**Q2a** Name and explain the factors on which resistivity of a conducting material depends.

**Ans 2a** The factors, on which the resistivity of conducting materials depends are:-

Temperature: The electrical resistance of most metals increases with increase of temperature while those of semiconductors and electrolytes decreases with increase of temperature.

Alloying: Alloying is another factor, which affects the resistivity of a material. By the addition of some impurity to the metal, its resistivity can be changed. Alloys have more resistivity than that of the pure metal.

Mechanical stressing: When a material undergoes a mechanical treatment, its resistivity changes due to mechanical distortion of the crystal structure.

Age hardening: It increases the resistivity of an alloy.

**b** Explain temperature dependence of electrical resistivity and conductivity in conductors and semiconductors.

**Ans 2b** Temperature dependence of electrical resistivity and conductivity in conductor**s**:

As the temperature is increased, there is a greater thermal motion in the atoms, which decreases the regularity in the atoms spacing with a consequent decrease in the mobility of the electrons. The resitivity of most of the conductors therefore increases with an increase in the temperature. Since the number and the energy of the electrons at top of the Fermi distribution curve vary insignificantly with temperature, the change in temperature must be associated with a change in the mean free path. In a perfectly regular lattice, each electron will exist in a particular energy state and will have a fixed velocity. Practically metals do not have a perfect lattice because of impurities and because of deviations of the atoms about their mean positions due to lattice oscillations. Since the lattice oscillations decreases at low temperature the scattering of electron waves falls and the conductivity therefore increases rapidly as the temperature reaches absolute zero. There is a limiting value beyond which the conductivity will not increase. In general, purer the specimen higher is the conductivity. the conductivity of many conductors decreases linearly as the temperature is increased above the room temperature but below this temperature the conductivity increases markedly.

Temperature dependence of electrical resistivity and conductivity in semiconductors:

The electrical conductivity of the semiconductors changes appreciably with temperature variations. At absolute zero, it behaves as an insulator. At room temperature, because of thermal energy, some of the covalent bonds of the semiconductor break. The breaking of bonds sets those electrons free, which are engaged in the formation of these bonds. This results in few free electrons. These electrons constitute a small current if potential is applied across the semiconductor crystal. This shows the conductivity for intrinsic semiconductor increases with increase in temperature as given by $\eta$=A exp(-$E_g$/2kT) where $\eta$ is the carrier concentration, $E_g$ is the energy band gap and T is the temperature and A is constant. In case of extrinsic semiconductors, addition of small amount of impurities produces a large number of charge carriers. This number is so large that he conductivity of an extrinsic semiconductor is many times more than that of an intrinsic semiconductor at the room temperature. In n-type semiconductor all the donors have donated their free electrons at room temperature. The additional thermal energy only serves to increase the thermally generated carriers. This increases the minority carrier concentration. A temperature is reached when the number of covalent bonds that are broken is so large that the number of holes is approximately equal to the number of electrons. The extrinsic semiconductor then behaves as intrinsic semiconductor.

**Q3a** Explain the effect of a dielectric on the behavior of a capacitor.

**Ans 3a** Effect of dialectic on the behavior of a capacitor:

Suppose that two large plane parallel plates separated by a distance d(meter) in vaccume are maintained at a potential difference V. the plates will become charged positively and negatively with charges $\neq$Qo and a uniform electric field with intensity E=v/d will be created between the plates. The magnitude of the charge accumulated on each plate is proportional to the applied p.d, i.e. $Q_0 \infty V$ or Qo= CoV, where Co is defined as the capacitance.

By applying gauss theorem the magnitude of the flux density D with the parallel plates is given by D=Qo/A since the electric field strength E is related to the flux density by the relation D= OE, the field strength in the region between the plates is given by E=D/Eo = Qo/AEo. Since V=Ed, the capacitance of the system is given by Co=Eo A/d where Eo is termed as the absolute permittivity of free space and is expressed in farads meter. The value of Eo can be determined from experiment and is its value is nearly equal to 10-9/36λ if the space between the plates is now filled with a dielectric and V is kept constant, it is found that the value of charge is found that the value of charge is in reused to a value given by Q=cv hence the new capacitance is given by C=E A/d where E is defined

As the absolute permittivity of the dielectric and the ratio $\in_r = \frac{c}{c_0} = \frac{\in}{\in_0}$ is called the relative permittivity or the dielectric constant of the materials.

**b** Explain the ionic and orientational polarization

**Ans 3b** Ionic polarization: The ionic polarization takes into account of the fact that when some of the atoms in the molecule have excess of positive or negative charge (resulting from the ionic character of the bonds), an electric field will tend to shift the positive ions relative to the negative ions. This leads to an induced moment of different origin from that induced by electron clouds shifting relative to the nuclei. The ionic Polarization measures the shift of the ions relative to each other just a the electronic Polarization measures the shift of the electrons relative to the nucleus.

Orientational polarization: If two different atoms form a chemical bond, one of the two is more likely to part with one or more of its valence electrons than the other. When $Z_{Ae}$ and $Z_{Be}$ represents the nuclear charge on the two atoms where Z represent the atomic number and if A atom has the tendency to give the valence electrons to the atom B, there are more than $Z_{\mathbf{B}}$ electrons around the nucleus of atom B and fewer than $Z_A$ electrons around that of atom A. so atom A is more electropositive than atom B. consequently, the bond between atom A and B may be said to be of ionic kind and therefore it is clear that the molecule AB carries an electric dipole moment even in the absence of an electric field. For molecule consisting of more than two atoms, several atoms may carry a permanent dipole moment and the resulting dipole moment as a whole is obtained by the vector addition of the moments associated with the various bonds. When an external field 'E' is applied to the molecule carrying a permanent dipole moment, the former will tend to align the permanent dipole along the direction of E. the contribution of this process of this orientation of permanent dipoles to the polarization P is called ORIENTATIONAL OR DIPOLAR POLARIZATION.

**Q4** Explain the terms dielectric losses and dielectric constant.

**Ans 4a** ( i) Dielectric Constant

Every insulation material has the capacity to store charge when placed in between two conducting plates as in capacitors. Relative permittivity or dielectric constant, it is the ratio of the capacitance of a capacitors with a specified dielectric material placed between the plates, to the capacitance of the same capacitor with free space i.e. air between the plates.

(ii) Dielectric Loss

When an insulating material is subjected to an alternating voltage except in the case of purified gas as an insulator, there is some consumption of power due to flow of small amount of leakage current. This loss is called dialectic loss. Dielectric loss increases with increase in applied voltage and frequency.

**b** What are the important requirements of a good insulating material?

**Ans.4b** Important requirements of good insulating materials: -

The requirement of good insulating materials can be classified as electrical, mechanical, thermal and chemical. Electrically the insulating materials should have high resistivity to reduce the leakage current and high dielectric strength to enable it to with stand higher voltage with out being punctured or broken down. Also the insulator should have small dielectric loss.

Insulators should have low density; a uniform viscosity for liquid insulators ensures uniform thermal and electrical properties.

Liquid and gaseous insulators are used also as coolants. For example, transformer oil, Hydrogen and Helium are used for both insulation and cooling purposes. For such materials, good thermal conductivity is desirable. The insulators should also have small thermal expansion to prevent mechanical damage. It should be none ignitable or if ignitable, it should be self-extinguishable.

Chemically, the insulators should be resistance to oils, liquids, gas fumes, acids and alkalis. It should not deteriorate by the action of chemicals in soils or by contact with other metals. The insulators should not absorb water particles, since water lowers the insulation resistance and the dielectric strength.

Insulating materials should have certain mechanical properties depending on the use to which they are put. Thus when used for electric machine insulation the insulator should have sufficient mechanical strength to withstand vibration. Good heat conducting property is also desirable in such cases Example of insulating materials are mica & porcelain. Mica sheets are used for the insulating leaves between commutator segments.

Porcelain insulators are used for transmission line insulators, conductor, rail support on railways etc.

**Q5 a** Differentiate between diamagnetic, paramagnetic and ferromagnetic materials.

Also give one example of each.

**Ans5a**. Diamagnetic materials:- These are the materials whose atoms do not carry permanent magnetic dipoles. If an external magnetic field is applied to a diamagnetic material, it induces a magnetization in a direction opposite to the applied field intensity. For these materials the relative permeability is negative. These are hardly used as magnetic material in electrical /electronic engineering applications. Example: aluminium oxide, copper, gold, barium chloride, superconductor.

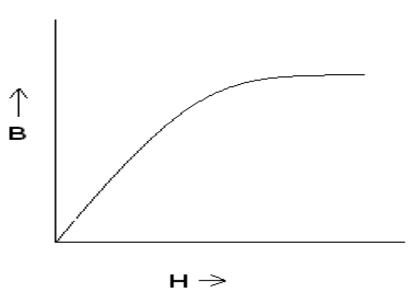
Paramagnetic material: - The atoms of these materials contain permanent magnetic dipoles. Individual dipoles are oriented in random fashion such that the resultant magnetic field is zero negligible. For these materials relative permeability is slightly greater than unity and it is independent of magnetizing force. Example: Chromium chloride, chromium oxide, manganese sulphate, air. In the presence of external magnetic field, paramagnetic materials get weakly magnetized in the field direction and the susceptibility is given by $\chi$=C/T where C is the curie constant and T is the temperature.

Ferromagnetic material: - These are materials in which the magnetic dipoles interact in such a manner that they tend to line up in parallel. A ferromagnetic substance consists of a number of small regions or domains, which are spontaneously magnetized. The direction of magnetization varies from domain to domain. The resultant magnetization is zero or nearly zero as the domains are randomly oriented. The relative permeability is very high. The ferromagnetic materials are widely used in the industries. Example: Iron, nickel, cobalt. The susceptibility of these is given by $\chi$=C/T-$T_c$ where C is curie constant, $T_c$ is the Curie temperature above, which the ferromagnetic substance behaves as a paramagnetic substance.

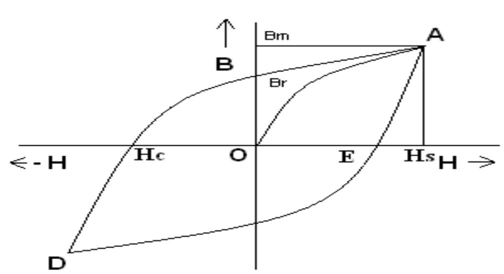
**b.** Draw B-H curve for magnetic materials used in electric machines and explain hysteresis loop.

**Ans 5b**. (i) B.H Curve for Magnetic Materials

A magnetic material is composed of magnetic dipoles oriented in random direction is zero. When a magnetic material is magnetized by applying a magnetizing force (= MI), the magnetic dipoles start orienting themselves in the direction of applied magnetic force. As the magnetizing force is increased by increasing the MI, more and more of the magnetic dipoles get oriented. A stage comes when almost all the magnetic dipoles gets oriented and as such any increase in magnetizing force does not result in any further increase in the dipoles getting oriented. The magnetic field is thus established in the forward direction.
This stage of magnetization is called magnetic saturation as shown in fig.



(i)



(ii)

When the magnetizing force is gradually reduced it is found that the magnetic dipoles again get de-oriented, the rate of de-orientation now being little less than the rate of orientation at a particular magnetizing forces. Thus the demagnetizing curve does not retrace back the magnetization curve as shown in fig (ii)

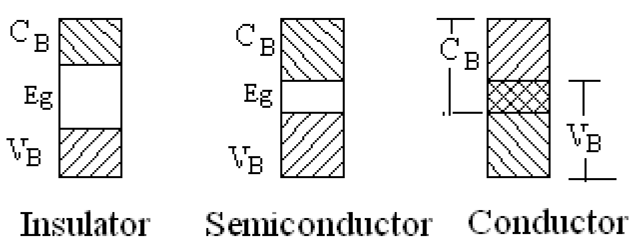
i. Hysterisis Loop

In fig (ii), OA is the magnetization curve and AB is the demagnetization curve. It may be seen that even when the magnetization force is reduced to zero, a small magnetization is left in the magnetic material. In the fig. OB represents the residual magnetization. If now the magnetizing force is applied in the negative direction, a small amount of magnetizing force OC will be spent in totally de magnetizing the material. Further increase in magnetizing force will orient the magnetic dipoles in the opposite direction thus establishing a magnetic field in the reverse direction.
When the magnetizing force is reduced to zero and then again increased in the forward direction the magnetization curve will follow the path DEA. The total curve ABCDEA is called the hysterisis loop.

**Q6 a** Classify the materials based on the energy band and explain them.

**Ans 6a.** Classification of materials based on energy bands

With reference to different band structures shown in fig. below we can broadly divide solid into conductors, semiconductors, and insulators. Conductors contain a large number of electrons in the conduction band at room temperature. No energy gaps exist and the valence and conduction bands overlap.




Insulator is a material in which the energy gap is so large that practically no electron can be given enough energy to jump this gap.

These materials might conduct little electricity if their temperature are raised to very high values enabling a number of electrons to join the conduction band. A semiconductor is a solid with a energy gap small enough for electron to cross easily from the valence band to the conduction band. At room temperature sufficient energy is available for valence electrons to bridge the energy gap to the conduction band, thus the material sustains some electric current.

The energy distribution of electrons in a solid is governed by the laws of Fermi – Dirac statistics.

The Fermi level is such that at any temperature, the number of electrons with greater energy than the Fermi energy is equal to the number of unoccupied energy levels lower than this. In conductors, the Fermi level is situated in a permitted band (since the valence band and conduction band overlap with no energy gap.). In insulators, it lies in the centre of the large energy gap while in semiconductors it lies in the relatively small energy gap.

**b** Explain the term mobility, doping, diffusion, ferroelectricity.

**Ans 6b.**

Mobility: Average drift velocity of the electrons in an applied field is proportional to the field, the absolute magnitude of the proportionality factor eq/m, called the mobility of the electrons, which is denoted by $\mu$. The mobility may thus be defined as the magnitude of the average drift velocity per unit field.

The mobility of the electrons can be determined by knowing the conductivity of the material and estimating the number of free electrons. Unit of mobility is $m^2$/volt.sec

Doping: Semiconductors in its extremely pure form are called intrinsic semiconductor These intrinsic semiconductor to which some suitable impurity is added in extremely small amount are called extrinsic semiconductor. This process is called doping and impurities are called doping agent. Usually the doping agents are pentavalent atom such as arsenic, antimony or trivalent atom such as gallium, indium, aluminium etc.
Ferroelectricity: Ferroelectric materials have a high dielectric constant, which is non linear I.e. it depends to a considerable extent on the intensity of the electric field such materials exhibit hysterisis loops, I.e. the polarization is not a linear function of the applied electric field. If the center of gravity of the positive and the negative charges in a body does not coincide in the absence of an applied electric field, the substance has an electric dipole moment and is said to be spontaneously polarized. Such a substance is called ferroelectrics and the phenomenon is called Ferro electricity. It contains small regions, which are polarized in different directions, even in the absence of an electric field. When the temperature exceeds a certain value called the curie point, the substance looses its ferroelectrics properties.
Ex: Rochelle salt, potassium dihydrogen phosphate, barium titan ate.

Diffusion: Although the mobility of the carriers in a semiconductor is greater than that of the electrons in a metal, the conductivity in the former is much less than that in the latter because of the too few current carriers. The conductivity is so less that the random movement of the carriers due to unequal carrier densities plays a greater part in conduction than the drift due to the applied fields. Diffusion arises essentially from density difference and the resulting current is called diffusion currents.
The defining equation for diffusion currents in one direction are

$$J_n = eD_n \frac{\partial n}{\partial x} \quad \text{for electrons}$$

$$J_P = -eD_P \frac{\partial P}{\partial x} \quad \text{for holes}$$

Where $J_n$ = diffusion current density of electrons

$J_P$ = diffusion current density of holes

$D_n$ =diffusion constant of electron

$D_P$ = diffusion constant of holes

$_n\frac{\partial n}{\partial x}$ = gradient of electron density

$\frac{\partial P}{\partial x}$ =gradient of hole density.

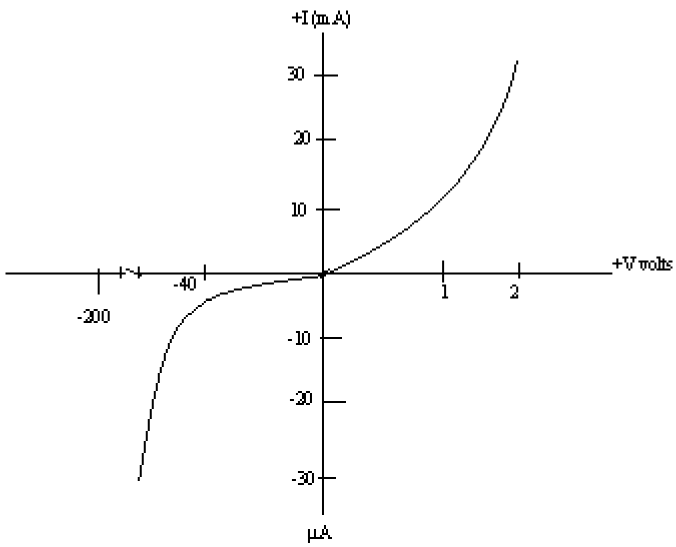
Therefore, the diffusion current due to the random motion of carriers from the dense to the less dense regions is proportional to the gradient or rate of increase of carrier density with distance.

The coefficient of proportionality is called the diffusion constant and is denoted by D.

**Q7a** What is a PN junction? Draw and explain V-I Characteristics of a PN junction diode.

**Ans 7a**.
P-N junction:

When a p-type semiconductor is suitably joined to an n-type semiconductor the contact surface so formed is called p-n junction. All the semiconductor devices contain one or more p-n junction. P-N junction is fabricated by special techniques namely growing, alloying and diffusion methods. The p-type semiconductor is having negative acceptor ion and holes. The n-type semiconductor is having positive donor ions and negatively charged electrons. When the two pieces are joined together and suitably treated they form a p-n junction.




Characteristics of a typical p-n junction diode

The leakage current for reasonable voltages in the reverse direction ranges between 0.01 and 1 µA depending on the semiconductor material and the doping level of the impurities. Several variations of this simple diode have been developed.

**b** Give the application and properties of silicon iron alloy and nickel iron alloy.

**Ans 7b**
Silicon Iron Alloy: Pure iron has low resistivity, which results in higher eddy current losses. The losses can be minimized by increasing the resistivity of the material, which is achieved by adding 1 to 4% of silicon to iron. Silicon increases the electrical resistivity of iron. It reduces hysterisis loss. The magnetostriction effect is also reduced.

Silicon iron alloy is used in the form of thin sheets called laminations. These laminations are used in transformers, small machines and large turbo –generators.

Nickel iron alloy: A group of iron alloys containing between 40 to 90% nickel have much higher permeability's at low flux density and lower losses than ordinary iron. The important alloys are permalloy and mumetal. Mumetal has lower permeability but higher resistivity. Addition of small amounts of other elements to nickel iron alloys improves their magnetic properties.

Nickel Iron alloy is widely used in transformer cores and loading coils for telephone circuits instrument transformers, for magnetic circuits of instruments, for magnetic screens of electronic equipments.

**Q8a** What is the function of a relay? How they can be classified in different categories?

Explain in brief.

**Ans8a**

Relays:

Relays are primarily switching devices employed to control large power or to perform a series of switching operations. They can be classified into the following five broad categories:

Electromagnetic
Thermal
Electronic valve
Transistor
Miscellaneous

Electromagnetic relays can be subdivided as follows:

Moving iron types which use the principle of armature attraction to close a contact assembly.
The contacts may be directly operated or through linkages.

Reed types the force of attraction between two thin magnetic strips contain in a glass tube surrounded by a field is used.

Moving coil types are sensitive relays operated by small currents.

Induction types are AC operated only and work on the same principles as induction watt meters.

**b** What is Metal Oxide film resistor?

**Ans 8b.**

Metallic –Oxide Film Resisors

When a solution of stannic chloride is sprayed on to a glass or porcelain at red heat, hydrolysis takes place and yields a glass –like layer of oxide. This layer may vary in thickness from a few hundred to many thousands of angstrom units, has a milky, translucent appearance and is electrically conducting. Additions of antimony trichloride to the spraying solution impart a blue color to the oxide layer. No film will be produced with pure antimony trichloride solution. Oxide films obtained by this process are hard, adherent to glass and ceramics and unaffected by chemical reagents. Besides the electrical resistance can be varied over a wide range of value by changing the composition of spraying solution. Usually films which have comparatively small temperature coefficients of resistance and small resistivities are used. The following are some of the advantages of oxide-film resistors.

1. No oxidation.
2. Soldering of end connections is comparatively easy
3. Maximum temperature ratings higher than that for carbon.
4. Reasonably low temperature- coefficient.

**Q9a** Describe diffused junction technique of fabrication in brief.

**Ans 9a.**

Diffused Junction technique:

This is the most common technique at the present time. The basic material is homogenous, single crystal n-type semiconductor. The is heated in an inert atmosphere and acceptor impurities in gaseous form, e.g. born, are diffused into the surface until a compensated p-type layer results. The rate of diffusion is governed by an equation of the form $JD_h = -eD_h\, dp/dx$, but the impurities diffuse at a much slower rate than carriers. Net p-type impurity concentration can be closely controlled by the furnace temperature and the concentration of the dopant. The area for diffusion is selected by a masking technique in which the surface of the n-type slice is oxidized by exposure to a water oxygen mixture at elevated temperatures, window are cut in the oxide by the photo etching techniques and diffusion only takes place where the oxide has been removed. Ohmic contact in the p-region is usually made by an evaporated metal film. In the discrete diode structure, each diode is separated from the parent slice and bonded to a suitable leader which serves as the other contact to diode.

**b** Give general properties of Junction field effect transistor (FET)

**Ans. 9b**

General properties of Junction field effect transistors (JFETs):

This class of transistors may be distinguished from solid-state devices by several features, which are common to all members of the class:

Flow of carriers in a particular device is controlled by the application of an electric field, which permeates into the main conduction path in a semiconductor; this gives rise to the term field effect.

Current flow along the main conduction path is almost entirely due to the motion of majority carriers; injection of minority carriers, a mechanism which is essential for the operation of the bipolar transistor is not a necessary requirement in field effect devices.

The generic term unipolar is therefore used as an alternative to field effect to describe the devices since they rely only on one type of carrier for current transport.

## TEXTBOOK

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