UNIT	ELECTRONICS

The branch of physics, which deals with the development of electron emitting devices and their utilization, is called Electronics.

Q.1. What is a P - N junction? Explain the diffusion of charges and the formation of depletion (barrier) region across a p-n junction.

P - N JUNCTION

When a P-type semiconductor is joined to an N-type semiconductor, a P – N junction is formed. The region where the two materials are joined is called a P – N junction. Such a junction between P and N materials forms P – N junction diode or a Semi – conductor diode.

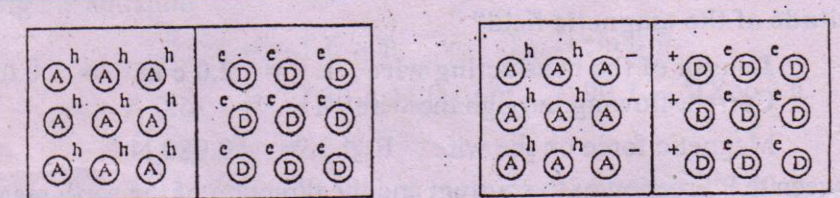

Fig.(1.1a) P and N materials at the instant they are joined; both are initially neutral.

Fig.(1.1b) The p-n junction showing charged ions after holes and electrons diffusion.

A = acceptor atom; h = associated hole; D = donor atom;
e = associated electron; + = positively charged ion; – = negatively charged ion

DIFFUSION OF CHARGES

Before joining, each of the two types of materials is electrically neutral. The reason is that each acceptor atom (A) and each donor atom (D) has the same number of electrons as protons. However, there is a greater concentration of electrons in the N-region as compared with their concentration in the P-region. Likewise, there is higher concentration of holes in the P-region as compared with the N-region. See Fig.(1.1a).

The carriers in each semiconductor move about in a random manner and diffuse from a region of high concentration to a region of low concentration.

(a) Some of the free electrons diffuse from the region of high concentration (N region) into the region of low concentration (P region).

(b) Simultaneously, some of the free holes diffuse from the region of high concentration (P region) into the region of low concentration (N region).

(c) Since the hole is the vacancy of an electron, when an electron diffuses into the P region the electron falls into the vacancy, that is it completes the covalent bond. This process is called electron – hole recombination.

(d) As a consequence , N region of the junction will have its electrons neutralizes by holes, leaving only positively charged ionized donor atoms which are bound and cannot move (immobile).

(e) Similarly the P region of the junction will have negatively charged ionized acceptor atoms which are also immobile.

(f) The region containing the uncompensated acceptor and donor ions is called depletion region.

(g) The transfer of these charges to either region disturbs the neutrality of the region, making the P region negative and the N region positive. This charge distribution is shown in Fig.(18.1b).

DEPLETION REGION (BARRIER REGION)

The region on either side of the P – N junction which becomes depleted (free) of the mobile charges carriers is called the depletion region. The thickness of this region is of the order of 10^{-6} m.

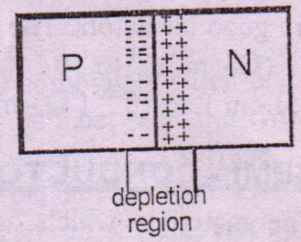

Fig.(1.2). The electric field E across the junction inhibits the diffusion current from the n- to p-side. There are no mobile charge carriers in the depletion region.

The accumulations of charge of opposite polarities in the two separated regions give rise to a potential difference and electric field across the junction region. The direction of the electric field is such that it opposes the flow of electrons from the n-region into the p-region, and the flow of holes from the p-region into the n-region. Therefore, after the initial surge of charge across the junction, the diffusion current dwindles to a negligible amount.

The region of the junction is populated by uncovered positive and negative ions. There are no mobile charge carriers in this region. The n-region electrons have migrated to the p-side and have filled the p-region holes. Because all charge carriers have been depleted (removed) from this region, it is called the **depletion region.**

Q.2.How are solids classified on the basis of their electrical resistively or conductivity?

ELECTRICAL CLASSIFICATION OF SOLIDS

The fundamental electrical property of a solid is its ability to conduct current. The requirement for electrical conduction is the presence of free charges within the material. On the basis of electrical properties, solids can be classified, as conductors, semiconductors and insulators.

CONDUCTOR

A substance which offers low resistance to the flow of electric current is called a conductor.

Current can pass easily through conductors. They contain free electrons. Metals such as silver, copper and aluminium are very good conductors. The conductivity of the conductors is of the order of 10^7 mho / m $(\Omega - m)^{-1}$. Their electrical resistivity is of the order of 10^{-7} ohm – metre $(\Omega - m)$.

INSULATOR

A substance which (at a particular voltage) does not allow the flow of electrons (current) through them is called an insulator.

They are very poor conductors of electricity. Charges are bound; no free electrons in insulators. Dry wood, diamond, glass, mica and polythene and most of the non-metals are good insulators. The conductivity of the insulators is very low, ranging between $10^{-10} (\Omega - m)^{-1}$ to $10^{-20} (\Omega - m)^{-1}$. Their electrical resistivity is of the order of $10^{10} (\Omega - m)$ to $10^{20} (\Omega - m)$.

SEMI - CONDUCTORS

The materials which have their conductivity in between those of conductors and insulators are called semiconductors. Elements of Group IV in the periodic table are semiconductors. For example, germanium and silicon are important semiconductors. Their conductivity lies between insulators and conductors. They have conductivity in the range of $10^{-4} (\Omega - m)^{-1}$ to $10^{-6} (\Omega - m)^{-1}$.

Q.3. Give a brief account of the energy band theory of solids. On the basis of this theory, distinguish among conductor, insulators and semi conductors.

ENERGY BAND THEORY

The energy of an electron in an isolated atom is quantized. The possible energies an atom can have are discrete and are known as atomic energy levels. When a large number of atoms are brought close together to form a solid, then as a result of the mutual interaction of the atoms, the energy levels associated with each atom are perturbed.. In particular the energies of the outer (or valence) electrons are perturbed significantly. The energy levels, which were sharp for individual atoms are broadened to become energy bands with forbidden energy gaps between the allowed bands. Normally, the electrons occupy the lower energy bands, known as valence bands, and the higher unoccupied bands are known as conduction bands. Ordinarily, we are concerned with the highest valence band and the lowest conduction band.

The properties of conductors, semiconductors and insulators can now be interpreted in terms of the occupancy of the conduction and valence bands.

CONDUCTORS

If the lowest conduction band contains some electrons but is not completely filled, the material is a conductor (Fig.1.3.a). Even a small external electric field can produce a flow of these electrons, and the material is a good conductor at all temperatures. There are some materials in which the valence

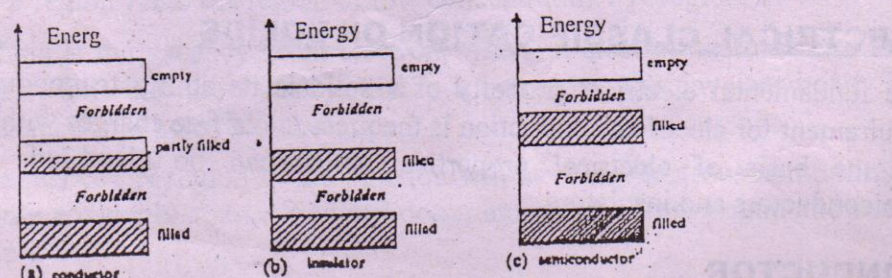

Fig. (1.3) (a) Conductors (b) insulator (c) Semi conductor band and conduction band overlap. Hence electron from the valence band can easily pass into the conduction band. They are also conductors.

INSULATORS

In an insulator, the top most valence band is completely filled and the conduction band is empty. The forbidden energy gap between the two bands is wide, Fig.(1.3.b). Modest temperature or electric fields are not sufficient to lift electrons to the conduction band. Electrons in the filled band are not free, and the material serves as a good insulator.

SEMICONDUCTORS

In semiconductors, like insulators, the top most valence band is completely filled and the conduction band is empty. However, the forbidden energy gap between the two bands is small Fig.(1.3.c). The thermal agitation, even at room temperature is sufficient to raise some electrons from the valence band to the conduction band. The electrons in the conduction band are free to transport charge. Further, the vacancies or holes left by the electron when they move to the conduction band also serve as charge carriers. Semiconductors are insulators at temperatures near 0 K but become somewhat conductors at somewhat higher temperature. They become steadily better conductors as the temperature is raised, because more electrons are transferred to the conduction band.

Q.4. Distinguish between intrinsic and extrinsic semiconductors.

There are two types of semi – conductors.

1. Intrinsic semiconductor.
2. Extrinsic semiconductor.

INTRINSIC SEMICONDUCTOR

The semi conductor in extremely pure form without any impurity is known as intrinsic semiconductor.

When a covalent bond is broken, an electron-hole pair is generated. The holes and electrons are mobile charges and can take part in electrical conduction. The conduction due to charges produced by pair generation in pure semi-conducting crystals is known as **intrinsic conduction.** The intrinsic current level is too low and so sensitive to small changes in temperature to be used for practical devices. Pure elemental silicon and germanium are intrinsic semi – conductors.

DOPING

In order to obtain desired conduction properties, a small amount of impurity in the ratio (1 : 10^6) is added to the pure semiconductor lattice. This process is called doping.

The process of mixing of impurity in the lattice of a semi – conductor material is called doping.

EXTRINSIC SEMICONDUCTOR

Those substances to which some impurities are added to obtain the desired conduction properties are called extrinsic semi – conductors.

The dopest semi – conducting materials are called extrinsic semi – conductors.

In order to obtain desired conduction properties, a small amount of impurity is introduced into the pure semiconductor lattice. In practice, pure Ge and Si crystals are doped with minute amount of selected impurities. The doped semiconductors are called extrinsic semiconductors.