at high pressure
- iii. Fire hazards

## Commonly used insulating gases:-

The insulating gases on the basis of dielectric strength, dielectric loss, chemical stability and corrosion etc. may be classified as follows

1. Simple gases
  - i. Air
  - ii. Nitrogen
  - iii. Hydrogen
  - iv. Helium
2. Oxide gases
  - i. Carbon dioxide
  - ii. Sulphur dioxide
3. Hydrocarbon gases
  - i. Methane
  - ii. Ethane
  - iii. Propane
  - iv. Freon gases
4. Electronegative gases
  - i. Sulphur hexafluoride
  - ii.  $\text{CH}_2\text{Cl}_2$

## **Short questions with answer**

Q1. What is ageing? 2019(W/N)

Ans. Ageing reduces the insulation resistance. As age of insulation material is increased, the insulation resistance decreases.

Q2. What is the effect of porosity?

2018(N), 2020(N)

Ans. Porosity is a measure of the void (empty) spaces in a material and fraction of volume of voids over the total volume between 0 & 1 or as a percentage between 0% and 100%

Q3. What is dielectric loss? 2020(W)

Ans- Electrical energy absorbed by the insulating material and dissipated in the form of heat when an alternating voltage is applied across it is called dielectric loss.

.Q4. What are the visual properties?

Ans. The visual properties are appearance and colour

Q5. Write the name of the commonly used insulating gases

2018(old)

Ans. The commonly used insulating gases are

I Simple gases

Ii Oxide gases

Iii Hydrocarbon gases

Iv Electronegative gases

## **Long questions**

Q1. Write classification of insulating materials on the basis of physical and chemical structure? 2018(old)

Q2. Classify insulating materials on the basis of physical and chemical structure.

2018(old)

Q3. Write down electrical properties? 2015(S)

Q4. Write down mechanical properties?

Q5. What are the factors affecting insulation resistance? 2020(W)

# CHAPTER: 4

## DIELECTRIC MATERIALS

- Introduction
- Dielectric Constant of Permittivity
- Polarization
- Dielectric Loss
- Electric Conductivity of Dielectrics and their Break Down
- Properties of Dielectrics.
- Applications of Dielectrics

### **Introduction :-**

Insulators also known as dielectrics are very poor conductors of heat and electricity. However they allow movement of some electrons at high temperature causing a small flow of current. Dielectrics are characterized by their high specific resistance, negative temperature coefficient of resistance and large insulation resistance. The insulation resistance is affected by moisture, temperature, applied electric field and age of dielectrics. Dielectric materials may be solid, liquid or gas.

### **Dielectric constant of permittivity:-**

The dielectric constant  $\epsilon_r$  (or relative permittivity) is a measure of polarization of dielectric materials. It is the ratio of absolute permittivity  $\epsilon$  and the permittivity of free space and is given by  $\epsilon_r = \epsilon / \epsilon_0$ . Here  $\epsilon_r$  is dimensionless. The value  $\epsilon_r = 1$  for air or vacuum  $\epsilon_r > 1$  for solids, its value for diamond is 5.68, for silicon is 12, for mica is 8 and for germanium is 16. Dielectric constant is influenced by frequency of applied field and temperature.

### **Polarisation: -**

Insulating materials are subjected to different types of electric fields. These may be static field, alternating and direct current fields, impulsive and frequency switching field. Their properties are different under different field. Therefore we first need to study insulating properties of dielectrics in static field to understand polarization. The polarization is the sum of total dipole moments produced within the solid on application of electric field. It occurs because on application of an electric field to a dielectric, the positive charges are displaced towards negative end of the field while negative charges are displaced towards the positive end.

Hence local dipoles are produced in the dielectric due to this displacement. These dipoles keep their moments and are called dipole moment. Total dipole moments within the volume of a solid is called polarization P.

The electric flux density D and the electric field strength E at a point in a dielectric material are related by

$$D/E = \epsilon_0 \epsilon_r$$

$$D = \epsilon_0 \epsilon_r E \dots\dots\dots 01$$

By adding and subtracting  $\epsilon_0 E$ , we may write  $D = \epsilon_0 \epsilon_r E + \epsilon_0 E - \epsilon_0 E$

$$= \epsilon_0 E + \epsilon_0 E(\epsilon_r - 1)$$

$$= \epsilon_0 E + P \dots\dots\dots 02$$

Value of D from Eqn (1) is put in Eqn (2)

$$\epsilon_0 \epsilon_r E = \epsilon_0 E + P$$

$$P = \epsilon_0 \epsilon_r E - \epsilon_0 E$$

The polarization process is affected by time, frequency of the applied field and temperature.

### Dielectric loss :-

While calculating the dielectric losses usually only the volume leakage current is taken consideration. Of course there is loss of certain amount of power due to surface leakage current but this power is primarily dissipated as heat into the surrounding atmosphere and this loss does not influence the heating of the dielectric in most of cases. The dielectric power loss(P) may be given by  $P = 2\pi fcv^2 \tan\theta$

Where V=voltage

C=Actual capacitance of the dielectric

Tan(θ)=Dielectric loss tangent

According to the above equation, the dielectric power loss is directly proportional to the frequency. The dielectric losses are greater at a high frequency and this makes it more difficult to select insulating material for high frequency applications.

### Classification of dielectric material:-

1. Solid insulating materials: Bakelite, PVC, rubber, mica, porcelain, glass
2. Liquid insulating materials: Asphalt, transformer oil, purified water, SF6
3. Gaseous insulating materials:
  - i. Electropositive gases such as N<sub>2</sub>
  - ii. Electronegative gases such as H<sub>2</sub>
  - iii. mixture gases such as air
  - iv. Hydrocarbon gases such as CO<sub>2</sub>, SO<sub>2</sub>
  - v. Oxide gases such as CH<sub>4</sub>, C<sub>2</sub>H

### Electric conductivity Of dielectrics and their breakdown-:

The voltage per unit thickness that can be sustained by an insulating material before its breakdown is called as dielectric strength. A good insulating material possesses high dielectric strength. Dielectric breakdown occurs on account of following factors.

These are called as

- i Intrinsic(zener)breakdown
- ii Thermal breakdown
- iii Electrochemical breakdown
- iv Discharge breakdown
- v Defect breakdown

#### **Intrinsic breakdown:-**

It occurs when electrons in the valance band cross the forbidden gap under the influence of applied voltage and enter into conduction band. A large conduction current and extremely high local field is created in the process. This failure is called as zener breakdown. Intrinsic breakdown can happen at a lower voltage if impurities are present in the dielectric material.

#### **Thermal breakdown:-**

It occurs at high temperature due to poor heat dissipation and hence accumulation of non dissipated heat produced by electrical energy. Failure occurs by melting and can be avoided if heat dissipation is more than heat generation.

#### **Electrochemical breakdown:-**

It takes place when the leakage current increases due to large mobility of ions at raised temperature. The dielectrics convert into their oxides and insulating resistance decreases due to this chemical action. Breakdown of rubber is an example of this kind.

#### **Discharge breakdown:-**

It occurs due to the presence of gas bubbles in the solid and their bombardment on application of applied field. Gaseous atoms get ionized at lower potential than the solid atoms and hence cause deterioration.

#### **Defect breakdown:-**

It occurs on the surface of dielectric material due to detrimental effects of moisture on the cracks and pores. Fire proof silica, high strength mica and other chemically inert materials are used to provide good surface finish.

#### **Properties of Dielectrics:-**

Insulating materials are a very poor conductor of electric current. Dielectrics have no loosely bound electrons and so no current flows through them. When they are placed in an electric field, the positive and negative charges within the dielectrics are displaced minutely in opposite direction, which reduces the electric field within the dielectric. Example of dielectric include glass, plastics and ceramics.

#### **Applications of Dielectric:-**

The function of dielectric is to store energy. Capacitor is the most common example in which use of dielectrics is made. Depending upon the type of dielectric used, the capacitors may be grouped into following categories

1. Capacitors that use vacuum, air or other gas as dielectrics-: These capacitors are used in applications where the energy loss (in the capacitors) must be small and where the value of capacitance needed is not very large. Dielectric losses in these capacitances are very small.
2. Capacitors that use mineral oil as dielectric-: These are used in applications where a large value of capacitance is required and where a small amount of dielectric loss can be tolerated.
3. Capacitors which use a combination of solid and liquid dielectrics-  
: Oil impregnated paper dielectric is used for making capacitors of large values of small size. Such capacitors are required in the applications where precision is not so important but a high value capacitance is required. e.g. power factor correction in electric power distribution system
4. Capacitors which use solid dielectric such as glass, mica-: These are employed in laboratories as standard capacitors. Mica is commonly used as solid dielectric in making standard capacitor.  
Dielectric loss of mica is very small.

## **Short question with answer :**

### **Q1. What do you mean by dielectric constant? 2018(Old)**

Ans. Dielectric constant is the ratio of absolute permittivity  $\epsilon$  and permittivity of free space  $\epsilon_0$  and is given by  $\epsilon_r = \epsilon / \epsilon_0$

### **Q2. What is dielectric strength? 2019(S)(BP)**

Ans. The maximum voltage that can be applied to a given material without causing its breakdown usually expressed in volt or kv per unit of thickness is known as dielectric strength.

### **Q3. Write the application of dielectrics. 2018(S)**

Ans. Dielectric materials are solid. E.g. Porcelain, Mica, glass, plastic and the oxide of various metals. Some liquids and gases can serve as good dielectric material. Dry air is an excellent dielectric and is used in variable capacitor. Distilled water is a fair dielectric.

### **Q4. Which is liquid insulating material?**

Ans. Asphalt, transformer oil, purified water, Sulphur hexafluoride

### **Q5. What are the factors affecting dielectric strength of insulating material? 2020(W)**

Ans. The factors affecting dielectric strength are temperature, moisture and voltage applied

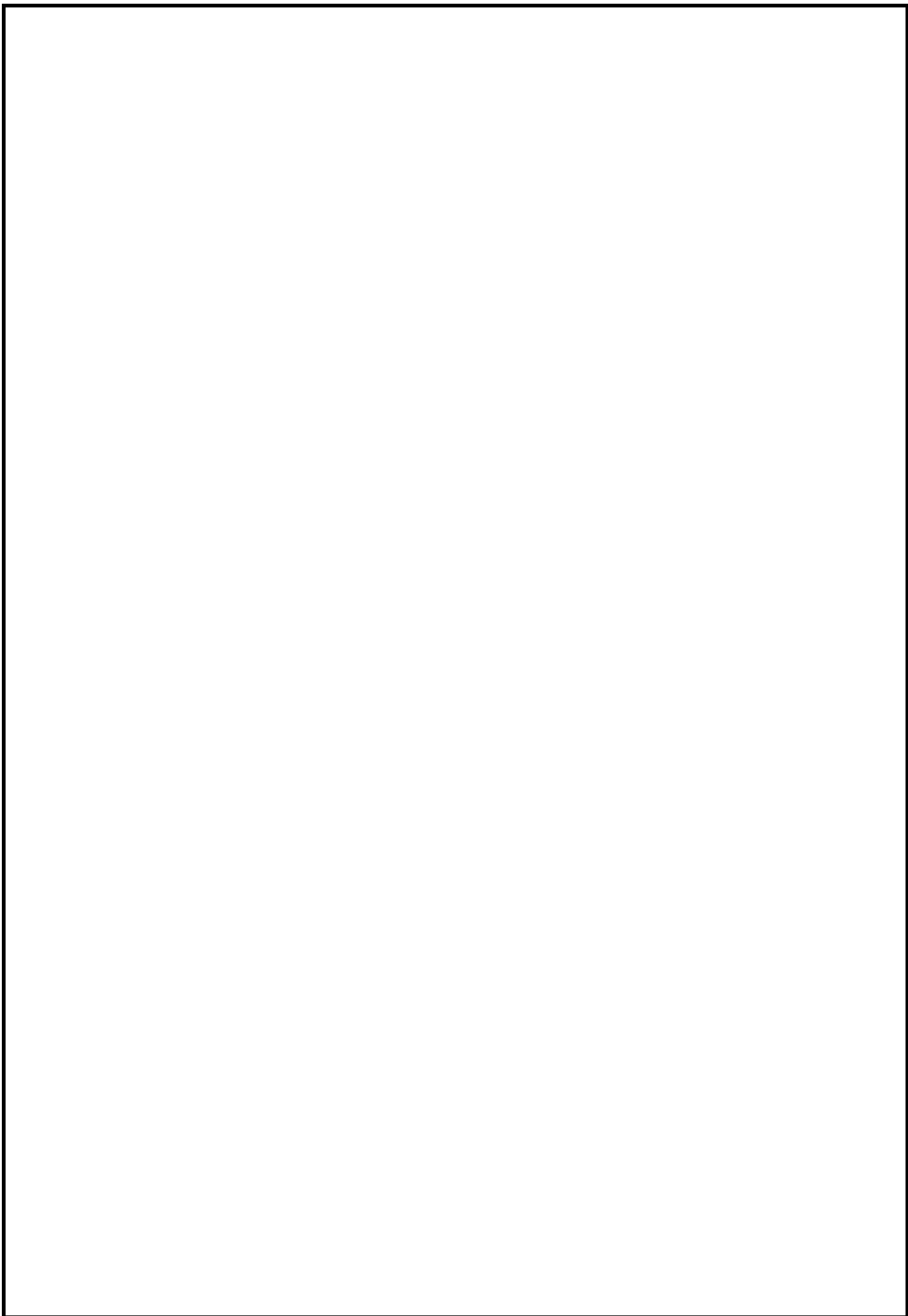
## **Long questions**

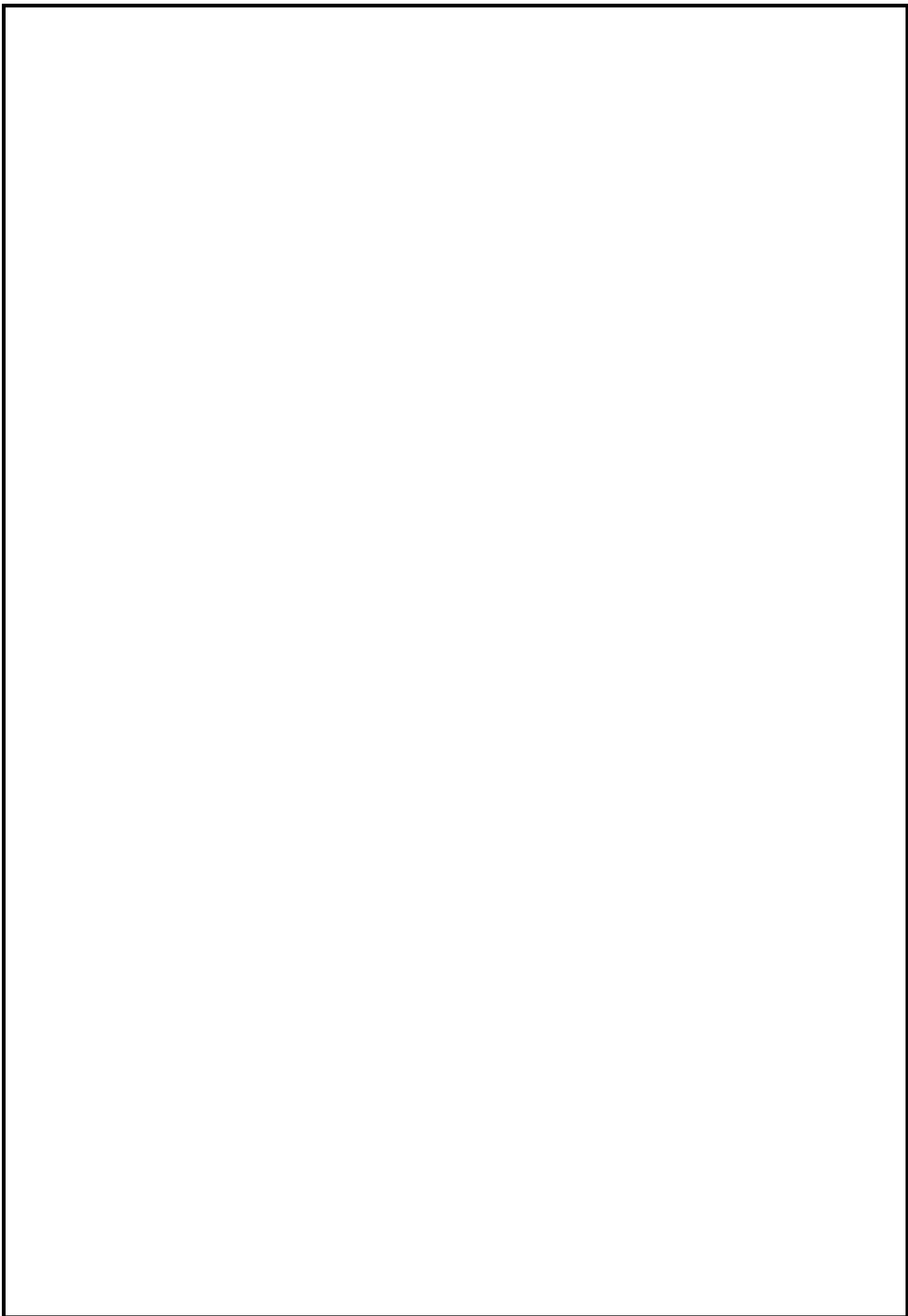
Q1. Explain polarisation? 2018(New)

Q2. Write down the electric conductivity of dielectrics and their breakdown?

Q3. Write down the application of dielectrics? 2018(Old)

Q4. Write short note on dielectric material? 2018(New)





## CHAPTER : 6

### MATERIALS FOR SPECIAL PURPOSES

Introduction  
Structural Materials  
Protective Materials  
    Lead  
    Steel tapes, wires and strip  
Other Materials  
    Thermocouple materials  
    Bimetal  
    Soldering Materials  
    Fuse and fuse materials  
    Dehydrating material

#### **Introduction:-**

The Materials used for special purpose are structural materials, protective materials, thermocouple materials, bimetal, Soldering materials, Fuse materials, dehydrating material.

#### **Structural materials:-**

Structural materials are those which are used for the construction of various structures such as poles ,towers ,supports for transformer, circuit breaker ,foundation for rotating machines like motor and generator etc. The usual structural materials used in electrical engg. Structures are wood, iron and steel, cement ,brics, mortar, concrete and reinforced cement concrete(RCC).

Factors to be considered while selecting a structural material are as follows:-

Line voltage  
Type of place and its location  
Initial cost of erection  
Costs and other problem  
Availability of materials  
Transportation facilities  
Environmental factors  
Future expansion consideration

#### **Protective materials:-**

It is of different type

- i. Corrosion protection material
- ii. Lightning protection material Fire protection
- iii. material Pipe protection materials Personal
- iv. protective material Heat protection material
- v. Eyesight protection material

#### **Lead:-**

Lead (**Pb<sub>82</sub>**) is a soft and malleable metal. Lead is used in building construction, lead acid batteries .Lead is a bright and silvery metal .Its melting point is 600.61K. Its boiling point is 2022k. It is a corrosion resistant metal. Several lead alloys are widely used. Solder, an alloy that is nearly half lead and half tin is a material with a relatively low melting point that is used to join electrical components.

## Steel tapes, Wires & Strip:-

A steel tape is a tape measure that is made of steel and is marked off in a linear scale. The scale could be in inches and or centimeters. The steel tape is used for taking measurement and it is also referred to as a tapeline.

Electrical wire is the medium through which electricity is carried to and through each individual home that uses electrical power. It is made of a metal that easily conducts electricity, usually copper, in a plastic sheath called an insulator.

- i. Residential wire colour code-Neutral
- ii. wire: white Ground wire(earth):Green

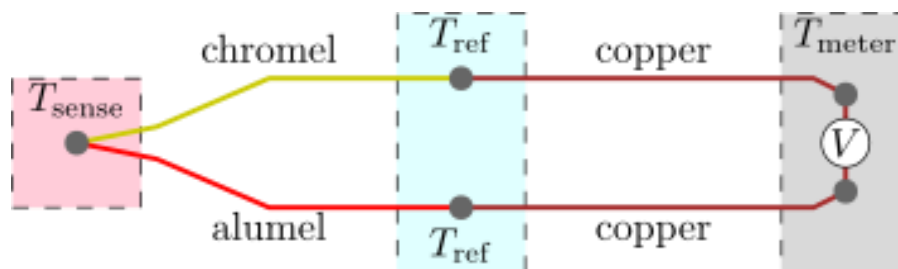
Electrical wire size is taken by considering AWG(American wire gauge).AWG uses a complex numbering pattern ranging from 40 to 0000 wherein 40 indicates the thinnest and 0000 refers to the thickest wire size. Increasing gauge numbers give decreasing wire diameter.

Strip is a long narrow piece of a material. Small no. of wires are called strip.

## Other materials:-

### Thermocouples & Thermocouple materials:-

Thermocouples are perhaps the most simple and most widely used devices for measurement of temperature .It essentially consists of two dissimilar metal wires insulated from each other but welded or brazed together at their ends forming two junctions. When heat is applied to the hot junction of two dissimilar metals, an EMF is generated which can be measured at the cold junction.



While many materials exhibit the thermoelectric effect to some degree, only a small number of pairs such as platinum-rhodium, chrome- alumel iron- constantan are in common use

### Bimetal:-

Bimetal refers to an object that is composed of two separate metals joined together. Each metal having a different coefficient of thermal expansion. Alloys of iron and nickel with low coefficient of thermal expansion are used as one element of bimetallic strip. The other element consist of materials having high value of coefficient of thermal expansion,

e.g. iron, nickel, constantan ,brass etc .Bimetals are used as relay, thermometer, switches

**Soldering materials:-** Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal(solder) into the joint. The filler metal having a lower melting point than the work piece. Soldering differs from welding in that soldering does not involve melting the work piece .In brazing the filler metal melts at a high temperature, but the work piece metal does not melt. There are two types of solder. hard solder, soft solder.

**Hard solder:-**

The tensile strength is up to  $50\text{kg/mm}^2$  and the melting point is higher than  $400^\circ\text{C}$ . Their common use is for making connection in power apparatus.

**Soft solder:-**

The tensile strength is  $5.7\text{ kg/mm}^2$  and melting point is up to  $400^\circ\text{C}$ . Tin lead or lead tin solders come in this category. It is commonly used in electronics devices for soldering electrical connections.

**Fuse & Fuse element materials:-**

A fuse is a short piece of metal, inserted in the circuit which melts when excessive current flows through it and thus break the circuit. The fuse element is generally made of materials having low melting point, high conductivity and least deterioration due to oxidation e.g. silver, copper etc. It is inserted in series with the circuit to be protected. Under normal operating condition, the fuse element is at a temperature below its melting point. Therefore it carries the normal current without overheating. However when a short circuit or overload occurs, the current through the fuse increases beyond its rated value. This raises the temperature and fuse element melts, disconnecting the circuit protected by it.

The most commonly used materials for fuse element are lead, tin, copper, zinc and silver. For small currents up to 10A, tin or an alloy of lead and tin is used for making the fuse element. For larger currents, copper or silver is employed. It is a usual practice to tin the copper to protect it from oxidation.

**Dehydratic material :-****Silica gel:-**

It is inorganic chemical, colloidal, highly absorbent silica used as a dehumidifying and dehydrating agent, as a catalyst carrier and sometimes as a catalyst.

Calcium chloride and silica gel are used in dehydrating breather to remove moisture from the air entering a transformer as it breathes. Silica gel breathers are a more recent development and are replacing the calcium chloride breathers.

Its main advantage is that when it becomes saturated with moisture it does not restrict breathing as does calcium chloride. Silica gel when dry is blue in color and the color changes to pale pink as it becomes saturated with moisture. If it is found to contain excessive moisture, it must be replaced or reconditioned.

## **Short questions with answers**

**Q1. What are the thermocouple materials? 2019(S)(new), 2019(S)BP**

Ans. The thermocouple materials in pair are copper-constantan and iron-constantan

**Q2. Which properties should a fuse material possess? 2020(W)**

Ans. The fuse material should possess high conductivity and low melting point

**Q3. What is bimetal? 2019 W/N**

Ans. Bimetal refers to an object that is composed of two separate metals joined together.

**Q4. What do you mean by soldering?**

Ans. Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal into the joint.

**Q5. State the use of steel tapes, wires and strips in electrical engg. 2018(Old)**

Ans. A steel tape is a tape measure that is made of steel and is marked off in a linear scale.

Electrical wire is the medium through which electricity is carried to and through.

Small no. of wires are called strips.

## **Long questions:**

Q1. Write down about thermocouple? W-17

Q2. Explain about the fuse materials. 2018(New)

Q3. Write about soldering materials briefly. 2020(W)

Q4. Write a short note about dielectric material. 2018(Old), 2019(S)BP

Q5. What are structural materials and what factors to be considered while selecting a structural material?