CLASS NOTES

SUBJECT - EEM (Theory)

3rd SEM

ELECTRICAL ENGG.

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Conducting material (CHAPTER-01) (8114986593)

Introduction:

* Materials which are used commercially for conducting electricity can be classed as conducting material. Conducting materials have very low values of resistivity as compared to non-conducting or insulating material.
* Conducting materials can further be subdivided into low resistivity and high resistivity material.

Properties of conductors:

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Electrical Properties:

* The conductivity must be good.
* Electrical energy displayed in the form of heat must be low.
* Resistivity must be low.
* Temperature Resistance Ratio must be low.

Mechanical Properties:

Ductility: It is that property of a material which allows it to be drawn into a wire.

Solderability: The joint should have minimum contact Resistance

Resistance to corrosion: should not get rusted when used outdoors

* With stand stress and strain
* Easy to Fabricated.

Economical factor:

* Low cost
* Easily available
* Easy to Manufacture

Resistivity :

* Resistivity or specific Resistance of a material may defined as the Resistance between the opposite face of a meter cube of that material.
* The unit of Resistivity is ohm - meter (Ωm).
* The Resistance 'R' of any given material is directly Proportional to its length 'l' and inversely Proportional to its cross- sectional area 'a'.

$$R \propto \frac{1}{a}, \quad R \propto l$$

$$\boxed{R = \rho \frac{l}{a}}$$

$$\boxed{\rho = \frac{aR}{l}}$$

where,

R = Resistance in Ω

l = length of the material in meter (m)

a = are of cross- section in m

ρ = Resistivity in (Ωm)

(2) 2

...rical conductivity (σ) :-

Electrical conductivity is a Measure of a material's ability to conduct an electric current.

* Electrical conductivity is that electrical Property of a material owing to which the electrical current flow easily through the material i.e the material Provides an easy Path for the flow of electricity through it.

* Electrical conductivity Permits the movement of electrical charge from one location to another.

2

$$\boxed{\sigma = nq\mu}$$

where,
n = no. of charge carriers of the material
q = charge carried by each charge carrier
μ = mobility of charge carrier.

* When an electrical Potential difference is Placed across a conductor, its movable charges flow, giving Rise to an electric current.

Resistivity :- (ρ)

* Resistivity is the measure of strongly an atom opposes the flow of electricity (Its the Power to Resist electricity).
* Electrical conductivity is affected by Resistivity.
* Hence, Electrical conductivity is inversely Proportional to Resistivity.
* Insulators have high Resistivity.
* Resistivity depends upon 2 factors :

- The length of the wire : The longer the wire the higher the Resistivity.
- The crossectional area of the wire : The larger the cross-sectional area the lower the Resistivity.

(3)

$$\sigma = \frac{1}{\rho}$$

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

$$\rho = \frac{1}{\sigma}$$

$$\text{Resistance} = \text{Resistivity}\left(\frac{\text{length}}{\text{area}}\right)$$

* Resistivity is expressed in <u>ohm-m</u>.
* Electrical Property of a material is its Resistivity.

Long type

* <u>Factor affecting the Resistivity</u> :-
* Following factors are affect Resistivity
    * Temperature
    * Alloying
    * Cold work
    * Age Hardening

* <u>Temperature</u> :-
* The electrical Resistance of most Metals increases with increase of Temperature, while those of semiconductors and electroly- decreases with increase of temperature.
* Many Metal have vanishing Resistivity at absolute zero temperature. This Phenomenon is known as superconducti-vity.

* <u>Alloying</u> :- (A Metal that is combination of 2 or more element)
* Alloys generally have a less Regular structure than Pure Metals.
* consequently, the electrical conductivity of a solid solution all- drops off Rapidly with increased alloy content.

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...ication of conducting materials :-

...ucting materials are classified into three categories

* Zero Resistivity material
* Low Resistivity material
* High Resistivity material

* Zero Resistivity material :-

* These material conduct electricity with zero Resistance below transition temperature.
* It is also called super conductors. 3
* There are two type
  * Type-1 super conductor
  * Type-2 super conductor
* Type-1 super conductor Examples are Pb, Al, Cr, Hg, Sn, Zn etc
* Type-2 super conductor Examples are Zr, Nb_3, Ge, $YBa_2Cu_3O_7$ etc.

* low Resistivity materials :-

* These materials have very high electrical conductivity.
* They are used as conductors in electrical devices and other aperatus.
* They are also used for transmission and distribution of electrical energy.
* Examples are : copper, silver, Gold, Aluminium, steel etc.

* High Resistivity materials :-

* These materials have high Resistivity and low temperature co-efficient of Resistance.
* These materials are used to make Resistance and heating devices Thermo-couple etc.
* They are generally alloys of metal
* Examples are Tungsten, carbon, Platinum, mercury etc.

* For an alloy (say copper), the Resistivity is expressed as,

$$\rho_{alloy} = \rho_{copper} + x \rho_i \quad \mu\text{-ohm-cm}$$

where x = Atomic Percentage of added impurity

ρ_i = Increase in Resistivity for one atomic Percent addition of impurity

* When Ni is added to copper we have

$$\rho_{Ni-cu} = (\rho_{cu} + x\, 1.3)\ \mu\text{-}\Omega\text{-cm}$$

i.e by the addition of 1% of Ni the Resistivity of cu goes up by 1.3 μ-Ω-cm.

(ρ of cu = 1.73 μ-Ω-m
ρ of zn = 6 μ-Ω-m)

* <u>cold work</u> :—

* Mechanical distortion of the crystal structure decreases the conductivity of a metal because localized strains interfere with electron movement.

* Thus hard drawn copper wire has a lower conductivity than annealed copper.

* Hard drawn copper has a Resistivity of 1.9×10^{-6} ohm-cm at 20°C where as annealed copper has a Resistivity of 1.72×10^{-6} Ω-cm at 20°c.

* <u>Age Hardening</u> :-

* Age hardening increases the Resistivity of an alloy.

...t of Temperature on Resistivity :-

...resistance of most of the conducting materials increases ...th temperature.

...he change in Resistance of a material per ohm per degree ...change in temperature is called the "temperature co-efficient of resistance" of that material.

* The Resistance of a conductor changes with temperature according to the Law :

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

where R_t = Resistance of the conductor at t degrees
R_0 = Resistance of the conductor at zero degrees
α = Temperature co-efficient of Resistance.

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* If the Resistance of the same material at any other temperature t_1 degree centigrade be R_{t_1}, the according to expression (1)

$$R_{t_1} = R_0 (1 + \alpha t_1) \quad \text{--- (2)}$$

Dividing expression (2) by expression (1)

$$\frac{R_{t_1}}{R_t} = \frac{1 + \alpha t_1}{1 + \alpha t} = \frac{1 + \alpha t + \alpha t_1 - \alpha t}{1 + \alpha t}$$ (adding and substracting αt in the Numerator)

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

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

$$R_{t_1} = R_t \left[1 + \frac{\alpha}{1 + \alpha t} (t_1 - t) \right] \quad \text{--- (3)}$$

* This means that the Resistance at any temperature t_1 degrees can be calculated if the Resistance at 't' degrees is known.

* The Relationship between temperature co-efficient of R with change in temperature can also be found out by follow

Let us assume that R_1, R_2 and R_3 be the Resistance of a conductor at t_1, t_2 Respectively then

$$R_2 = R_1 [1 + \alpha_1 (t_2 - t_1)] \quad \text{—— (4)}$$

$$R_3 = R_1 [1 + \alpha_1 (t_3 - t_1)] \quad \text{—— (5)}$$

$$= R_2 [1 + \alpha_2 (t_3 - t_1)] \quad \text{—— (6)}$$

$$\frac{R_3}{R_2} = 1 + \alpha_2 (t_3 - t_2) \quad \text{—— (7)}$$

Dividing equation (5) by (4) we get

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

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

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

$$= 1 + \frac{\alpha_1}{1 + \alpha_1 (t_2 - t_1)} \times (t_3 - t_2) \quad \text{—— (8)}$$

comparing equation (7) and (8) we get

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

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

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

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* It offers high Resistance to corrosion.
* It is ductile and malleable.
* Its electrical Resistivity is 2.669 micro ohms cm at 20°c.
* It is good conductor of heat and electricity.
* Its specific gravity is 2.7
* Its melting point is 658°c.
* It forms useful alloys with Iron, copper, zinc and other metal
* It cannot be soldered or welded easily.

Uses :-

* overhead transmission Line wires, busbar, ACSR conductor.
* well suited for cold climate.
* ACSR (The steel Reinforced aluminium conductor) is extensively being used for long span transmission Line.
* Aluminium is used in air craft industry.

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COPPER	ALUMINIUM
* Metal is costly.	* Metal is cheap
* 100 Per cent conductivity	* 75 Percent conductivity.
* Good Resistance to corrosion	* Good Resistance to corrosion.
* Heavier as compared to aluminium.	* Lighter as compared to copper.
* Good ductility and Malleability	* Good ductility and malleability
* Excellent soldering and welding capacity.	* Poor solderability and weldability
* less suited for low temperature	* well suited to cold climate.
Because of softness and flexibility It can easily be twisted Repeatedly.	* Due to brittleness, cannot be twisted.
* Very small cross-section can carry heavy current.	* 50% more cross-section carry the same current as that of copper.
* The wind Pressure and weight of Snow is less because of smaller cross-section.	* The wind Pressure and weight of snow is more because of Higher cross-section.
* The tensile strength and Permissible tension is more.	* The tensile Strength and Permissible tension is only 0.53

Low Resistivity materials and Their Application :-

Copper :-

Properties :-

* Pure copper is one of the best conductors of electricity and its conductivity is highly sensitive to impurities.
* It is Reddish - brown in colour.
* It is malleable and ductile.
* It can be welded at red heat.
* It is highly Resistant to corrosion.
* Melting Point is 1084°c.
* specific gravity of copper is 8.9.
* Electrical Resistivity is 1.682 micro ohm cm.
* Its tensile strength Varies from 3 to 4.7 tonnes/cm^2.
* It forms important alloys like bronze and gun-metal.

uses :-

* wires, cables, winding of generators and Transformers, overhead conductors, busbars.
* Hard drawn copper is used for conductors in low voltage overhead distribution Lines and busbar.
* copper conductors having a steel core are employed for Long span transmission Line.
* silver bearing copper is used for Rotor conductors of large turbo generators and commutators.

Alumunium :-

Properties :-

* Alumunium occurs in abundance on earth's surface. it is available in Various forms such as oxides, sulphates, silicate, Phospha
* It is a white metal with bluish tinge and is very light in weight. It is 3.5 times lighter than copper.

(6)

Silver :-

* Silver is a best known electrical conductor but is very costly.
* It is highly ductile and Malleable.
* It is not affected by weather changes and has a Resistivity of 1.65 $\mu\Omega$-cm.
* It is used for special contacts, high Rupturing capacity fuses, Radio frequency conducting bodies and for Leads in instrument.

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* Silver possesses the highest electrical conductivity of any metal and the highest thermal conductivity of any metal.
* Silver metal is used industrially in electrical contact and conductors, in mirror and in catalysis of chemical Reaction.
* Most silver is produced as a byproduct of copper, gold, lead and zinc Refining.
* Many medical antimicrobial uses of silver have been supplanted by antibiotics.

Gold :-

* Gold is the most Malleable of all metals.
* Gold leaf can be beaten thin enough to become transparent.
* Gold Readily dissolves in mercury at room temperature to form amalgam and forms alloys with many other metals at high temperature.
* These alloys can be produced to modify the hardness and other metallurgical properties to control melting point.
* Gold is a good conductor of heat and electricity and Reflects infrared Radiation strongly.

Steel :-

* Steel is not very often used as a conducting material because of its low electrical conductivity.
* Steel is employed as conductor Rail in traction on account of its cheapness and Rigidity.
* For wire, Steel with 0.1 to 0.15 % carbon is used.
* When alternating current flows in steel wires, its Resistivity and losses are much higher than when D.C current flows, due to magnetic Properties of steel.
* Steel is easily corroded by moisture and heat.
* Overhead steel conductors are galvanized to Prevent corrosion.
* Galvanised steel and iron wires are generally used for earth conductor in low voltage distribution system.
* Steel alloyed with chromium and aluminium is used for making starter rheostats, where ~~lightness~~
* Steel overhead conductors, due to less electrical conductivity are used only to transfer small amounts of Power.
* Steel Reinforced aluminium conductor gives high tensile strength to overhead lines.

characteristics	copper	Aluminium	Steel
* Density at 20°c - g/cm³	8.94	2.703	7.8
* Electrical Resistivity	17.2	28.3	107 - 200
* Thermal conductivity W/m-K	397	240	
* Temperature Co-efficient of Resistivity °c⁻¹	0.0039	0.0039	0.006 - 0.0036

* ~~Strand~~ Standard Stranding consists of 6 wires around 1 wire, then 12 wires around the Previous 6, then 18 wires around the 12, then 24 wires around the 18 and so on.

* The number of Layers to be Provided will depend upon the number of wires to be Provided. Central wire is not counted as a Layer.

* If 3 Stranded wires are Put in the centre, 9 wires will be in the first Layer, then 15 wires in the Second Layer and so on.

* Stranded conductors are expressed as:

7/2.24, 19/2.50, 37/2.06, 61/2.50 etc.

* The first number i.e 7, 19, 37, 61, etc indicate the total number of wires in the Stranded conductor.

* The Second number i.e 2.24, 2.50, 2.06, 2.59 etc. Represent the diameter of each wire in millimeters.

* A 37/2.06 Stranded conductor has 1 wire at the centre, 6 wires in first Layer, 12 wires in second Layers and 18 wires in the third Layer. Therefore total number of layers $n = 3$.

Total number of wires = $1 + 3n(1+n)$

$$= 1 + 3 \times 3 (1+3)$$
$$= 37$$

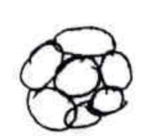
Overall diameter $= (1+2n)d = (1+2\times3) \times 2.06\ mm = 14.42\ mm$.

(1-6-12)

(Cross section of a 19 wire stranded circular conductor Having 1 wire at centre, 6 wires in 1st Layer and 12 wires in the 2nd Layer)

A Stranded circular conductor showing How wires are twisted together.

Circular Stranded conductor



Compact circular Stranded conductor

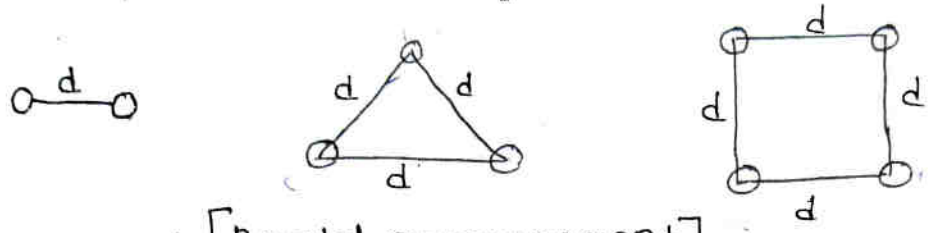
* Gold is use in coins and Jewelery and as a Protective coating on other more Reactive metals.
* Gold is almost insoluble.
* Gold ions in solution are Readily Reduced and Precipitated as metal by adding any other metal as the Reducing agent.
* Gold has been widely used throughout the world as money, for efficient indirect exchange Purpose.
* The Gold content of alloys is measured in carats (K).
* Pure Gold is designated as 24K.
* Gold has long been considered the most desirable of Precious metals and its value has standard for many currencies.

imp
Stranded conductor :-

* When a single conductor of large cross-section is used, and is liable to kinks it becomes rigid in construction and breaks while handling.
* To avoid this, conductors are made of a number of thin wires, bunched together, called strands.
* Stranding makes the conductor Flexible and eliminates to a large extent the risk of its breaking through the Insulation.
* A stranded conductor is made by twisting the wires (strands) together to form layers.
* Stranding is done in opposite direction for successive layers.
* This means, if the wires of one layer are twisted in left-hand direction, the next layer of the wires will be twisted in the Right hand direction and so on.

Bundle conductors :-

* It is defined as the arrangement of a group of conductors in which distance between any two consecutive conductors are same.



[Bundel arrangement]

* A bundel conductor is a conductor made up of two or more ("sub conductors") and is used as one phase conductor.
* Bundle conductors are also called duplex, triplex etc.
* Bundle conductors is a number of conductors in parallel.
* Bundle conductors are used to increase the amount of current in a line. bundle conductors may carry more current for a given weight.

Advantages of bundle conductors :-

* Reduction of corona loss and audible noise in case of Extra high voltage (EHV).
* Reduction of High-voltage gradient at the conductor in EHV.
* Reduction of the Reactance so power transfer will be more.
* If number of conductors in a bundle is increased, then corona loss and Reactance will be Reduced.

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Low Resistivity copper alloys :-

* Copper become mechanically hard when it is drawn. hardening of copper can also be done by allowing with other metal.
  * Brass
  * Bronze
  * Beryllium copper alloy

Brass :-

* When copper is alloyed with zinc (60% copper, 40% zinc), it is called Brass.
* Brass has high tensile strength but has lower conductivity than copper.
* It is weldable and solderable and is fairly resistance to corrosion.
* Due to these reasons Brass has gained wide application as a current carrying and structural material in plug-points, socket-outlets, switches, fuse holders, sliding contacts for starters and Rheostats etc.

Bronze :- copper when alloyed with tin (8% to 16%) and a very small percentage of a 3rd element cadmium, Beryllium, Phosphorous, silicon etc. is called Bronze.

* When the third element is Phosphorous, the alloy is called phosphor bronze. if the 3rd element is silicon, the alloy called silicon bronze.
* All bronzes posses high mechanical strength as compared to copper but have lower conductivity.
* Bronzes are more free from corrosion than brases.
* cadmium bronze is used for contacting conductor and commutator segments.
* Beryllium bronze is used for making current carrying springs, sliding contacts, knife switch blades etc.

Beryllium copper alloy :-

* The copper alloy containing beryllium is also called Bronze.
* It has high conductivity and mechanical strength.
* Its hardening and elasticity property can be changed by giving appropriate heat treatment.
* It is used for making current carrying springs, brush holders, bellows, coil springs, sliding contacts and knife switch blades.

Superconductivity :-

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* A state of material in which it has zero resistivity is called superconductivity.
* For example, Mercury becomes superconducting at approximately 4.5 kelvin (−268.5° C).
* Superconductivity was discovered by Professor Heike Kamerlingh Onnes.
* There are two types of superconductors known as
    * Type-1 superconductors
    * Type-2 superconductors

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Type-1 superconductor :-

* Type-1 superconductors are soft superconductors.
* They are usually pure specimens of some elemental metals.
* These are very little use in technical application
* Ex:- Pb, Al, Cr, Hg, Sn, Zn etc.

Type-2 superconductor :-

* Type-2 superconductors are hard superconductors,
* They are usually alloys of metals with high value of resistivity in normal state.
* These are very useful as compared to type-1 material
* Ex :- Nb_3, Ge, YBa_2, Cu_3O_7 etc.

* Superconducting material :-

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: Many metals and compounds have superconducting property at very low temperature.

* Superconductivity has been observed to occur in poorer metallic conductors such as tin, lead and tantalum.
* Superconductors may not only be pure metals but also various ~~metals~~ alloys and chemical compounds.
* The highest temperature at which superconductivity has been observed to occur is 20 K (−253°C) for a compound consisting of Niobium, Aluminium and Germanium.

Application of Superconductor Materials :-

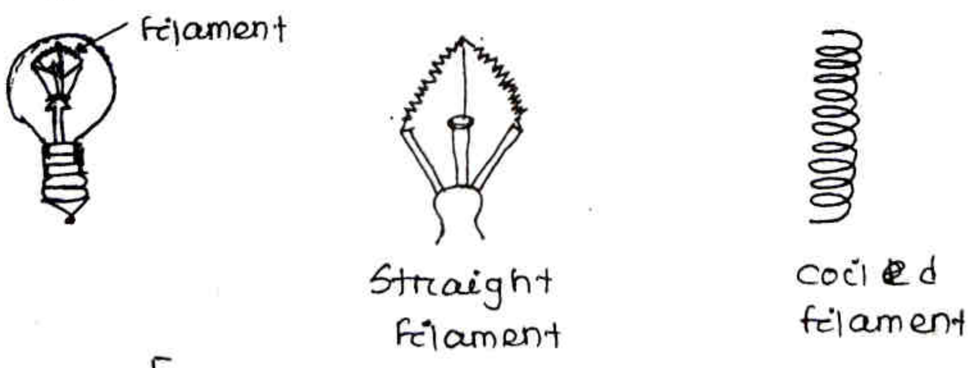
* Electrical machines :- Efforts are being made at present to develop electrical machines and Transformers utilizing superconductivity.
* It is used in Generator and motor.
* Power cables :- Superconducting materials if used for power cables will enable transmission of power over very long distances using a diameter of a few centimetres without any significant power loss or drop in voltage.
* Electromagnets :- Superconducting Solenoids which do not produce any heat during operations have been produced.
* Superconductivity can be destroyed if the magnetic field exceeds a critical value.
* Design electromagnets using superconductivity for use in Laboratories and for low temperature device like the maser.
* Future Prospects :-
* Cryogenics technology has been developed to tackle the conductor has to be kept at near 0°K.
* Helium is used to achieve Low temperature Required for superconductivity.
* Superconducting materials are used as electronic switching devices called cryotrons.

High Resistivity Materials and Their application :-

* High Resistivity Materials are
  * Tungsten
  * carbon
  * Platinum
  * Mercury

* Tungsten :-

* It is very hard metal. Resistivity of tungsten is about twice that of aluminium.
* Its Melting point is the highest of all metals (3300°c). It can be drawn into very thin wires Required for making filaments.
* It has very high tensile strength. 10
* Tungsten is very commonly used in incandescent Lamps, as heater in electron tubes etc.
* It oxidises quickly in the presence of oxygen even at a temperature of few hundred degree centigrade, but in the atmosphere of an inert gas like nitrogen or organ, or in vaccum, it will Reliably work upto 200°c.
* when ~~the~~ tungsten is used as filament in incandescent Lamps, in ~~straight, coiled~~. The filament is made in Straight, coiled or coiled-coil form.



[Incandescent Lamp having tungsten filament]

* Tungsten is used in Radars and as grids of electronic Valves
* It is used for sparking and contact Points.

Carbon :-

* Carbon materials used in the field of electrical engineering are manufactured from graphite and other forms of carbon like coal etc.

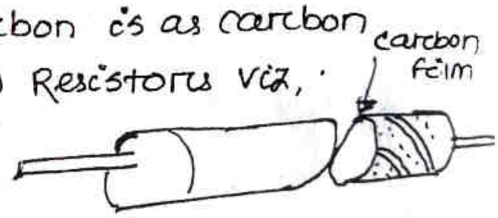
* Graphite occurs in nature as a mineral with high content of carbon (upto 90% or more).

* Carbon has very high value of Resistivity, negative temperature co-efficient of Resistance, Pressure sensitive and low surface friction.

* Carbon is used in applications like brushes for electrical machines and apparatus, electrodes for electric-arc furnaces, carbon pile Resistance, non-wire Resistors, and other components for telecommunication equipments, battery cell, arc lamps, arc welding etc.

* An important Application of carbon is as Carbon brushes for electrical machines and apparatus.

* Another important application of carbon is as carbon Resistors. There are two types of carbon Resistors viz,
    * Film type
    * Solid type.



(Film type carbon Resistor)

* Film type carbon consist of a thin Layer of carbon deposited on the surface of ceramic rod.

* A solid type carbon Resistor consists of a solid rod of special material composed of carbon and binding agent.

* Carbon does not weld to metals.

* Carbon is used in automatic Voltage Regulator for making the Pressure Sensitive Pile Resistor.

Platinum :—

- Platinum is greyish white metal which is non-corroding. It is malleable and ductile and is Resistant to most chemicals.
* Platinum is a heavy metal having specific weight of 21.4 gm/cm². Its melting point is 1775°c. The Resistivity of Platinum is 0.1 × 10⁻⁶ ohm-meter.
- Platinum can be drawn into thin wires and strips. It does not oxidize in air and has no tendency to arc.
- Platinum ~~can be drawn into thin wires~~ finds application as a heating element in Laboratory ovens and furnaces.
- Platinum is also used as electrical contact material and as material for grids in special Purpose Vacuum tubes.
* Platinum-rhodium thermocouple is used for Measurement of temperature upto 1600°c.
* Platinum being highly Resistance to corrosion and having a high melting Point is often used for making Lightly loaded contacts (current not exceeding 1A).

Mercury :-

- Mercury is a heavy silver white metal. It is only metal which is Liquid at Room temperature.
* Its specific weight is 13.55 gm/cm².
* Its boiling Point is 357°c. its Resistivity and temp. co-efficient of Resistance 0.95 × 10⁻⁶ Ω-m and 0.00027 Per degree c.
* Mercury is Poisonous.
* In the field of electrical engineering mercury finds application in mercury arc Rectifier, gas filled tubes, as Liquid contact material in electrical switches etc.
* Mercury being used for making and breaking contact in Buchholz Relay used for transformer Protection.

OMM SAI BABA

CHAPTER-02

Semiconducting Materials :-

: Semiconductors are a group of materials having electrical conductivities intermediate between metals and insulators.

* The most basic semiconductor device is a P-n junction diode.

: More complex devices based on semiconductors includes bipolar transistor, field-effect transistors, opto electronic device and others.

* Semiconductors are used in integrated circuits which allow integration of complex circuit consisting of many thousands of transistor, diodes, Resistors and capacitors to be included in a chip of semiconductor.

* Semiconductors are also the building blocks of Power electronic devices.

* Examples of elements which are semiconductors are B, C, Si, Ge, Sn, P, As, Sb, Bi, S, Se, Te and Iodine.

Semiconductor :-

: A semiconductor is neither a good conductor nor a good insulator.

: Typical semiconductor materials are Germanium and silicon each of which have 4 valence electrons.

* Semiconductor become better conductors as the temperature is Raised.

* Semiconductors can support internal electrical fields.

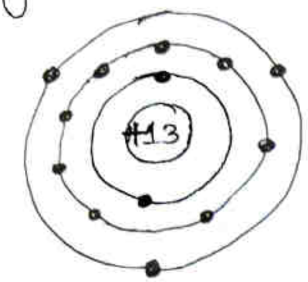
* These materials are generally hard and brittle.

* Semiconductors are expensive materials.

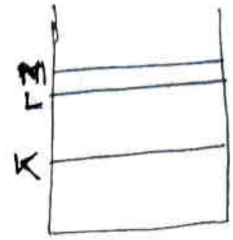
* Semiconductors are non-linear Resistors.

Electron energy and Energy band Theory ÷

* Figure shows the Bohr model of an aluminium atom.

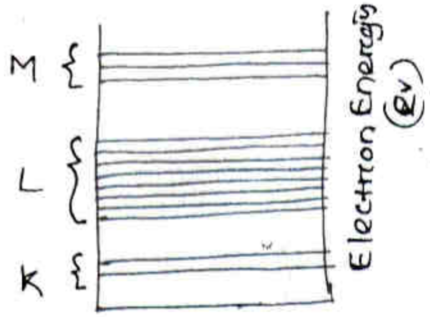


(a) The Bohr model of An Aluminium atom



(b) Simplified Energy Level Representation of the Shells

* An electron Revolving around the nucleus of an atom has Potential energy, centrifugal energy, Rotational energy and magnetic energy, all of which together determine the total energy or the energy level of an electron.
* This value is measure is electron Volts, (eV).
* The Larger the orbit in which an electron Revolves, the greater is its energy.
* Electrons with least energy are on the K Level i.e the orbit closest to the nucleus.
* Each succeeding level contains electrons with higher energies.
* If we consider an individual atom then all the atoms in a given level shall possess the same energy as shown in figure (b). 2
* The nuclei of neighbouring atoms exert forces of attractions of varying degrees on each other's electron.
* So, no two electrons share exactly the same orbit, and Therefore, the energy of no two electrons is the same.
* Each level or shell is therefore, divided into subshells, each subshell having a different energy level.

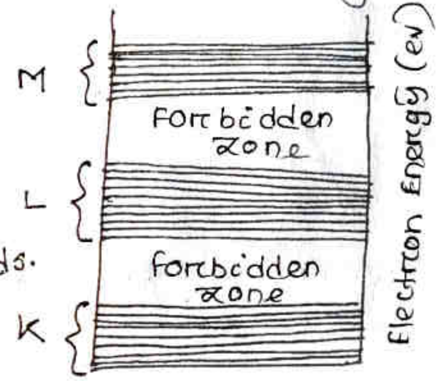


(Energy levels of a Typical Atom)

* Figure Represents the actual energy levels of an aluminium atom.

* Each electron now occupies an energy level different from that of any other.

* In this figure the energy levels have been grouped into energy bands.



[Energy levels Grouped as Bands]

* Figure shows a more general method of Representing energy bands.

* The areas between them are called energy gaps; They are also called forbidden Zones,

* since no electron can have an energy Represented by These area.

3

Excitation of Atoms :-

: When each electron in an atom is in its normal orbit, the atom is said to be in an unexcited state.

* To move an electron further away from the nucleus Requires additional energy.

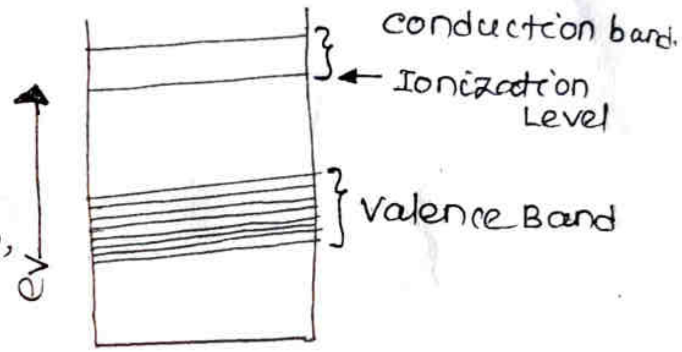
* The additional energy can be obtained from any of the following sources i.e heat, Light, Electrostatic, Magnetic, Kinetic etc.

if a Required amount of heat energy is absorbed by electron, it will jump to a higher energy level.

* When the <u>electron</u> is in the <u>higher energy</u> level, the atom is said to be in an <u>Excited state</u>.

* The quantum of energy, in electron volts, Required to move an electron ~~it will jump to a higher energy level~~. from one energy level to a higher energy level varies from material to material.

* When the Required amount of light or heat energy is absorbed by a Valence electron, it will leave the Valence band and may move up to the Ionization level.



(Energy Band Representation of Ionization)

* If it does, it is Released from the attractive forces of the Nucleus.

* The it is free to Float around between the atoms and to conduct.

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* The electron above the ionization level is said to be in the conduction band and is called a free electron.

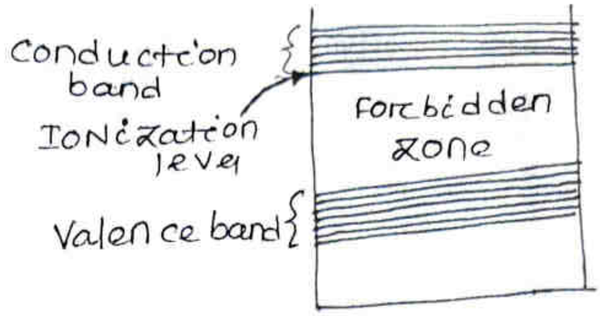
* The word "ionization level" is used because when an electron leaves the Valence band, the Remaining atom is no ~~atom~~ longer Neutral but has a Positive charge and is called a Positive ion.

* The atom is said to be ionized.

Insulators, Semiconductors and Conductors :-

Insulator :-

* Figure shows the ionization level of an insulator.



(Insulator)

* The forbidden zone between the valence band and conduction band is quite large.
* This indicates that electrons in the valence band require large amount of additional energy to move up and become free.
* Valence electrons are unable to move up to the conduction band, there can be no electron flow.

Semiconductor :-

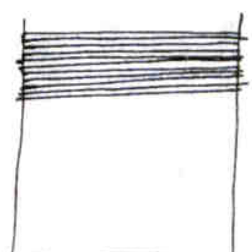
* Figure show, in case of semiconductors, the forbidden zone is reduced.

(Semiconductor)

* Thus the valence electrons require less energy to free themselves from the attraction of the nucleus.

Conductor :-

* Figure shows that in a conductor there is no gap between the valence band and conduction band.



(Conductor)

* Here conduction and valence bands may even overlap.
* Electrons from the valence ring may be moved into the conduction zone by a small amount of energy thus becoming free.
* By applying a voltage across such a material a large flow of electrons will result.

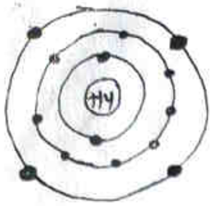
* In an insulator, the valence electrons are tightly bound to the nucleus of the atom. They can be freed to move up to the conduction band.
* But it require large amount of energy.
* Ambient room temperatures cannot free the valence electrons in an insulator.

* In a conductor, such as copper or aluminium, the valence electrons are very loosely bound to the nucleus.
* Their high energy level places them very close to the ionization level and thus very close to the conduction band.
* There are free electrons and positive ions, the materials in this case copper or aluminium, remains neutral because it still has an equal number of protons and electrons

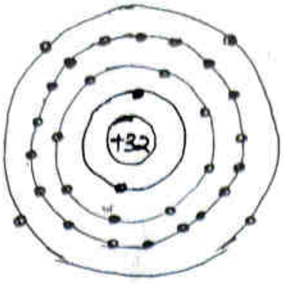
Semiconductor Materials :- 6

* The electrical characteristics of semiconductor materials fall between those of insulator and conductors.

* The two most widely used semiconductor materials are silicon (si) and Germanium (Ge).



[Si]



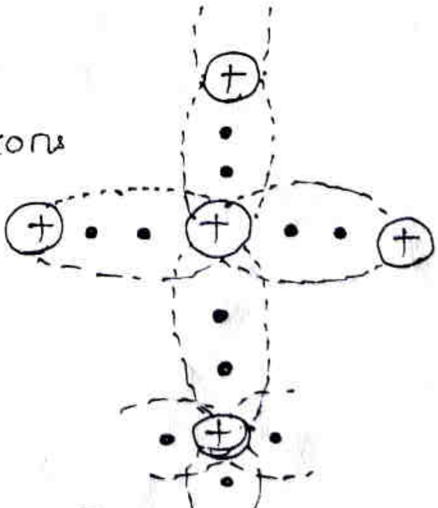
[Ge]

[Simplified Si and Ge Atom]

* In the Silicon atom K and L shells are full but M shell contains only four electrons.
* According to $2n^2$ formula, the M shell can contain 18 electrons however, the M shell in silicon is the valence shell thus can never contain more than Eight electrons.
* In the Germanium atom the K, L, and M shells are filled and the N shell is the valency shell containing four electrons.
* Since the valence electrons only are important from the chemical and electrical point of view.

COVALENT BONDS:-

* A covalent bond Results from sharing of pairs of valence electrons by two or more atoms.
* The atoms of materials having 4 or more than 4 electrons revolving in their outermost orbits must share their electrons with the Neighbouring atom.



[Sets of covalent or sharing]

* Figure show covalent bonding which hold atoms in place. Each bond with two electrons in an electron pair bond.
* When atoms enter into covalent bonding, each atom in effect has eight valence electrons and this it would appear, would result in making such a material a good insulator.
* A good insulator must have a perfect crystal structure. covalent bonding leads to the development of a polycrystal i.e several individual crystals held together imperfectly.
* The extra atoms are not properly locked in place and there are missing atoms in some parts of the structure.
* Due to impurity there may be extra electrons which cannot lock into the covalent bond structure.
* As a result of the above reasons, the material does not have a perfect crystal structure and is therefore, not a good insulator but a poor insulator or what is usually called semiconductor.

imp

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Intrinsic Semiconductor :-

* If a crystal (silicon or Germanium) does not contain any impurity atoms i.e if, it contains only one type of atoms, it is called an intrinsic material.
* If its temperature is brought down to 0k (-273°C) this intrinsic material will act as a good insulator and very little current will flow through it.
* When an electron is freed from the atom of an intrinsic material it breaks a covalent bond and leaves behind a vacancy (called a hole).

* The free electron and the hole form an electron-hole Pair.
* Higher the temperature, the greater the thermal agitation giving rise to more electron-hole Pair.

* A hole in effect means the loss of an electron and is therefore considered to be positively charged.

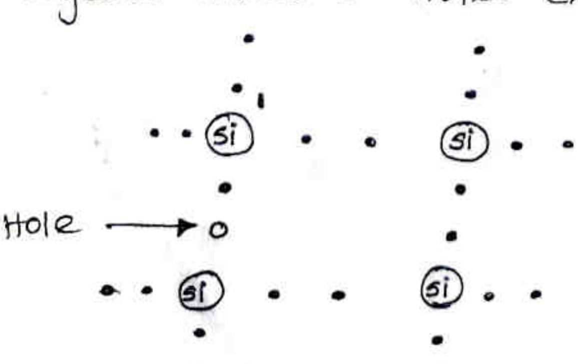
* when a Voltage is applied to an intrinsic material at a temperature above 0°K, it acts as conductor.

* The higher the temperature, the more the free electrons and therefore better conduction.

* The free electrons drift from negative terminal of the Voltage source, through the semiconductor, to the +ve terminal of the Voltage source.

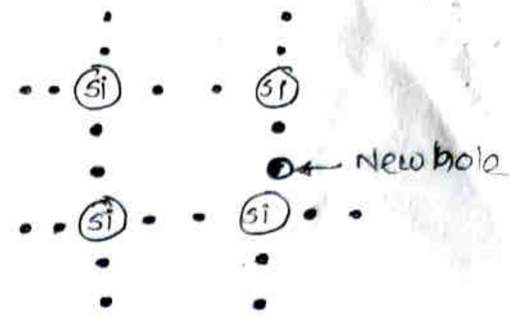
* The holes created by the free electrons are fixed in the atomic structure and do not actually move.
* They appear to move from the +ve to the -ve terminal
* This is because when a hole is created by an electron breaking a covalent bond due to thermal energy a valence electron from a neighbouring atom may have just enough energy to break its bond and jump over into this hole, thereby creating a new hole.

* hole has moved from one atom to another.
: figure shows a holes existing in the silicon atom.



* Here No other holes are Present.

* figure show, a valence electron from the silicon atom has broken its bond and jumped over to fill the original hole, leaving behind a hole in its atom.



* Thus the hole has jumped from one silicon atom to another.
* This movement of holes, which are positively charged, constitutes a current flow.
* current flow in a semiconductor is therefore, composed of free electron movement and hole movement.

* If a voltage is applied to a semiconductor containing free electrons and holes, current consisting of two parts will flow: free electrons moving in one direction and holes moving in opposite direction.
* The total current is the sum of the two parts.
* Intrinsic semiconductors have -ve temperature coefficient.

Extrinsic Semiconductor :-

* The material may function properly as a semi-conductor we must add certain impurity.
* The addition of impurities is called doping.
* A material which has been doped (i.e impurities are added) is called an extrinsic material.

* Extrinsic semiconductors are of two type viz
  * N-type
  * P-type.

N-type material :-

* It is formed by adding Penta Valent impurity to intrinsic semiconductor.

* Pentavalent impurity are phosphorus (P), antimony (Sb) Arsenic (As) etc.

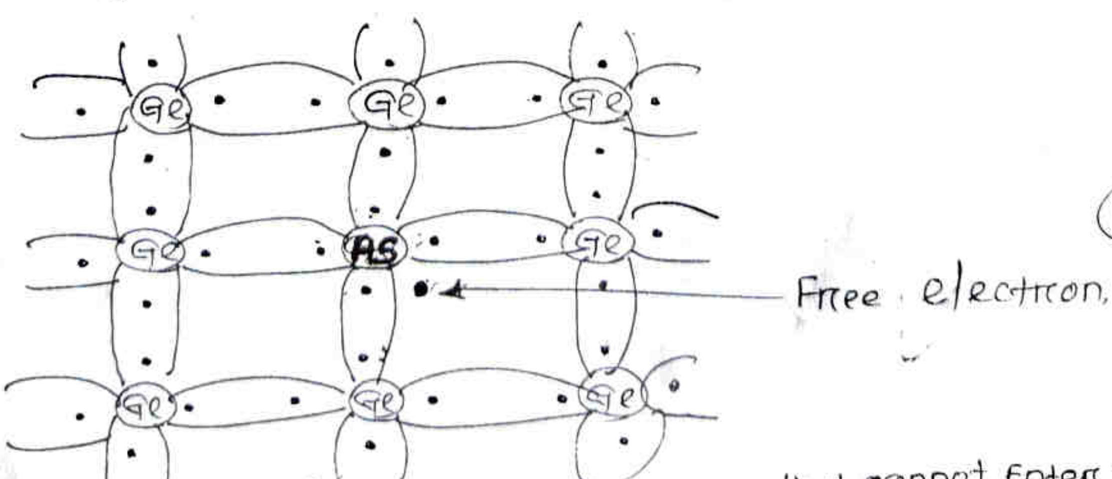
* When pentavalent impurity is added to an intrinsic material, only Four of its Valence electrons Lock into the covalent bond formation of the atomic structure.

* The fifth valence electron of the impurity atom is free.

: Since Pentavalent atoms Provide (or donate) an extra electron, they are called donor impurities.

* A material doped with a donor impurity has excess of electrons in its structure and is therefore known as Negative or N-type material.

* Here majority are electron and minority are holes.
* It has comparatively better conductivity.
* As majority carrier are -vely charged, so it is n-type.



[Arsenic impurity Atom Provides a fifth electron that cannot Enter the covalent bond structure]

P-type material :-

* It is formed by adding trivalent impurity to intrinsic semiconductor.

* The trivalent impurity has three valence electron and its examples are Aluminium (Al), Gallium (Ga), indium (In) etc.

* When trivalent impurity is added, all three electrons take part in bonding, but 4th bond remain incomplete. To complete the bond, an electron is borrowed from neighbour, creating a hole.

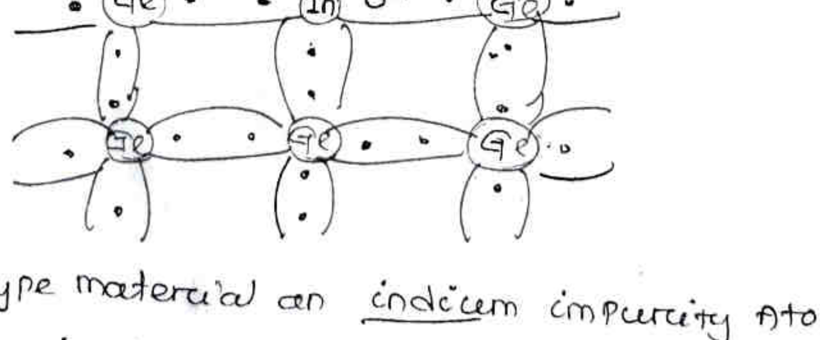
* Here majority carrier are hole and minority carrier electrons.

* As majority carriers are produced by accepting an electron, so the impurity is also known as acceptor type impurity,

* It has comparatively less conductivity.

* As majority carrier +vely charged, it is called P-type material.

*



In P-type material an indium impurity Atom creates a hole in the covalent bond structure to provide an attraction for an electron

Majority and minority carriers :

* if the number of free electrons is large they are called majority carriers
* If holes being small in number are called minority carriers.

* In N-type
* electron = Majority carrier
* hole = Minority carrier.

* In P-type
* Hole = Majority carrier
* electron = Minority carrier.

Semiconductor materials :-

Semiconductor materials are Boron, carbon, silicon, Germanium, Phosphorus, Arsenic, Antimony, sulphur, selenium, Tellurium, Iodine etc.

* The Resistance of semiconductor materials can also be controlled by the following factors;
  * illumination
  * voltage
  * electric field.

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semiconductor can be classified as :-

* mono-crystals with an atomic Lattic structure Like Carbon, silicon, germanium and Poly-crystals with molecular lattic structure like selenium, tellurium, antimony, arsenic et.
* oxides of such metals as copper, zinc, cadmium, titanium, molybdenum, tungsten.

* Sulphides, selenides and tellurides of lead, copper, cadmium
* chemical compounds of certain element of third group like aluminium, gallium, indium and fifth group Like Phosphorus, antimony, arsenic.

V.V.IMP

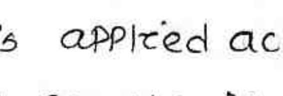
Applications of Semiconductor materials :-

RECTIFIERS :- * Germanium and Silicon Rectifiers
* Copper-oxide and Selenium Rectifier.

* Germanium and Silicon Rectifiers :-

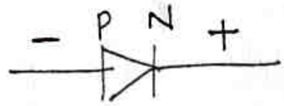
* A P-type and N-type material are joined together to form a junction called P-N Junction.

* When an external voltage is applied across the two materials a flow of current results if the positive and negative terminals of the voltage source are connected respectively to the extreme end of the P-type and N-mate[rial]. Voltage applied in this way is called forward baising the P-N Junction.



(forward biasing) 14

* If the applied voltage is reverse i.e the positive of the supply voltage is connected to N-side and the -ve supply voltage is connected to P-side, there is no flow of currend. This is called Reverse biasing



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(Reverse biasing)

* Thus, the P-N Junction offers high conductivity when forward biased and no conductivity when Reverse biased.

* P-N Junction Rectifiers use germanium or silicon as the semiconductor material.

* Germanium Rectifiers were invented earlier than silicon Rectifier.

* In heavy current application silicon Rectifiers find wider industrial app[lication]

* Germanium and silicon semiconductors find wide use in both high frequency and supply frequency ckt particularly as (8) Non-controlled Rectifiers (e.g diode) and controlled Rectifiers (e.g transistor and silicon controlled Rectifier).

Germanium and silicon Rectifiers can operates at high current densities and Reverse voltages with efficiency of about 98%..

Silicon Rectifiers can operate at temperatures upto 200°c. silicon diodes have an advantages over germanium diodes in high frequency electronic circuits as they are more sensitive to weak signal.

A silicon controlled Rectifier (SCR) is the combination of two transistors one n-p-n type and other p-n-p type.

* Silicon Rectifiers are available for very high PIV Rating, of the order of 25 KV and current Rating of the order of 1000 amps. but frequency Response is poor.

* silicon Rectifier are normally used in Power Rectifying devices.

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Copper-oxide and Selenium Rectifiers :-

* copper oxide Rectifier is a plate of 99.98% pure copper on which a film of cuprous oxide is produced by a special process.

* one side of the plate is cleaned of cuprous oxide and an electrode is soldered directly to the copper.

* The second electrode is soldered to the cuprous oxide film.

* when +ve potential is applied to the oxide layer and

and -ve to the copper, it corresponding to forward biasing a P-N Junction.

* copper oxide Rectifiers are available for low PIV and Current Rating.

* Here Frequency Response is better.

* copper-oxide Rectifier are comparatively cheaper than silica Rectifiers.

* They are used in Rectifiers type instruments as in electronic multimeter.

* Selenium Rectifiers use more than 99.99% Pure selenium.

* The Selenium Rectifiers has a greater Permissible current density and a wider working temperature Range as compared to copper oxide Rectifier.

* selenium Rectifiers find application in battery charges and electroplating supplies.

* crystalline selenium which has a melting point of 220°c is used for making Rectifiers.

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* Both copper oxide and selenium Rectifiers are Protected against moisture by giving their elements a coating of insulating Varnish.

* copper oxide Rectifiers are sealed in hermatic container for this Purpose.

* copper oxide Rectifiers completely fail at high Reverse Voltage

* selenium Rectifiers sometimes self seal, if breakdown occurs at high Reverse Voltage, by fusion into the amorphous form of selenium which is an insulator.

Temperature-Sensitive Resisters or Thermister :-

* Increasing the temperature of semiconductor materials cause their resistance to decrease.
* This Property has found application in devices called thermister
* Thermisters are thermally Sensitive Resistors.
* They are made from oxides of certain metal such as copper, manganese, cobalt, iron, zinc.
* Thermisters find application in temperature measurement and control.
* They sense temperature Variations and convert these Variation into electrical signal which is then used to control heating device.
* other applications of thermisters include measurement of Radio frequency, Power, Voltage Regulation, timing and delay ckt

Photoconductive cells :-

* The Resistance of semiconductor material is low under Light and increases in darkness.
* This Phenomenon is used in Photoconductive cells where a Semiconductor material is connected in series with a voltage source.

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* The Resistance of the Semiconductor varies with the intensity of Light and thus the current in the circuit is controlled.
* Application of Photoconductive cells are door openers, burglar alarms, Flame detectors, Smoke detectors and control for Street Lights.

Photovoltaic cells :-

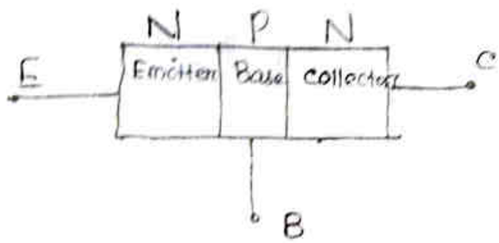
* Photovoltaic cells are devices that develop an e.m.F when illuminated.
* Thus They convert Light energy directly into electrical energy
* No outside source of electrical energy is Required to Produce current

Varistors :-

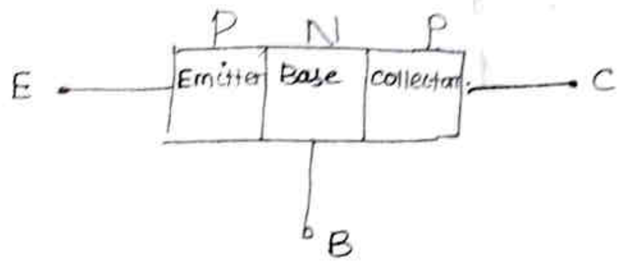
* The resistance of semiconductors varies with the applied voltage.
* This property is used in devices called Varistors.
* Use of Varistors is made in voltage stabilizers and motor speed control.

Transistors :-

* The current in a semiconductor does not follow ohms law and increases far more rapidly than the voltage. This property has been used in the device called transistor.
* A Transistor is a two junction three terminal device.
* The two junctions being formed by joining P, N and P materials or N, P and N materials.



[NPN Transistor]



[PNP transistor]

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Hall Effect Generators :-

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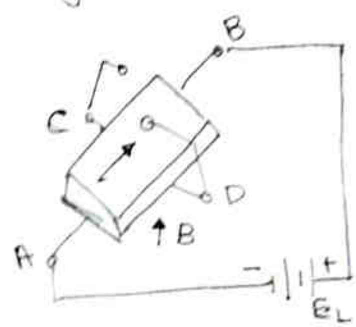
* When a current flows through a semiconductor bar placed in a magnetic field, a voltage is developed at right angle to both the current and the magnetic field.
* This voltage is proportional to the current and the intensity of the magnetic field. This is called Hall effect.



(50)

...nsider the semiconductor bar shown in figure, which has contacts on all four sides. (10)

If a voltage E_L is applied across the two opposite contacts and B a current will flow.

if the bar is placed perpendicular to a magnetic field B, as shown in figure, an electric potential E_H is generated between the other two contacts C and D.

This voltage E_H is a direct measure of the magnetic field strength and can be detected with a voltmeter.

The Hall effect generator may be used to measure magnetic field.

It is capable of measuring magnetic field strength that have a strength 10^{-6} of that of the magnetic field of the earth.

Strain gauges :-

Silicon and other semiconductor material make very sensitive strain gauges which are devices used to measure small changes in the lengths of solid objects.

Strain gauges are used to test the tensile strength of materials and determining the change in the length of structures.

The major drawback is its temperature sensitivity.

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Solar Power :-

Sun is a vast source of energy.

Solar cell is the most important photovoltaic device which directly converts the solar radiations (light energy) into electrical energy.

Solar cell is basically a thin disc of P-N junction with a large surface area.

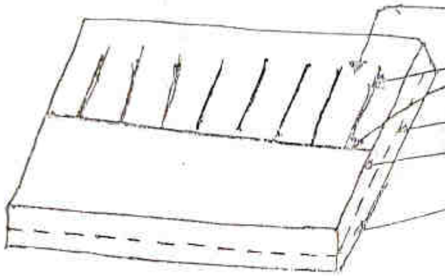
... of P-type material of the order of few microns is diffused on the upper surface of the disc to form a shallow P-n junction.

This is then enclosed in a glass container with the top surface filled with silicon grease to prevent losses by reflections.

When light rays fall on the surface of this arrangement electrons start flowing from n-plate to P-plate by means of the photoemission process.

This gives rise to a potential difference and constitutes flow of an electric current.

A commonly used solar cell is shown in figure.



[TOP view of a commonly used solar cell]

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A solar cell as shown in figure is developed in the form of a slice of single crystal silicon.

The N-P configuration is obtained by diffusing phosphorous into the boron doped crystal. Metal contacts are placed on the front and the back of the cell and active surface is coated with SiO_2.

The output depends on the intensity of sun rays.

As the cell is turned away from the sun, the output decreases.

The rise in temperature causes a sharp fall in conversion efficiency.

The presence of moisture or CO_2 in the atmosphere affects performance of a solar cell.

The total voltage or current required can be increased by series/parallel connections of solar cells thus developing solar batteries.

Application of solar cells are watches, calculators, telephones in rural areas, solar water heater, solar pump, space research.

DIELECTRIC MATERIALS

Introduction :-

* The materials which are used for storing of electrical energy are classified as dielectric materials.
* Dielectric materials are essentially insulating materials.
* The function of an insulating material is to obstruct the flow of current, The function of dielectric material is to store electrical energy.
* This difference of function demands that the material to be used as dielectric.
* It is used in condensers used for Power factor correction in tube Light.

Dielectric constant OR Permittivity :-

* Consider two insulated conducting Plates forming a capacitor having air inbetween them.
* Let the value of capacitance be C_0.
* if a Piece of another dielectric, say glass, is introduced in the space between the two Plates it is observed that the value of the capacitance increases.
* Let the value of the capacitance in this case be C.
* Since the charge storing capacity of the condenser increases when air is Replaced by another dielectric, in this case glass.
* The Ratio of capacitance using a material as the dielectric to the capacitance when air is substituted for the material is called the Permittivity or dielectric constant of that material.
* The dielectric constant of air is Practically taken as 1.
* Permittivity of dielectrics other than air are more than 1.

* Permittivity of a dielectric is analogous to Permeability of a magnetic material.

* Permittivity is different for different dielectric.

* Permittivity of most gaseous dielectrics is nearly equal to that of air but Permittivity of Liquid and solid dielectric Varies from 40 to 90 depending upon temperature.

$$D = \epsilon E$$

$$C \propto \frac{A}{d}$$

$$C = \epsilon \frac{A}{d}$$

A = Area
d = distance

* This equation gives a Relation between the electric Flux density and the electric field intensity. The Proportionality constant ϵ, is the dielectric constant of the medium.

* Dielectric constant ϵ unit is Farad.meter^{-1} or Farad Per meter.

$$\epsilon_r = \frac{\epsilon}{\epsilon_0}$$

$$\Rightarrow \epsilon = \epsilon_0 \epsilon_r$$

$$D = \epsilon_0 \epsilon_r E$$

where.

$\epsilon_0 = 8.854 \times 10^{-12}$ farad.meter^{-1} (dielectric constant or Permittivity of vacuum)

ϵ = dielectric constant

D = Electric Flux density

E = electric field intensity

ϵ_r = Dielectric constant of the Metal

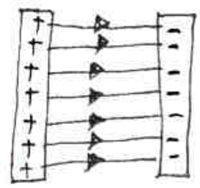
* The dielectric may be expressed by ϵ_r, Relative to that of Vaccum.

* Water as dielectric is not used because it is very difficult to keep water in Pure state.

Material	Permittivity
Air	→ 1
Bakelite	→ 5-6
Glass	→ 3.3
Empire cloth	→ 2
Mica	→ 3-8
Rubber	→ 2-3.5
Transformer oil	→ 2.

POLARISATION :- Polarisation :-

* In the dielectric materials the bound electrons are Predominant (in conductors free electrons are in abundance)
* Under the application of an external electric field, the bound electrons of an atom are displaced such that the centroid of the electronic cloud is separated from the centroid of the Nucleus.
* The atom is then said to be Polarized thereby creating an electric dipole. This Phenomenon is called electronic Polarization.
* polarization is defined as the definite orientation of electrostatic dipoles in a material due to an applied electric field.
* consider the two conducting Plates of a capacitor.
* when the capacitor is charged a definite Potential will exist between the two capacitor Plates.
* Electric field existing between the two charged capacitor Plate is shown in figure.
* when dielectric is introduced in between two Plates it has been observed that the intensity of the electric field and hence the Potential difference which Was existing between the two charged Plates is Reduced.

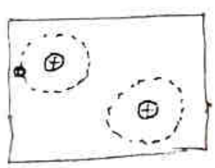


(Electric field Between two charged capacitor Plates)

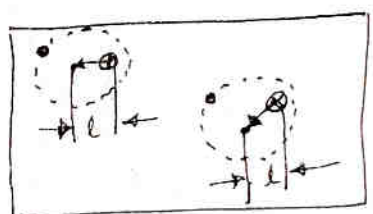
* This is due to Polarization of the dielectric material under the influence of an electric field.
* The better the dielectric material (a better dielectric material will have higher dielectric constant) The more will be the effect of Polarization.

What happens when a dielectric gets polarised:

* The molecules of a dielectric may be classified as either polar or non-polar.
* A non-polar molecule is one in which the "centre of gravity" of the positive nuclei and the electrons normally coincide.
* When placed within an electric field, the electrons are attracted by the +ve charge of one electrode and are repelled by the -ve charges of the second electrode.
* As a result the electrons undergo some displacement towards the direction of the +vely charged electrode.
* This displacement of the electrons within atoms is called electronic polarization.
* Electronic polarisation makes each atom a dipole.



(No electric field)

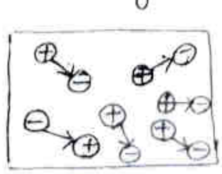


(electric field)

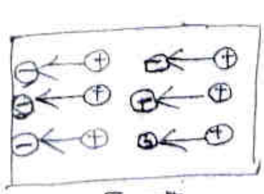
* A polarised particle will possess an elementary electric dipole moment which can be expressed mathematically as $M = q \cdot l$

where q is the charge of the particle.

* The sum of the dipole moments per unit volume of the material of the dielectric is equal to the polarization of the dielectric.
* The stronger the field, the greater will be the number of dipoles pointing in the direction of the field. The above phenomenon is shown in figure.



[E=0]



[Behaviour of polar molecules]

Hf (4)

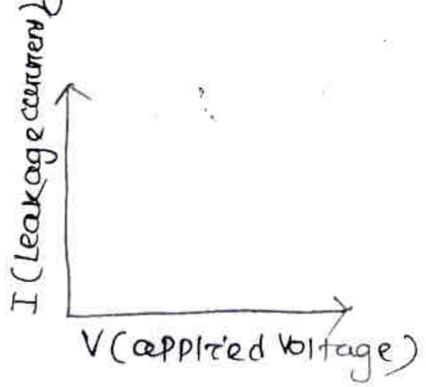
whether the molecules of an dielectric are non-Polar or Polar (3) the net effect of an external field on the dielectric is the same. As a Result of Polarisation in the Presence of an electric field the dipoles Line up in the direction of the applied field.

DIELECTRIC LOSS :-

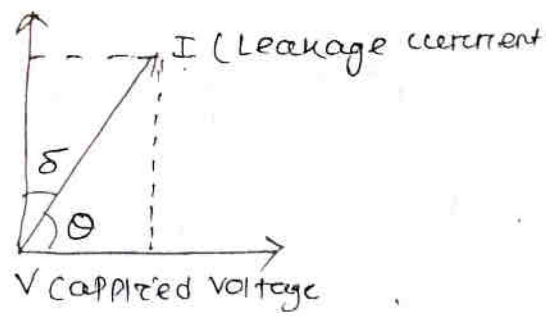
* In the case of Polar dielectrics the orientation of the dipoles in the electric field is not a Pure elastic displacement Process.
* It involves overcoming of certain internal friction Forces on which certain amount of energy is expended.
* This amount of energy is irreversible and is wasted as heat in the dielectric.
* This wastage of energy is known as dielectric loss.

Factor Affecting dielectric loss :-

* The loss increases Proportionately with the Frequency of applied Voltage.
* Presence of humidity increases Loss.
* Temperature rise Normally increases the Loss.
* Voltage increases causes increased dielectric loss.



No Power Loss



$\delta = 90 - \theta$

δ = dielectric Loss angle.

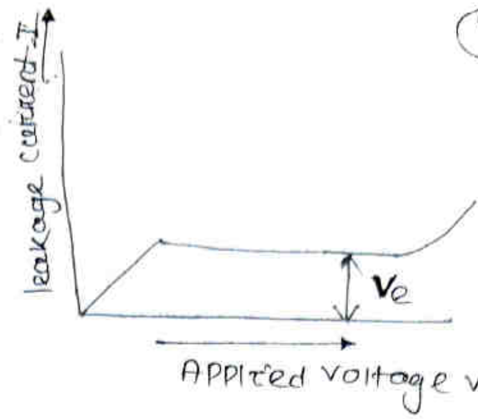
* Electrical conductivity of Dielectric and Their breakdown

* Gaseous Dielectrics
* Liquid Dielectrics
* Solid Dielectrics

* Gaseous Dielectrics :-

* The electrical conductivity of all gaseous dielectrics is identical
* Air is the most commonly used gaseous dielectric.
* Air constituents Nitrogen and oxygen.
* Under the influence of various Natural ionizing Factors e.g cosmic Rays and ultra violet rays some ionization takes place in air.
* This Natural ionization gives rise to equal Number of Free electrons and +ve charge appearing at the same time.
* If subjected to an electric field there will be no directed motion of free charges and hence there will be no flow of current through the gaseous dielectric.
* Under the influence of an electric field, the free charges get a directed motion and gives rise to an electric current which is known as the leakage current.
* Free electrons will move towards the +ve Plate whereas the +ve ions will be attracted towards the -ve Plate.
* The conductivity of a gaseous dielectric thus may be deemed to be as both electronic and ionic.
* Electron gets accelerated to a very high speed due to the applied electric field and this in turn knocks out an electron from other gas atoms and ionizes them. This Procedure is known as ionization by collision.
* Due to ionization by collision the number of the free charges increases in geometric Progression and the Strength of the leakage current increases Rapidly.
* The conductivity of gaseous dielectrics, under the influences of an applied Potential is shown figure.

* The voltage at which a sudden increases in Leakage current takes Place in a gaseous dielectric is called the breakdown voltage.



* V_e = breakdown Voltage.

Liquid Dielectrics :-

* All Liquid dielectrics easily get contaminated with some impurity in the form of solid Particles which become suspended in such dielectric.
* In All Liquid dielectrics the impurity conductivity Plays a very significant Role.
* The basic molecules of a Liquid dielectric get dissociated under the influence of an electric field.
* Dissociation (separate) of molecules causes conductivity. The degree of dissociation of the molecules of a Liquid dielectric depends upon the molecular structure.
* Dielectrics having high value of Permittivity have Low conductivity
* In Liquid Dielectrics can increases the conductivity under the action of an applied electric field.
* When the dielectric is Placed in an electric field, the contaminants become electrically charged and may act as current carriers.
* A breakdown in a contaminated Liquid dielectric may occur due to the formation of conductive bridge between the electrodes by the contaminant drawn into the interelectrode space by the applied electric field.
* This is Predominant if some fibrous Particles are Present as contaminant in a dielectric Like oil.
* The Fibrous Particles will absorbs moisture and are liable to arrange themselves into a continuous chain extending from one electrode to the other.

* There may be breakdown of the dielectric through the bridges thus formed.
* At the place where breakdown occurs, considerable amount of heat will be produced which will result in convection flow of the liquid dielectric.
* This will break up any bridge formed and the dielectric strength will be restored.
* Further ionization resulting in ultimate breakdown of the dielectric.

Solid dielectrics:-

* Electrical conductivity of solid dielectrics may be ionic electronics or combined (ionic plus electronics) in nature.
* Solid dielectrics depends upon the presence of various contaminants or impurity.
* At low temp. the volume of electrical conductivity of solid dielectric may be wholly due to impurity.
* Breakdown in solid dielectrics may commonly be either electro thermal or electrical depending upon the prevailing condition.
* Electrothermal breakdown is caused by the destruction of the dielectric due to heating produced by dielectric losses.
* Solid dielectrics are poor conductor of heat.
* Dielectric loss in these dielectrics increases sharply with increases in temperature.
* If the heat generated is not conducted away rapidly through the dielectric then there will be thermal breakdown of the dielectric.

* If at a particular applied voltage, the dielectric is not able to radiate away the heat generated due to dielectric loss in it, and if the applied voltage is kept for a long period the material will be charred or melted thus short circulating the electrodes.
* Electric breakdown of solid dielectric is caused by factors which have not yet been clearly understood.
* The most probable mechanism of electric breakdown in many solids particularly crystals, is collision ionization by electron.

Application of Dielectrics :-

* The most common example of the use of dielectrics for the Purpose of storing energy is in capacitor.
* Capacitors are generally classified according to the kind of dielectric used in them. Broadly capacitors may be grouped into the following :

* Capacitors that use Vacuum, air or other gases as dielectrics.
* Capacitors in which the dielectric is a mineral oil
* Capacitors in which combination of solid and Liquid dielectrics such as paper, films of synthetic materials, glass, mica etc and mineral oil, silicon etc are used.
* Capacitors with only a solid dielectric such as glass, mica titanium oxide etc.

* The first type of capacitors are used in applications where the energy loss in the capacitances must be small.
* The dielectric Losses in vacuum, air and other gaseous dielectric are very small : such capacitors are used in (Radio frequency circuit and in low frequency measuring circuit.)
* Capacitors using oil as a dielectric are used in application where a Large value of capacitance is Required and where a small amount amount of dielectric Loss can be tolerated.
* Oil impregnated paper dielectric is used for making capacitor of Large values of small size. e.g for power factor correction in electric power distribution system.
* Mica, a solid dielectric is used in making standard capacitors for Laboratories because its dielectric constant does not change much with temp. and with time.
* Dielectric Loss of Mica is very small.

Electrolytic capacitor :-

* Electrolytic capacitors make use of electrolytic materials as polarizing agent.
* Electrolytic capacitors are fixed value of capacitors.
* They are polarized devices with high capacitance Rating normally used for by pass, coupling and motor starting application.

* Tantalum oxide in comparison to aluminium oxide is more suitable in electrolytic capacitors but is costlier.

* Boric acid is also used in electrolytic capacitors.

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Properties of Dielectric :-

Material	Dielectric constant	Dielectric strength (kv/mm)	Tan δ	max working Temp. (at °C)	Thermal conductivity	Relative density
Air	1	3	—	—	0.025	0.0013
Alcohol	26	—	—	—	180	0.79
Asbestos	2	2	—	400	80	3.0
Cellulose film	5.8	28	—	—	—	0.08
Cotton fabric :-						
dry	—	0.5	—	95	80	—
impregnated	—	2.0	—	95	250	—
Ebonite	2.8	50	0.005	80	150	14
Glass :-			—	—	1100	4.5
Flint	6.6	6	0.02	—	600	2.2
crown	4.8	6				
Mica	6	40	0.02	750	600	2.8
Paper :-						
dry	2.2	5	0.007	90	130	0.82
impregnated	3.2	15	0.06	90	140	1.1
Porcelain :						
Quartz	5.7	15	0.008	1000	1000	2.4
Fused	3.5	13	0.002	1000	1200	2.2
Silk	—	—	—	95	60	1.2
Sulpher	4	—	0.0003	100	220	2.0
water	70	—	—	—	570	1.0
Paraffin wax	2.2	12	0.0003	35	270	0.88

4/8/17

Chapter-6 | Materials for Special Purpose

(Checking point) on doubt 8

Introduction :-

* Materials to be used for special purpose like in fuses, solders, bimetals, storage battery plates, thermocouples etc.

Structural Materials :-

Cast iron, steel, timber, rainforced concrete are the common materials used for structural materials.

Cast iron is used as material for the frames of small and medium sized electrical machines.

Steel finds its use in fabricated frames for large electrical machines, tanks for transformers, fabrication of transmission towers and a large number of other application.

Timber and Rainforced concrete are commonly used poles for overhead lines.

Protective Materials :-

Lead :-

Lead is soft, heavy and bluish-grey metal.

It is highly resistant to many chemical action but can corrode by nitric acid, acetic acid, lime and rotten organic substances.

The electrical conductivity of lead is only 7.8%.

Lead and its compounds are toxic.

Lead is mechanically weak, it cannot withstand vibration at high temperature.

(29)

→ The field of electrical engineering lead is used in storage batteries and as sheathing of cables.

* Pure lead cable sheaths are liable to fail in service due to formation of cracks formed because of vibration. This difficulty can be eliminated by using lead alloyed.

* Lead alloys easily with tin and zinc and forms many alloys including solders and bearing metals.

Steel taps, wires and strips :-

* Steel tapes, wires and strips are commonly used as protective material for mining cables, underground cables, weather proof cables etc.

Bitumens :- Bitumens are used for protection against corrosion.

OTHER MATERIALS :-

⊛ Thermocouple materials :-

* When two wires of different metals are joined together an e.m.f exists across the junction which is dependent on the types of metals or alloys used and also directly proportional to the temperature of the junction.

* When one tries to measure this e.m.f more junctions are to be made, which also give rise to e.m.fs

* When all the junctions are at the same temperature the resultant e.m.f will not zero.

* This resultant e.m.f is proportional to the temperature difference of the junctions and is called Thermoelectric e.m.f.

* The e.m.f produced by a thermocouple is very small.

* Materials used for thermocouples (cold junction is at 0°C):

Materials	Temperature Range (°C)	e.m.f at 500°C mV
Copper/constantan	−200 to 400	27.6
Iron/constantan	0 to 900	26.7
Nickel/Nickelchromium	0 to 1100	10.0
Platinum/platinumrhodium	500 to 1400	4.5

* Thermocouples can be used for the Measurement of Temperature.

Bimetals :-

A bimetal is made of two metallic strips of unlike metal alloys with different co-efficients of thermal expansion.

At a certain temperature the strip will bend and actuate switch or a lever of a switch.

The bimetals can be heated directly or indirectly.

When heated, the element bends so that the metal with the greater co-efficient of expansion is on the outside of the arc formed while that with smaller co-efficient on the inside.

When cooled the element bends in the other direction.

Bimetallic strips are used in electrical apparatus and in devices such as Relays and Regulators.

* The e.m.f produced by a thermocouple is very small.
* Materials used for thermocouples (cold junction is at 10°C)

Materials	Temperature Range (°C)	e.m.f at 500°C mV
Copper/constantan →	−200 to 400 →	27.6
Iron/constantan →	0 to 900 →	26.7
Nickel/Nickelchromium →	0 to 1100 →	10.0
Platinum/platinumrhodium →	500 to 1400 →	4.5

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* When cooled the element bends in the other direction.
* Bimetallic strips are used in electrical apparatus and in devices such as Relays and Regulators.

Soft Solders are composed of lead and tin in various proportions.

Hard solders may be any solder with a melting point above that of lead-tin solders.

* common hard solders are silver solders, aluminium solders copper-zinc solders etc.

: Hard solders have high melting point and therefore to be used for metals which can withstand high temperature.

: The application of soft solders is in electronic devices and the hard solders is in power apparatus for making permanent connections.

Flux : It is an improved variety of organic flux which is used with Alca P for aluminium cable jointing.

: This on decomposition at a temperature a little below the jointing temperature of approximately 316°C removes the refractory oxide from the strands of the core and makes the surface receptible to solder.

* Thus, avoiding damage to the paper impregnation and the insulation.

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Fuse and fuse material :

* A fuse is a protective device, which ~~consists~~ consists of a thin wire or strip.

- This wire or strip is placed with the circuit, it has to protect, so that the circuit current flows through it.

: When this current is too large, the temperature of the wire or strip will increases till the wire or strip melts thus breaking the circuit and interrupting the sup

* The current is cut-off by the fuse as follows: upon melting of the wire, the metal-ions form an arc and constitute a conducting path through which the current continues to flow.

* In order to quench the arc, the Resistance in the arc path must rise to such an extent that the available voltage is no longer able to sustain the arc.

For proper quenching of the arc in a fuse the following measures can be taken:-

* The material chosen for a fuse wire is that whose metal ions after melting have low conductivity. silver are such material.

* if the temperature of the arc-path is kept low, its Resistance and therefore the voltage drop along the arc will be high due to less mobility of the metal-ions and electrons.

* The cooling of the arc in a fuse can be achieved by embedding the fuse wire in quartz sand as is done in cartridge and HRC fuses.

* The higher the pressure of the gas in which the arcing take place, the higher will be the Required voltage to sustain the arc. This is achieved by putting the melting wire in ar. explosion tight enclosure, in which a pressure is automatically built up by the heat produced by the arc.

* so a Rewireable fuse is not at all suited to quench an arc properly because any type of the wire can be used: no proper cooling of the arc can be provided and no pressure can be built up.

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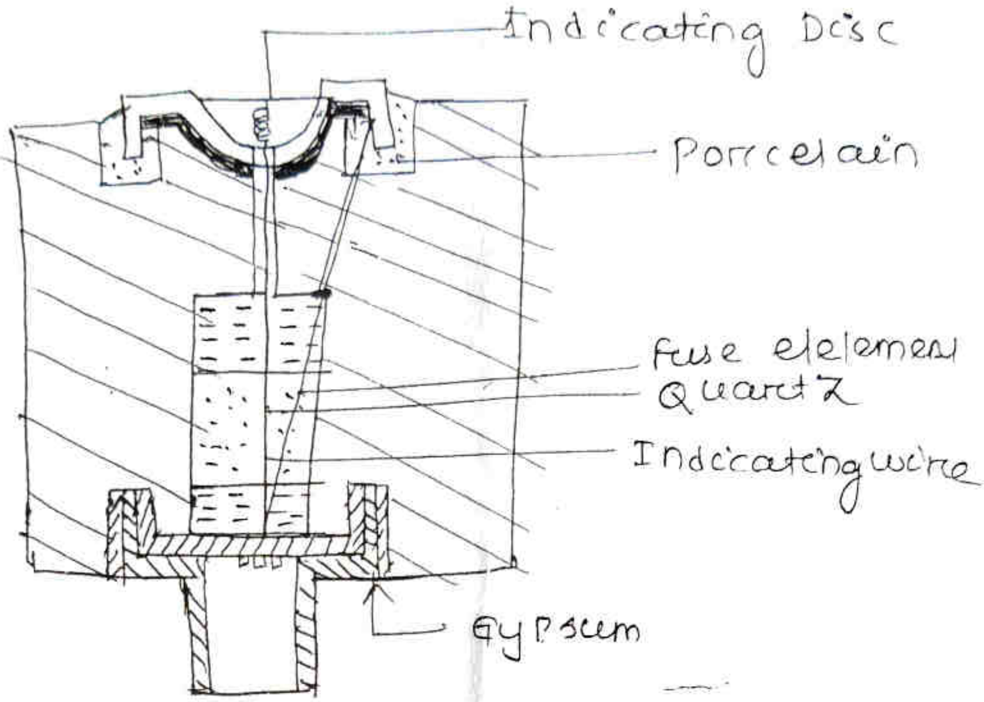
* Figure shows the cross-sectional view of a cartridge fuse :-



Fuse material :- A fuse material should possess the following properties :

* Low Resistivity : This means, thin wire can be used, which will give less metal vapour after melting of the wire. Less metal vapour in the arc gives lower conductivity and thus makes quenching of the arc easier.
* Low conductivity of the metal vapour itself.
* Low melting Point : This means that the temperature of the fuse material for normal currents stays at a low value.
* Only lead was used as fuse material because of its low melting point. But as the Resistivity of lead is high, thick wires are Required.
* For Rewirable fuses alloys of tin and lead or tinned copper wires are commonly used.
* In cartridge fuses silver and silver alloys are used in fuses of lower Rating and copper alloys are used in fuses of high Ratings

* The fusing current can be calculated using the Relation.

$$I = ad^n$$

where I = Fusing current in amperes
d = wire diameter in c.m
a = constant, value varies from material to mater

* The Rating of any fuse depends entirely on its dimensions, mounting, surrounding powders or liquids, enclosure and other factors which affect its heat dissipating capacity and its ability to extinguish arcs after fusing.

Dehydrating Material :- (silicagel)

* it is an inorganic chemical, a colloidal, highly absorber silica used as a dehumidifying and dehydrating agent as a catalyst carrier and sometimes as a catalyst.
* calcium chloride and silicagel are used in dehydrating breathers to Remove moisture form the air entering a transformer as it breathes.
* silicagel breathers are Replacing the calcium chloride breathers.
* Its main advantages is that when it becomes saturated with moisture it does not Restrict breathing as does calcium chloride
* silicagel, when dry, is blue in colour and the colour changes to pale pink as it becomes saturated with moisture
* It can be dried by heating it in an open contained at a
(8) temperature of between 150°C and 200°C for two hours.
* calcium chloride can be dried by heating it in the same manner at a temperature of between 180°C and 200°C until completely dry

Mechanical Properties.

Insulating material.

Introduction :

* Primarily any material that is able to insulate i.e to prevent the flow of electricity through it when a difference of potential is applied across it is called insulator.

* Insulating materials are those which offers very high Resistance to the flow of electric current.

* Insulators when used primarily for storage of electrostatic energy, as in capacitors, are known as dielectric.

* But when used to prevent leakage of current to any undesired conducting medium, they are known as insulators.

* The insulator provide mechanical strength as well as insulation to the conductor.

* Typical examples of gaseous, liquid and solid insulators are :

Gaseous :
* Air
* SF-6 (sulphur hexa Fluoride)
* CO_2 (carbon dioxide)

Liquid :
* Petroleum oils
* Halogenated aromatic. hydrocarbons
* silicon oils

Solid :
* sulphur
* Polysterene

Mechanical Property: (64)

* Mechanical Properties such as impact strength, tensile strength, toughness, hardness, elongation flexibility, abrasion, Resistance etc. have to be consider when choosing an insulating material.

Viscosity: It's of importance in liquid dielectric used in varnishes for impregnated.

* The ability of varnish to fill the voids of insulation and displacing air, depends upon its viscosity.
* Low viscosity liquids are more mobile and help in transmission of heat by easy circulation in the case of transformer and switch gear.

Porosity:

* An insulating material of high porosity will absorb more moisture and thereby affect the other electrical properties.
* Porosity is advantageous as in the case of a paper which is to be impregnated with oil.

Solubility:

* certain insulating material like varnish should be applied only after it dissolves in proper solvents like acetone.
* such substance should not dissolve when they come in contact.

Thermal Stability :- The Insulating materials used must be stable within the allowed Temperature.

* certain materials Like waxes, plastics, bitumen, compounds and Resin are softened at Low or moderate temperature.

* This may cause the deterioration of mechanical Properties and the insulation may melt out of the coils, winding etc causing internal short ckt.

Melting Point :- The insulating material chosen with a melting point much above of the operating temperature.

Flash Point :- Flash point of a Liquid dielectric is that temperature at which the Liquid begins to ignite.

* The insulating material should not catch fire at the operating temperature.

Heat Resistance :- The insulating material used must be able to withstand the heat Produced due to continuous operation, and Remain stable during the operation.

* This Property is known as heat Resistance Property.

Chemical Properties :-

Resistance to external chemical effects :- insulating materials should be chemically stable and offer chemical Resistance to oils, solvents, acids and alkalies.

chemical changes in the material :- certain chemical changes may take Place in the material itself during use, but its Properties should not deteriorate.

Hygroscopicity :- The moisture may act on insulator or may be absorbed by the insulation.

* The Process of absorption of moisture is known as Hygroscopicity. This affect the electrical Property adversely.

Ageing :- Ageing is the Long-term effect of heat, chemical action and Voltage application. These factor decide the Material ... electrical apparatus.

1) What is skin effect ?

(ANS) * skin effect occurs in a.c.

* Due to this effect the distribution of current density in not uniform.

* In the surface if it is more and the current density decreases as we go towards the inner Portion.

2) Mention the specific use of Paper Relating to insulating material.

ANS) The use of Paper Relating to insulating materials are :

* cable
* Transformer
* capacitor.

3) What is enamel.

(ANS) Enamels is a fusible insulated coating of Normally some organic base material which is generally apply on conducting material.

* Enamels finds extensive use in coating wires used for the windings of Low Rates motors, transformer and various type of instrument.

(4) Define PVC.

* It is also called as Polyvinyl chloride.

* when acetylene and hydrogen chloride are combined in the Presence of catalysts Like Peroxides at about 50°C then Polyvinyl chloride Resin is Produced.

* It is used in cables, sheath Purposes.

5) Define Ductility.

* It is the Property of the conducting materials different sizes and shapes of the conductors are Required for different application.

* To fulfill this Requirements the conducting material should be ductile enough to enable it to be drawn into different sizes and shape.

Resistance to corrosion effect, contact Parts; mica sheets are used for the insulation between commutator segment.

Transformer oil :- It is used to cool the heated coils in a Transformer.

(15) what are the types of magnetic materials and give the example of each.

Ans) Dia magnetic - Bismuth, lead, Gold, Sb, P
Para " - copper, Al, oxygen, Platinum
Ferro " - Fe, CO, Ni, GD

(16) what are the constituent Part in manufacturing Porcelains.

Ans) The constituent Parts to make Porcelains are china clay, quartz, ball clay, Feldspar, finely Powdered and mixed with water etc.

(17) what are the Properties of cotton in electrical Engg. Purposes.

Ans) cotton cloth or tape made from cotton Fibre is Flexible, mechanically strong thin, hygroscopic and gives high space factor when used to warping of coil winding.

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(85)

(10) Give a few examples of ceramic materials.

(Ans). A few examples of ceramic materials are :

Porcelain, Titanate ceramics ($BaTiO_3$, $SrTiO_3$, $CaTiO_3$).

(11) Class A and class H type insulating materials will have how much limiting temperature.

(Ans)

class	maximum working Temperature
A →	105°C
E →	120°C
B →	130°C
F →	155°C
H →	180°C
C →	above 180°C

(12) What are the materials used for line insulator.

(Ans) The materials used for the line insulator are (i) For transmission line Porcelain
(ii) Glass insulators are also used in transmission lines to reduce the weight.

(13) Write at least four properties of good insulating materials.

(Ans) * High dielectric strength.
* Easy workability
* High operating temp. limits
* Good surface property.

(14) Write the Name of 4 insulating material and their uses.

* Porcelain : which is used in electrical power system for the insulator (pin type or shackle type) etc.

* Varnishes : It is used to insulate the windings.

Resistance to vertical effect contact Points.

mica sheets are used for the insulation between commutator segment.

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Magnetic Materials

Introduction :-

Materials which can be Magnetized are called Magnetic Materials.

When magnetized, such materials create a Magnetic Field around them.

In general Magnetic materials can be classified under two categories; one application wise as hard and soft Magnetic Materials and other according to their behaviour as diamagnetic, Paramagnetic, Ferromagnetic, antiferromagnetic, Ferrimagnetic and Super Paramagnetic.

* soft magnetic materials are used for large scale generator, transformer, inductors, motors and other application.

* Hard magnetic materials are used for making Permanent magnet.

* In a Magnetic materials such as iron and steel there are a number of unneutralized orbits which produce a Resultant m.m.f creating Magnetic Poles, called Magnetic dipoles.

In a Magnetized material the dipoles Lines up Parallel with exciting m.m.f.

The Property of a material by virtue of which it allows itself to be magnetized is called Permeability (μ).

For most material, except those which are called magnetic Material, the Value of Permeability is constant and is same as for Free space.

* The Permeability of free space is denoted by μ_0.

$$\mu_0 = 4\pi \times 10^{-7}$$

For magnetic material Permeability (μ) is given by

$$\mu = \mu_0 \times \mu_r$$

where μ = Permeability

μ_0 = Permeability of Free space

μ_r = Relative Permeability.

* The value of μ_r varies from material to material and depends on the degree to which the material is capable of being magnetized.
* It may have a value as high as 2500.

* From the study of electromagnetism it is known that in free space the Magnetic Flux density 'B' is Related to the intensity of Magnetization 'H', as follows

$$B = \mu_0 \times H$$

B unit wb/m^2

H unit Ampere-turn/mm.

* In solid material $B = \mu H$, where $[\mu \neq \mu_0]$

This expression may be written as

$$B = \mu_0 (H+M) = (\mu H)$$

where M = Magnetization of the solid

* The Magnetization, (M) of a material may be Regarded as Resulting from the alignment of magnetic dipoles of the material parallel to the applied field intensity (H).
* This means that the more the applied field intensity the greater will be the number of dipoles which will align parallel to the applied field.
* Therefore the magnetization is Proportional to the applied field thus. $M \propto H$

$$M \propto H$$

$$M = \chi \times H$$

where,
χ = constant of Proportionality and is called susceptibility.

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

$$B = \mu_0 (H + \chi H)$$

$$B = \mu_0 H (1 + \chi)$$

$$B = \mu_0 \mu_r H$$

$\mu_r = 1 + \chi$ = Relative Permeability of the Medium.

* For a Non magnetic Material $\chi = 0$, i.e $\mu_r = 1$
* Relative Permeability depends upon the Nature of the Material and on temperature.

Classification of Magnetic Material :-

* The material can be classified into non-magnetic and Magnetic material.
* Non-magnetic materials are those which donot Respond to an external Magnetic Field.
* Material are classified into
  * Diamagnetic material
  * Para magnetic Material
  * Ferro magnetic Material.
* Diamagnetic and Paramagnetic materials are classified as Non-magnetic material. Ferromagnetic material are classified as magnetic material.

Diamagnetism :-

* There are many materials in which the cancellation of magnetic fields due to electrons rotating in opposite directions in the various orbits of the atom.
* Permanent magnetic dipoles are absent in them.

* Materials which lack permanent magnetic dipoles are called Diamagnetic.

* If an external magnetic field is applied to a diamagnetic material it induces a magnetization 'M' in opposite direction to the applied field intensity H.

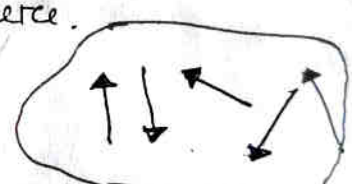
* This means that the Relative Permeability μ_r of a diamagnetic material is -ve.

* This makes diamagnetism unimportant for electrical engineering application.

* Paramagnetism :-

* Many materials have small but +ve Relative Permeability. Such materials are called Paramagnetic.

* In such materials the individual atomic dipoles are oriented in a random fashion as shown in figure.



* The Resultant Magnetic field is thus Negligible.

* On the application of an external magnetic field the Permanent magnetic dipoles orient themselves parallel to the applied magnetic field and gives rise to a positive Magnetisation (M).

* The orientation of dipoles parallel to the applied Magnetic field is not complete, therefore the Magnetization M is small.

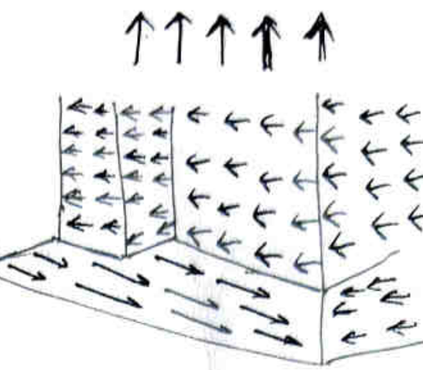
* The Relative Permeability of Paramagnetic material are therefore very approximately unity.

* Thus Paramagnetic materials have negligible application in the field of electrical engineering.

Ferromagnetism :-

Ferromagnetic materials are generally crystalline solids. The Permanent atomic dipoles are aligned Parallel to each other within groups called domains.

Figure shows each domain is therefore at all times completely magnetized.



* To give the material a Net magnetization one direction must Predominate in the domains of the material.

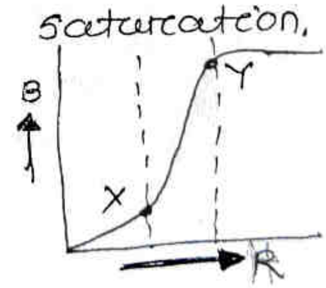
When a weak external magnetic field is applied, it is not enough to cause any change in the orientation of the domains.

* The flux density with such low applied field is entirely due to the externally applied magnetic field.

* when the externally applied magnetic field is increased, it is still weak, the domains will starts orienting themselves such that their Resultant magnetic field coincides with externally applied magnetic field, and the material will develop strong magnetic field of its own.

* Rate of strengthening of the internal magnetic field decreases with increases in the applied magnetic field and gives rise to a state of Magnetic saturation.

imp.
Magnetisation curve :-



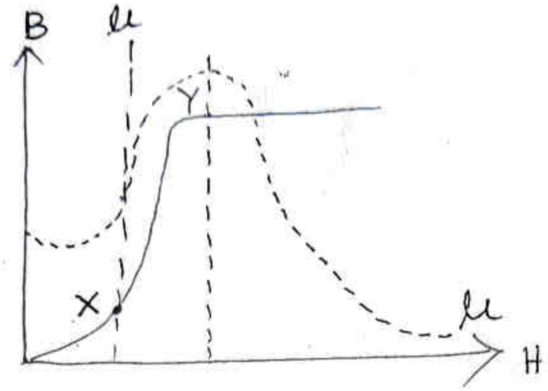
* With very weak external applied field H, the flux density B, rises in direct Proportion.

(magnetisation curve for a Ferromagnetic material)

* This means that during this Region upto point 'x', the domains of the ferromagnetic material do not orient themselves Parallel to the applied field and therefore the material is not magnetized.

* The flux density is entirely due to the external field.

* Thus the Permeability $\left[\mu = \frac{B}{H}\right]$ of the material upto the Point 'x' is constant. This is called initial Permeability.



* if the external field, H is increased beyond the point 'x' there is sharp increases in the flux density. This is because the external field, through still small, is strong enough to orient Parallel to its own axis.

* This means that upto Point 'Y' the Relative Permeability of the material is no Longer constant but keeps sharply increasing.

* when Point 'Y' is Reached the increase in flux density is slow.

* In other words the Permeability of the material, after the Point Y, starts decreasing.

* The combined graph of B and μ against the applied magnetic field 'H' is shown in figure.

* When the Magnetization curve Reaches the Point 'y', the material is said to start saturating.

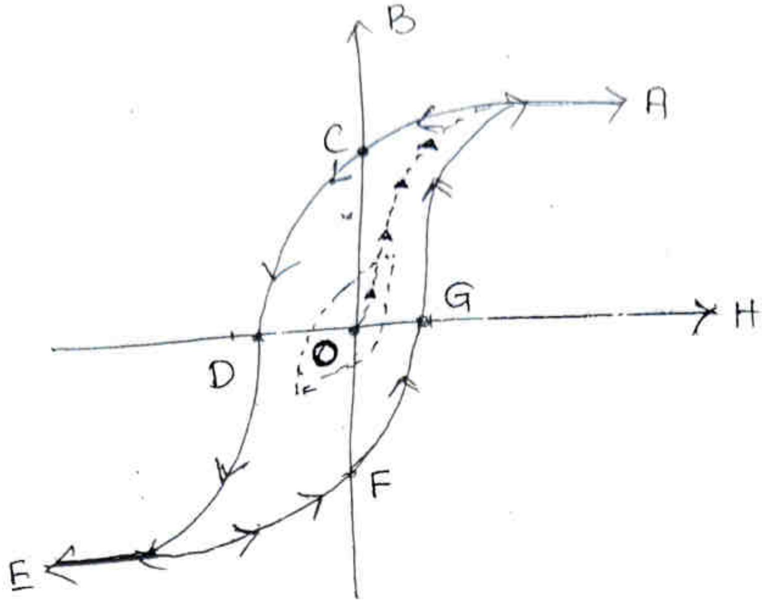
* After this, increasing in H and the curve becomes almost horizontal with only a slight slope upwards.

Imp

* HYSTERESIS :-

* In a ferromagnetic material the Flux density B increase when external magnetic field applied to it is increased.

* When saturation arrives, the increase in 'B' almost ceases even though H may be increased.



[Hysteresis Loop for a ferromagnetic material]

In figure, If now the external magnetic field is gradually Reduced it is found that the original curve 'OA' is not retraced.

* at 'H' equal to zero, the material is still magnetised and the flux density has the value 'OC'. This is called the remnant flux density or the Residual magnetism.

* In order to demagnetize, the material completely the external magnetic field H, must be Reversed and when it Reaches the value OD, in the Reverse direction it is seen that B is now zero.

* The applied magnetizing force, H in the Reverse direction (in this case equal to OD) which causes 'B' to be zero is called coercive force.

- Further increases of H in the Reverse direction will now increases 'B' in the Reverse direction and again at 'E' saturation occurs.

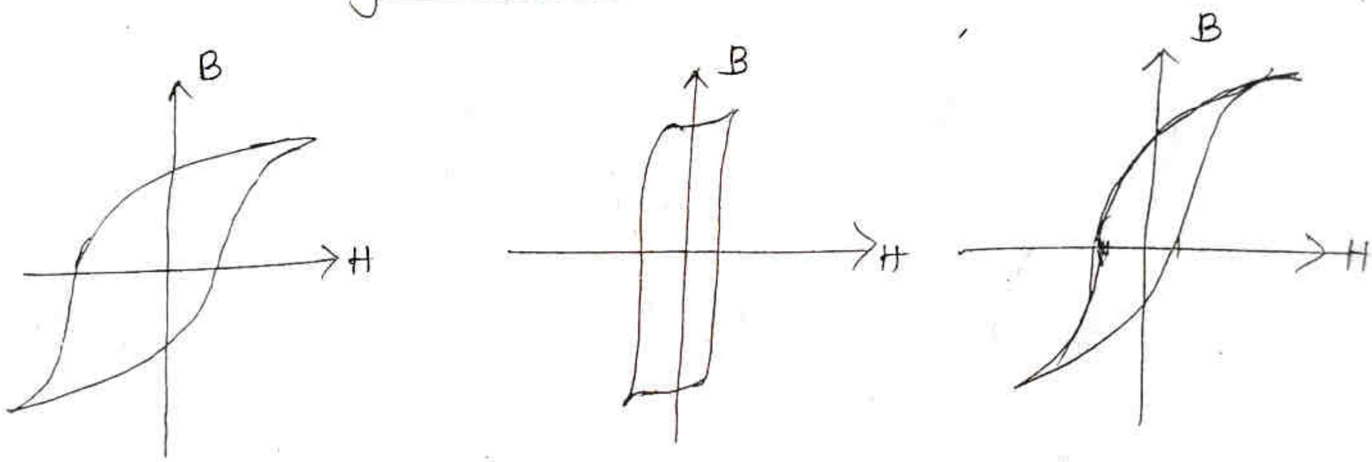
* The Residual magnetism in the Reverse direction is Represented by 'OF' and to Neutralise, 'H' must be increased to the value OG in the +ve i.e original direction.

* Further increase of H in the +ve direction will again magnetize the material in this direction and saturation will occurs at A.

* Here In figure shows, that B always Lags behind H. This Property of B Lagging behind H is a characteristics of the magnetic behaviour of Ferromagnetic material.

* From the above, when the material is taken through one complete cycle of magnetization i.e when H is taken from +ve maximum through zero to Negative maximum and then through zero again back to +ve maximum.

* The graph Relating B and H traces a Loop ACDEFGA This is called Hysteresis Loop.



Hysteresis Loops for different magnetic material

Hysteresis Loss :-

* When a ferro-magnetic material is subjected to Repeated cycle of magnetization, the Losses due to hysteresis are directly Proportional to the supply frequency.

* Hysteresis Loss for a given material is usually expressed in watts per kg.

* Hysteresis loss depends upon flux density and frequency of variation of flux and can be expressed as

$$\text{Hysteresis Loss} = K B_m^{1.6} F V_c \text{ watts}$$

(5)

where, K is a constant whose value depends upon the core material.

B_m = maximum flux density of the magnetic field.

F = frequency of variation of flux.

V_c = volume of the core material in m^3.

EDDY CURRENTS :-

* magnetic materials placed in alternating magnetic fields also have eddy currents induced in them.
* This is because the material is subjected to rate of change of flux linkages and in accordance with faraday's law of electromagnetic induction, e.m.fs are induced in the material causing currents, called eddy currents to flow in the materials.
* These currents cause loss of energy (I^2R loss in the material where I = value of eddy current, R = Resistance).
* This results in the heating up of the material.
* The expression for eddy current loss can be represented as

$$\text{Eddy current loss} = K \cdot B_m^2 F^2 t^2 V_c \text{ watt}$$

where K = constant which depends upon the core material.

t = Thickness of the core lamination

F = frequency

V_c = volume of the core material.

* Eddy current loss is proportional to the square of the frequency and the square of the thickness of the material and is inversely proportional to the resistivity of the material.
* This is why magnetic cores to be used in alternating magnetic field.
* Eddy current losses are proportional to the square of the flux density.

(63)

CURIE POINT :-

* There is a critical temperature called curie Point above which the ferromagnetic material Lose their magnetic Properties.
* Above the curie temperature, the domain structure tends to disrupt and the domains loss their alignment, become arranged in Random fashion ; thus the material Loses its ferromagnetic Property.
* This Temperature is a characteristic of magnetic material and differs from material to material.

MAGNETOSTRICTION :-

* When ferromagnetic materials are magnetized a small change of dimensions of the material take Place.
* There is a small extension with corresponding Reduction of cross-section of the crystals of which the material is made
* When subject to Rapidly alternating magnetic fields there is a Rapid and continuous extension and contraction of the material.
* This is called magnetostriction.
* Magnetostriction is the major cause of hum in transform and chokes.

SOFT AND HARD MAGNETIC MATERIALS :-

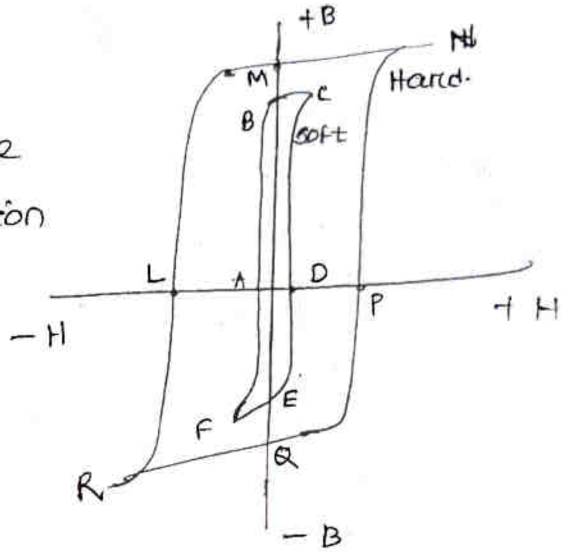
* All ferromagnetic material may be devided into two broad group viz a) soft magnetic material
  b) Hard magnetic material.

* Material which have a steeply rising magnetization curve, Relatively small and narrow hysteresis Loop and consequently small energy Losses during cyclic magnetization, are called soft magnetic material.

* Soft magnetic materials are employed in building building (c) (?) … ories for use in alternating magnetic fields.

The commonest soft magnetic materials are soft iron, Nickel-iron alloys and soft Ferrites.

* Figure, a typical narrow hysteresis loop marked ABCDEFA for soft magnetic material.



(?) Magnetic materials which have a gradually rising magnetisation curve, Large hysteresis Loop area, and consequently Large energy Losses for each cycle of magnetization are called hard magnetic materials.

* hard magnetic materials are used for making Permanent magnets.

Examples of hard magnetic material :- carbon steel, tungsten steel, cobalt steel, alnico, hard Ferrites, etc.

* figure, A typical Hysteresis Loop marked LMNPQRL for hard magnetic material.

* Soft magnetic Materials :-

* Soft magnetic materials which are used for the construction of cores for electric machines, transformers, electro magnets, Reactors, Relay etc.

(65)

* The economic construction of such equipment demands that the magnetic Flux should be Produced in the minimum space and with min. loss.

* we know that $\Phi = B \times A$ — B = Flux density, A = cross-sectional area.

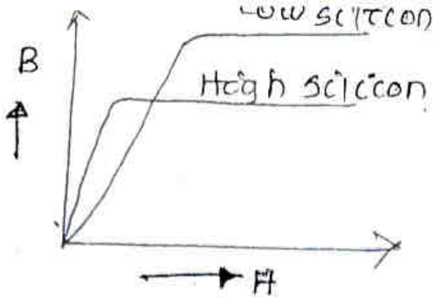
* Soft magnetic materials from the magnetic circuit in an electrical machine, like transformers, motor etc.
* They should have low hysteresis and eddy current losses.
* The core of electrical machine and transformers must be made of laminations of reduced eddy current losses.

Pure iron :

* Pure iron is meant for a ferrous material with an extra-low carbon content.
* Examples are low carbon steel and electrolytic iron.
* The resistivity of pure iron is very low by virtue of which it gives rises to large eddy current loss.
* Pure iron is widely used in many kinds of electrical apparatus and instruments as magnetic material core for electromagnets, component for relay electrical ~~equipment~~ instruments etc.
* Pure iron is not used in rotating electrical machines.

Iron-silicon alloys :-

* Alloying constituent is silicon which is added to iron in amount from about 0.5 to 5% by weight.
* Extensive use is made of iron-silicon alloy is usually called silicon steel. ~~for~~ ~~Rotative~~
* iron-silicon alloys is used in transformers, electric rotating machine, reactors, electromagnets and relays.
* silicon increases the electrical resistivity of iron thus decreasing the iron losses due to eddy current.
* The magnetostriction effect is also reduce.

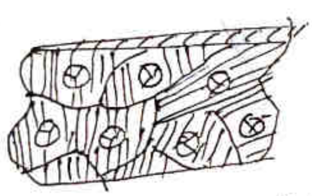


(magnetisation curves of High silicon and Low silicon steel)

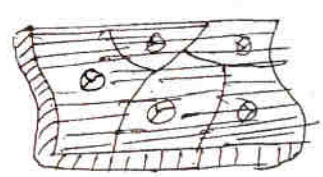
Grain oriented sheet steel :-

For easy magnetization, the crystal direction in which the external magnetic field is applied. This is achieved in practice by controlling the rolling and annealing of silicon-iron sheets.

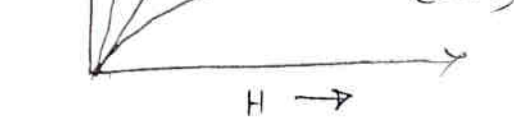
* The direction of easy magnetization then i.e in the direction in which steel is rolled then it is called 'grain oriented' steel otherwise called non-oriented grain.



(sheet steel with Non-oriented grain)



(sheet steel with oriented grains)



* Higer Permeability and Higher Saturation value for Grain oriented silicon.

* Hysteresis Loss is also Reduced as a Result of grain orientation.

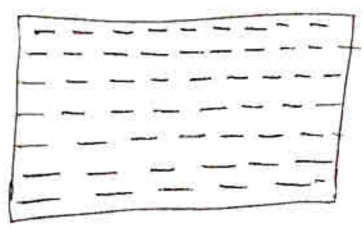
* The Grain orientation (or texturing) of silicon steel is obtained by a special manufacturing technique called cold Rolling. (G-)

Sheet steel obtained as a Result of such Process is called cold Rolled Grain oriented silicon steel (CRGO). (imp).

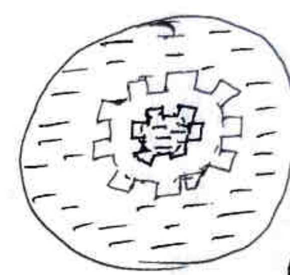
* CRGO silicon-steel is widely used for making transformer cores.

: The magnetizing current Required by transformer using CRGO steel is Low.

* using CRGO steel to built transformer cores care must be taken to assemble the core in such a manner that the crystal direction is Parallel to the Flux Path because otherwise the core will offer high Reluctance (Low Permeability) rather than high Permeability.



(Grain oriented steel Lamination broken Lines indicate the orientation of the Grain)



(b) (Orientation of Grains when CRGO steel is used for Rotating Machine)

* figure (b) shows, most Part of the iron Path the grains are not oriented in the direction of Flux.

Advantages of CRGO

* It is used in Rotating machine.
* It Resulting Low Losses with CRGO sheet stampings.
* Low Running cost because it Reduces Losses.

Magnetic anisotropy :-

* The directional dependence of magnetic Property under the ~~Grain o~~ Grain oriented sheet steel, is called as magnetic anisotropy.

Annealing :-

* The magnetic Properties of ferromagnetic materials are adversely affected by strain due to Mechanical working like punching, milling, grinding, Machining etc.
* The magnetic Properties including the correct crystal direction in the case of CRGO sheet can be restored by heat treatment.
* This Process is known as annealing.

Nickel iron alloys :-

* iron and iron - silicon alloys have Low initial Permeability.
* For Power applications like transformers and Rotating electrical machines where core operated at high flux densities the initial Permeability is of no importance.
* It draws very Low flux density.
* But for high sensitivity and Low distortion needed in communication systems the iron - silicon alloys are Not suitable.
* The important alloys in this category are Permalloy, Supermalloy and Mumetal.

Permalloy :- This is used in manufacture of sensitive Relays. The curie Temp. is varies between 420 to 580°c and heat treated upto 1050 to 1100°c.

Supermalloy :- it consists of iron and nickel alloyed with copper and molybdenum. This alloy is distinguished by its high initial Permeability upto 100,000.

Mumetal :- it consists of iron and Nickel alloyed with copper and chromium. it is used for manufacturing instrument transformers and Miniature transformers.

Soft ferrites :- * Ceramic magnets called ferromagnetic ceramics and ferrites are made of an iron oxide, Fe_2O_3.

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Carbon steel, tungsten steel, cobalt steel :

* Soft magnetic materials can not be used for making Permanent magnets because they have narrow hysteresis Loops.

* When carbon is added in a material, its hysteresis Loop area is increased. So carbon steel was used for Permanent magnets.

* When material like tungsten, chromium or cobalt are added to carbon steel, its magnetic Properties are improved.

* Cobalt steel has exceptionally superior magnetic Properties but is expensive.

* Alnico :

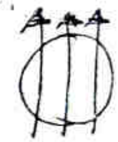
* Alloys Like ALNICO (Aluminium - nickel - iron - cobalt) are commercially the most important of the hard magnetic Materials.

* Alnico is an exceptionally hard magnetic material and due to this Reason now-a-days Permanent magnets are most commonly made of Alnico.

* High quality Permanent magnets are used in many electrical engineering application e.g in various electrical Measuring instrument.

Hard Ferrites :

* Hard magnetic ferrites like $BaO(Fe_2O_3)_6$ are used for the manufacture of Light weight Permanent magnets due to their Low specific weight.

	DIAMAGNETIC	PARAMAGNETIC	FERROMAGNETIC
* Response to applied Magnetic field	* They get weakly Repelled.	* They get weakly attracted	* They get strongly attracted
* Status of atomic dipole in the absence of external Magnetic Field	* No Permanent dipole. 	* Permanent dipoles Randomly oriented 	* Permanent dipoles alligned with a domain. 
* Relative Permeability ($\mu_r = \frac{B}{\mu_0 H}$)	* slightly less than 1	* slightly greater than 1	* Very high
* Magnetic susceptibility	* of the order of -10^{8}	* of the order of $+10^{8}$	* +ve and Very high/Large
* Temperature dependency of magnetic susceptibility	* independent of Temperature	* $\chi = \frac{C}{T}$	* $\chi = \frac{C}{T-T_c}$

55