**Q.2 a. Explain the effect of magnetic field on superconductor. (8)**

**Answer:**
**Effect of magnetic field on superconductors:**
It is possible to destroy superconductivity by the application of a strong magnetic field. When the magnetic field exceeds a certain critical value, the superconducting state disappears, the magnetic field penetrates the material and the electrical resistance is restored. The transition from the superconducting to the conducting state is reversible. The critical magnetic field $H_c$ is a function of temperature T.

The disappearance of superconductivity by means of a strong magnetic field is the principle on which switching elements like the cryotrons operate. Superconductors are used for producing a magnetic field of about 50 tesla

**b. Name and explain the factors on which resistivity of a conducting material depends. (8)**

**Answer:**
Various factors affecting the resistivity of electrical materials are.

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

ii. Alloying :- The electrical conductivity of a solid solution alloy drops off rapidly with increased alloy content. In other words, the addition of small amounts of impurities leads to a considerable increase in resistivity.

iii. Cold Work :- Mechanical distortion of the crystal structure decreases the conductivity of a metal because the localized strain interfere with electron movement . Thus hard drawn copper wire has a lower conductivity than annealed copper. Hard drawn copper has a resistivity of $1.9 \times 10^{-6}$ ohm-cm at 20˚ C whereas annealed copper has a resestivity of $1.72 \times 10^{-6}$ ohm-cm at 20˚C

Age Hardening :- Age hardening increases the resistivity of an alloy.

**Q.3 a. Explain Ionic and Dipolar polarization. (8)**

**Answer: Refer page 143 of Text book**

**b. Explain Claussis Morotti relation. (8)**

**Answer:**
**Clausius Mossotti Relation** :
Each dipole moment interacts with its neighbor through its local electric field and therefore the theory of dielectrics in the case of dense substances such as solids or liquids where the dipoles are close together is much more complicated than that for rarefied substances. The main problem which arises in the case of solids and liquids in the calculation of what is known as the internal, local or

the Lorentz field Ei, which is defined as the field acting at the locatio[33]assuming that the internal field is equal to the applied field. However, in solids and liquids the molecules are so close together that the field seen by a given particle is determined in part by the dipoles carried by the surrounding particles; in general therefore the internal field Ei is not equal to the applied field E. The dipole moment *m* induced in each of the atoms of a string of atoms of polarisability α is that given by

$$m = \alpha \mid Ei$$

If there are *N* dipoles per $m^3$

$$P = Nm$$
$$= N\alpha\ Ei$$

This enables us to derive a relationship between the measured dielectric constant, $\epsilon_r$ in terms of the polarisability , α.

Thus $D = \epsilon_0 E + P$ [ where, E is external applied field]

$$= \epsilon_0 E + N\alpha\ Ei$$

The observed dielectric constant is defined by

$$D = \epsilon_0 \epsilon_r E$$

Hence, $\epsilon_r = 1 + (N\alpha \mid Ei \mid) / (\epsilon_0 \mid E \mid)$ (i)

In order to determine $\epsilon_r$, from the observed experimental data, It is first necessary to determine the internal field | Ei|.

The internal field | Ei| is equal to the applied field | E| plus the field produced at the location of the particular atom by the dipoles on all other atoms. As a first approximation, the field produced due to the dipoles can be expressed in terms of the polarization, P.

or , $Ei = E + (v/\epsilon_0)P.$

Where v is proportionality constant which takes on different values depending upon the particular symmetry conditions which are met. For the special case of an isotropic substance or for one having cubic symmetry.

$$v = 1/3$$

And $Ei = E + P/3\epsilon_0$ (ii)

Equation (ii) along with the equation

$$P = N\alpha\ Ei$$
$$Ei = E/[1 - (N\alpha/3\epsilon_0)]$$

Which along with equation (i) gives

$$\epsilon_r = [1 + (2N\alpha/3\epsilon_0)]/[1 - (N\alpha/3\epsilon_0)]$$

$$\epsilon_r - 1/\epsilon_r + 2 = N\alpha/3\epsilon_0$$

This result is known as Clausius Mossotti Relation.

**Q.4 a. Explain the terms dielectric losses and dielectric constant. (8)**

**Answer:**

**Dielectric Loss:** When an insulating material is subjected to an alternating voltage except in the caseof 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.

**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.

**b. What is Piezo-electricity? Explain in brief. (8)**

**Answer:**
**Piezoelectricity:** When an electric field is applied to a substance it become polarized, the electrons and nuclei assume new geometric positions and the mechanical dimensions of the substance are altered. The phenomenon is called electrostriction. The reverse effect i.e. production of polarization by the application of mechanical stresses can take place only if the lattice has no centre of symmetry, the phenomenon being known as piezoelectricity.

**Examples of Piezoelectric materials:-**
Rochelle salt, quartz and $BaTi0_3$ exhibit piezoelectric properties. The change in crystal dimensions under the action of an electric field differs for different directions with respect to the crystals axis of symmetry. Therefore, different deformations will be obtained from a crystal of rods and plates having different orientation are cut from the crystal and placed between the condenser plates.

**Application of piezoelectric materials**:-Piezoelectric materials serve as a source of ultra sonic waves. At sea, they may be used to measure depth, the distance to shore, the position of icebergs, submarines and the like.

**Q.5 Differentiate between diamagnetic, Paramagnetic and ferromagnetic materials. Also give one example of each. (16)**

**Answer:**
**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 material 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 behave as a paramagnetic substance

**Q.6 a. What are the different types of semiconductor? Explain n-type and p-type semiconductor with the help of energy band diagram. (8)**

**Answer:**

**Semiconductors are of two types:**

**i. Intrinsic semiconductors:**

An intrinsic semiconductor is one which is made of the semiconductor material in its extremely pure form. In a semiconductor the energy gap is so small that even at ordinary room temperature, there are many electrons which posses sufficient energy to jump across the small energy gap from the valence to the conduction band. However , when each electron gets liberated into conduction band , a positively charge hole is created in the valence band, when an electric field is applied to intrinsic semiconductor at a temperature greater than $0^0$K, conduction electrons move to the anode and the holes in the valence band move to the cathode. Hence semiconductor current consists of movement of electrons and holes in opposite direction.

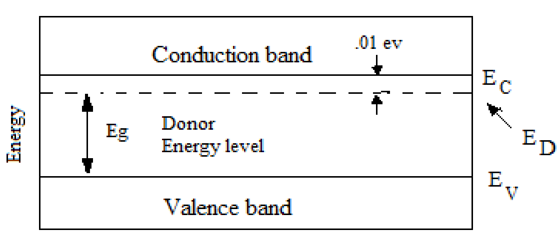
**ii. Extrensic semiconductor :**

Those intrinsic semiconductors to which some suitable impurity or doping agent is added in extremely small amount are called extrinsic semiconductors. Usually the doping agents are pentavalent. Antimony, arsenic atoms or trivalent atom (gallium, aluminium, boron).

Pentavalent doping atom is known as donor atom because it donates or contributes one electron to the conduction band of pure germanium. Trivalent doping atom known as accepter atom because it accepts one electron from the germanium atom.

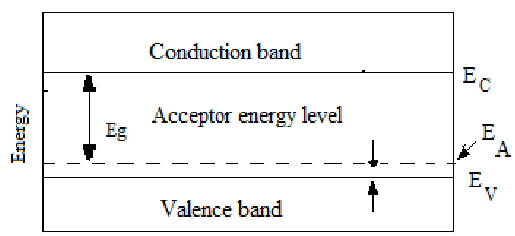
Depending upon the impurity added, extrinsic semiconductors can be further subdivided into two classes :

**N-type semiconductor.**




Energy band diagram of n-type semiconductors

**P- Type semiconductor.**




Energy band diagram of p-type semiconductors

If to pure germanium, a small amount of pentavalent impurity i.e. antimony is added.Four of the five valence electrons will occupy covalent bonds, and the fifth will be nominally unbound and will be available as a carrier of current. These are called N-type semiconductor.

In this type of semiconductor electron are the majority carriers.

If a trivalent impurity such as boron, Gallilium etc. is added to an intrinsic semiconductor, only three of the covalent bonds can be filled, and the vacancy that exists in the fourth bond constitutes a hole. These are called P type semiconductor in which holes are the majority carriers

**b. What is diffusion? Explain. (8)**

**Answer:**

**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 are called diffusion currents .

The defining equation for diffusion currents in one direction are

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

$$J_P = -eD_P \frac{\partial P}{\partial x}$$ 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

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

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

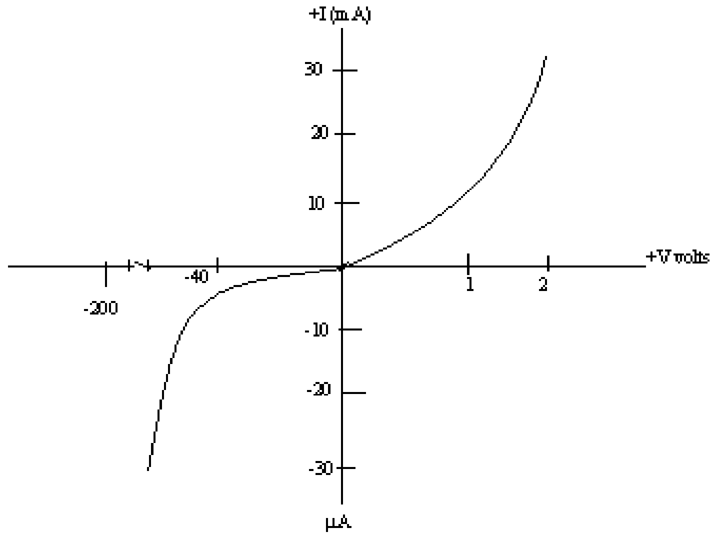
Therefore, the diffusion current due to the random motion of carriers from the dense to the less dense regions is proportional to the gradient or rate of increase of carrier density with distance.

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

**Q.7 a. What is a PN junction? Draw and explain V-I Characteristics of PN Junction diode (8)**

**Answer:**

**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. Explain the working of a tunnel diode. (8)**

**Answer: Refer page 301 from Book "Electronic Engineering Material and Devices by John Allison, TMH (1998)**

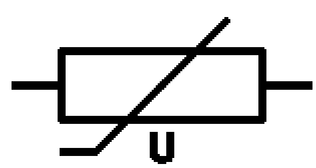
**Q.8 a. What is voltage sensitive resistor? What are the different types of voltage sensitive resistors? (8)**

**Answer:**

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. What are variable capacitors? Explain in brief. (8)**

**Answer:**
**Variable Capacitors-**
For tuning receivers and low-power transmitters air dielectric capacitors are usual. A two-gang variable capacitor suitable for used a radio receiver contains two variable capacitors operated by a single tuning control. In this construction. Fixed metal plated or vanes connected together form a stator and movable vanes connected together form a rotor. Capacitance is varied by rotating the shaft to make the rotor plates mesh with the stator plates. The movable vanes are spaced on the spindle by spacing washers so that they do not touch the fixed vanes at the point. The fixed vanes are insulated from the framework of the capacitor by mountings which are made of ceramic material. Full mesh of the two sets of vanes means maximum capacitance. Moving the rotor completely out of mesh provide minimum capacitance. The vanes can be suitably shaped to determine the law of variation of capacitance with respect to the angle of rotation. Losses in such air dielectric capacitors are small. The power factor at 1.5 MHz may be as low as 10-4 corresponding to a Q of 10.000.

**Q.9 a. Explain the operation of JFET with low drain voltage and draw the drain characteristics. (8)**

**Answer: Refer page 301 of Text Book**

**b. Discuss epitaxial diffused junction diode and its application. (8)**

**Answer:**
Such diodes are now being manufactured commercially on a large scale. The process involve the growing of a thin layer of single crystal semiconductor onto a supporting slice of parent material. The basic chemical reaction of silicon chloride in an atmosphere of $H_2$ at around $1200^0$C, Doped impurity layers and even compound semiconductors can be deposited by similar techniques. For discrete diodes, the parent slice called the substrate is highly doped to give it a low receptivity and the epitaxial layer lightly doped with the same impurity type. A pn junction is then formed in the layer and electrodes are deposited by the same processes that are used for diffused diodes. Diodes with high break down voltage and low capacitance can be fabricated in this way in the high resistivity. Epitaxial layer, while the low resistance supporting substrate reduces the series resistance of the diode.

**Application:** Epitaxy is used in nanotechnology and in semiconductor fabrication. Indeed, epitaxy is the only affordable method of high quality crystal growth for many semiconductor materials

## TEXT BOOK

I. Introduction to Electrical Engineering Materials by C.S. Indulkar and S. Thiruvengadam, 4th Edition, Reprint 2006 Edition, S. Chand and Company, New Delhi