Q.2 a. Explain the electron gas model of a metal.

Answer:

The electron gas model of a metal

The mechanism inside a current carrying conductor can be explained by the kinetic theory of gases. This is referred to as the electron gas theory of gases. The valance electron are supposed to be completely detached from the atoms. The basis for the electron gas theory is the picture of a conductor as a lattice (regular arrangement which remains fixed) of positive ions, through which an electron cloud or gas can move. The number of electrons in such a gas is equal to the number of valance electrons. If for the mono-valent metals one assumes that the number of free electrons in a given volume is equal to the number of atoms in the same volume, the former can be found by knowing the Avogadro's number. When not affected by external electric fields the valance electrons oscillate equally in all directions among the atoms just like the molecules in a gas. The statistics of this random electron velocity will be analogous to the statistics of the molecular motion in a gas.

In the absence of an electric field, the random velocities of the electrons will be determined by the temperature of the conductor. The temperature of the electrons need not be the same as that of the conductor. This temperature is a measure of kinetic energy of the electron.

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

Answer:

Temperature dependence of electrical resistivity and conductivity in conductors: 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.

Q.3 a. Explain in brief the various types of polarization phenomena.

Answer:

Polarization:

A dielectric consists of molecules the atomic nuclei of which are effectively fixed, relative to each other. In the absence of any external field the electrons are distributed symmetrically round the nucleus at any instant. When an electric field is applied the electrons of the atoms are acted upon by this field. This causes a movement of the electrons which are displaced in a direction opposite to that of the electrons which are displaced in a direction opposite to that of the field. This movement is opposed by the attractive forces between nuclei and electrons. The resultant effect is to separate the positive & negative charges in each molecule so that they behave like electric dipoles. The strength of each dipole is given by the dipole moment, which in its simplest form, consists of two equal point charges of opposite sign $\pm Q$ separated, by a distance d.

When the dipoles are created the dielectric is said to be polarized or in a state of polarization considers the dielectric to be composed of a large number of elementary cylinders each of length l in the direction of the applied field and of cross section δA. Let a uniform field of strength E be applied normal to the plates. This polarizes the dielectric inducing dipoles in each elementary cylinder, and charges δq appears on either end of the cylinder. The charge density, σ on the the surface δA of the cylinder is given by

$$\sigma = \frac{\delta q}{\delta A}\left(\frac{c}{m^2}\right) = l\frac{\delta q}{\delta A} = \frac{m}{\delta V}$$

Where m is the dipole moment and δV is the volume of the elementary cylinder. If the number of dipoles per unit volume be N i.e. if $N = \frac{I}{\delta V}$ then σ =Nm. The product Nm is called the polarization (P) of the dielectric and is the total dipole moment established within unit volumes of the insulating medium. Thus a dielectric subject to a homogeneous field carries a dipole moment P per unit volumes which may be written as

P=Nm.

Polarization are of three types.

(i) Electric polarization

(ii) Ionic polarization.

(iii)Dipolar polarization.

Electric polarization or polarization density is the vector field that expresses the density of permanent or induced electric dipole moments in a dielectric material. The SI unit of measure is coulombs per square metre.

The electric polarization **P** is defined as the difference between the electric fields **D** (induced) and **E** (imposed) in a dielectric due to bound and free charges, respectively. In cgs, $p = \frac{D - E}{4\pi}$ which can be written in terms of the electric susceptibility (χ_e) as

$P = \chi_e E$

In MKS, $P = \in_0 \chi_e E$

where $\in_0$ is the permittivity of free space.

Ionic polarization is polarization which is caused by relative displacements between positive and negative ions in ionic crystals (for example, NaCl).

If crystals or molecules do not consist of only atoms of the same kind, the distribution of charges around an atom in the crystals or molecules leans to positive or negative. As a result, when lattice vibrations or molecular vibrations induce relative displacements of the atoms, the centers of positive and negative charges might be in different locations.

These center positions are affected by the symmetry of the displacements. When the centers don't correspond, polarizations arise in molecules or crystals. This polarization is called **ionic polarization**.

Ionic polarization causes ferroelectric transition as well as dipolar polarization. The transition which is caused by the order of the directional orientations of permanent dipoles along a particular direction is called **order-disorder phase transition**. The transition which is caused by ionic polarizations in crystals is called **displacive phase transition**

Orientational Polarisation: 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 charges of the two atoms where Z represents the atomic numbers and if A atom has a tendency to give valence electrons to the atom B, there are more than Z_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 A and B may be said to be of an 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 bonds may carry a permanent dipole moment and the resulting permanent dipole moment as a whole is obtained by vector addition of the moments associated with the various bonds. When an external field ‘E’ is applied to a 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 orientation of permanent dipoles to the polarisation P is called Orientational or Dipolar Polarisation.

b. Derive Clausius-Mosotti Relation.

Answer: Page number 145-147 of text book

Q.4 a. What are the important requirement of a good insulating material.

Answer:

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 without 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.

b. What is ferro-electricity? Explain in brief.

Answer:
Ferro electricity: 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.u.

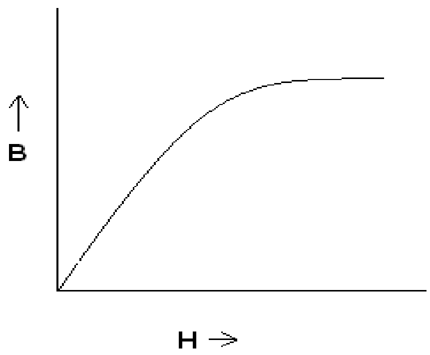
Q.5 a. Draw B-H Curve for magnetic materials used in electric machines and explain hysteresis loop?

Answer:

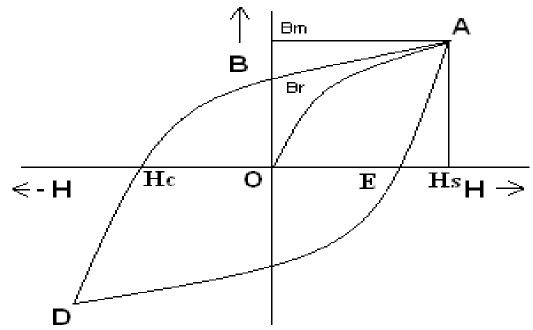
B.H Curve for Magnetic Materials

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)

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.

b. Explain the following in brief:
(i) Nickle-iron alloy
(ii) Ferrites

Answer:
i) 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.

ii) Ferrites: A group of magnetic alloys exhibit the property of magnetization which changes with the percentage of the different constitutes atoms in the alloy. A typical example of this type of alloy is $X0Fe_20_3$ with X=Mn, Co, Ni, Cu, Mg, Zn, Cd or Fe^{++}. The alloys are called ferrites.
The manganese ferrite is a 1:1 mixture of manganese oxide and iron oxide.

Suitability of ferrites for high frequency applications:-

Ferrites are widely used in computers and in micro wave equipments. Ferrites are advantageous at high frequencies because of low eddy current losses. Ferromagnetic metals and alloys cores have to be eliminated in order to reduce the losses. At high frequencies laminations have to be so thin that both fabrication and assembly become expensive processes. At these frequencies duet cores which consists of fine particles of ferromagnetic material insulated form each other may be used. But these have the disadvantage of diluting the ferromagnetic martial and decreasing the effective relative permeability. a further disadvantage is that the flux density varies through the core due to non-uniform spacing of the particle. At points where there is greater concentration of particles; the flux density is likely to be higher entailing larger hysterises losses.

For this reason, Ferrites are used for high frequency application.

Q.6 a. Classify the materials based on the energy band and explain them.

Answer:
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.

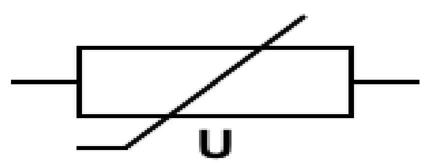
b. What is Hall effect? Derive the relation for Hall voltage.

Answer: Page no. 255-256 of text book'

Q.7 a. Explain the following:
(i) Thermistor
(ii) Varistor

Answer:
Thermistors and Varistors
Thermistors and varistors are non-linear resistances. The difference between the two is that the former make use of the resistive property of the semi-conductors while the latter make use of rectifying property of the metal semi-conductor contacts.
(i)Thermistors. Since free charges in a semi-conductor are produced due to thermal agitation of its atoms there is steep rise in the conductivity of certain semi-conductors with temperature. By measuring the conductivity it is possible to determine the temperature. Thus very low and very high temperatures can be measured by building semi-conductor thermometers or bolometers. Semi-conductor bolometers are exceedingly small in size because of the very high specific resistance of the semi-conductor. The small size of such bolometers cuts down the time required for them to attain the temperature of the surrounding medium. Thermistors are used to regulate voltage or current intensity. The oxides of copper, uranium, titanium and other elements are most extensively used as Thermistor materials

ii) A varistor is a voltage dependent resistor (VDR). The resistance of a **varistor** is variable and depends on the voltage applied. The word is composed of parts of the words "*var*iable res*istor*". Their resistance decreases when the voltage increases. In case of excessive voltage increases, their resistance drops dramatically. This behavior makes them suitable to protect circuits during voltage surges. Causes of a surge can include lightning strikes and electrostatic discharges. The most common type of VDR is the metal oxide varistor or MOV.
Varistor symbol The following symbol is used for a varistor. It is depicted as a variable resistor which is dependent on voltage, U.

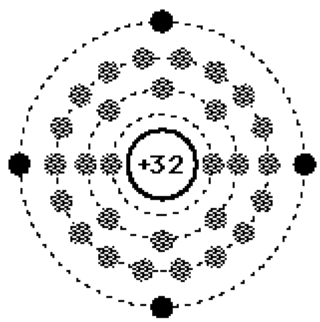


Varistor Symbol

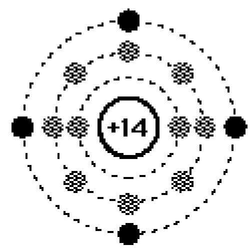
Types
The most important types are:
Metal oxide varistor – Described above, the MOV is a nonlinear transient suppressor composed of zinc oxide (ZnO)
Silicon carbide varistor – At one time this was the most common type before the MOV came into the market. These components utilize silicon carbide (SiC). They have been intensively used in high power, high voltage applications. The disadvantage of these devices is that they draw a significant standby current; therefore a series gap is required to limit the standby power consumption.

b. Describe the atomic structure of silicon and germanium.

Answer:
Germanium: - It is one of the most common semiconductor material used for the application in electronics. The atomic number is 32. The number of electrons in the first, second, third and fourth orbit are 2, 8, 18and 4. It is clear that germanium atom has four valence electrons in the outermost orbit. It is known as tetravalent element. The germanium atoms are held together through covalent bonds. The forbidden gap in this material is very small 0.7ev. So small energy is sufficient to lift the electrons from valence to conduction band.



Germanium



Silicon

Silicon: - Silicon is another most commonly used semiconductor. Its atomic number is 14.The number of electrons in first, second and third orbit are 2, 8 and 4. The silicon atoms are also having four valence electrons and are known as tetravalent element. The various silicon atoms are held together through covalent bonds. The atoms of silicon are arranged in orderly pattern and form a crystalline structure. The forbidden energy gap in this material is quite small i.e. 1.1ev. It also needs small amount of energy to lift the electrons from valence to
conduction band.

Q.8 a. What is Metal Oxide film resistor? Explain in brief.

Answer:
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

b. What are the different types of cores? Explain in brief.

Answer:
Types of Cores-
In Order to minimize losses while maintaining high flux density. The core can be made of laminated sheets insulated from each other or insulated powdered iron granules and ferrite material can be used.

Laminated Core:-
Each laminated section is insulated by a very thin coating of iron oxide and varnish. This insulating borders increase the resistance in the cross-section of core of reduce the eddy currents but allow a low reluctance path for high flux density around the core. Transformers for audio frequencies are generally made with a laminated iron core. A shell type core formed with a group of individual laminations.

Powdered Iron Core:-
To reduce eddy currents in the iron core of an inductance for radio frequencies, powdered iron is generally used. It consists of individual insulated granules pressed into one solid form.

Ferrite Core-
The ferrites are ceramic materials that provide high values of magnetic flux density but with the advantage of being an insulator. Therefore, a ferrite core can be used in inductance for high frequencies with minimum eddy current looses.

Q.9 a. Give general properties of Field Effect Transistor (FET).

Answer:

General Properties Of Field Effect Transistors (FETs):
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

b. Describe diffused junction technique of fabrication in brief.

Answer:

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 JDh = -eDh 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.

Text Book

Introduction to electrical engineering materials by C.S. Indulkar & S. Thiruvengadam, 6th Edition, Reprint 2012 Edition, S Chand & Company, New Delhi