CHAPTER NO. 17 (PHYSICS OF SOLIDS)

Question 17.1:- Distinguish between crystalline, amorphous and polymeric solids.

Answer:- Crystalline Solids The solids in which the atoms, ions and molecules are arranged periodically are called crystalline solids. Metals such as copper, zinc, and iron etc., ionic compounds such as sodium chloride and ceramics such as zirconia are the examples of crystalline solids.

Amorphous Solids The word amorphous means shapeless. Thus in amorphous solids, there is no regular arrangement of molecules like that in crystalline solids. The ordinary glass is an example of amorphous solids.

Polymeric Solids Polymeric solids are more or less solid materials with a structure between order and disorder. Natural rubber which is in pure state composed of hydrocarbons. Polythene, polystyrene and nylon are examples of synthetic polymers.

Question 17.2:- Define stress and strain. What are their SI units? Differentiate between tensile, compressive and shear modes of stress and strain.

Answer:- Stress The force applied on unit area to produce any change in the shape, volume or length of a body is called stress. Mathematically, $\sigma = \frac{F}{A}$

The SI unit of stress is newton per square meter ($N\ m^{-2}$), which is also called pascal (Pa).

Strain It is defined as the fractional change in length, volume or shape of a body when stress is applied on it. It is represented by ε. It has no unit.

Tensile Stress When applied stress changes the length, it is called tensile or compressive stress.

Tensile Strain It is defined as the fractional change in length on applying stress. Mathematically, $\varepsilon = \Delta l/l$.

Volumetric Stress The stress which causes change in volume of the body is called volumetric stress.

Volumetric Strain The fractional change in volume is called volumetric strain. This is the strain produced as a result of volumetric stress. Mathematically, Volumetric strain = $\frac{\Delta V}{V_o}$

Shear Stress The stress tending to produce an angular deformation or change in the shape is called shear stress.

Shear Strain The fractional change in area is called shear strain. This is the strain caused by angular deformation. Mathematically, $\gamma = \Delta a/a = \tan\theta$.

Question 17.3:- Define modulus of elasticity. Show that the units of modulus of elasticity and stress are the same. Also discuss its three kinds.

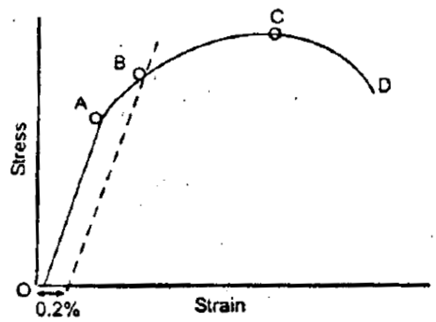
Answer:- **Modulus of Elasticity** The ratio of stress to strain is constant for a given material (if applied force is not too large) and is called modulus of elasticity. It is represented as E. Mathematically, $E = \frac{Stress}{Strain}$.

Young's Modulus In case of linear deformation, the ratio of tensile (or compressive) stress $\sigma = \frac{F}{A}$ to tensile (or compressive) strain $\varepsilon = \Delta l/l$ is called Young's modulus. Mathematically, $Y = \frac{F/A}{\Delta l/l}$.

Bulk Modulus In case of three dimensional deformation, the ratio of volumetric stress $\sigma = \frac{F}{A}$ to volumetric strain $\Delta V/V$ is called bulk modulus. Mathematically, $K = \frac{F/A}{\Delta V/V}$.

Shear Modulus In case of two dimensional deformation, the ratio of shear stress $\sigma = \frac{F}{A}$ to shear strain $\Delta a/a$ is called shear modulus. Mathematically, $G = \frac{F/A}{\Delta a/a}$.

Question 17.4:- Draw a stress-strain curve for a ductile material, and then define the terms: Elastic limit, Yield point and Ultimate tensile stress.

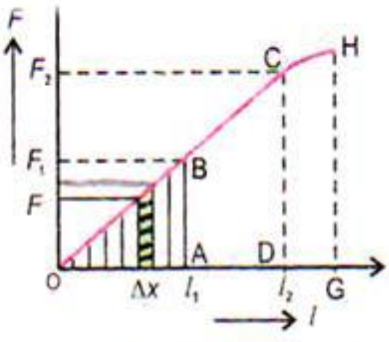


Answer:- **Elastic Limit** It is defined as the maximum stress a material can endure without any permanent deformation. The material shows elastic behavior in the region OB.

Yield Point The stress beyond which material starts to deform permanently is called Yield Point. It is denoted by point B on the curve.

Ultimate Tensile Stress It is defined as the maximum stress a material can withstand. It is denoted by point C on the graph.

Question 17.5:- What is meant by strain energy? How can it be determined from the force-extension graph?



Energy in stretched wire

Answer:- The amount of potential energy stored in a material due to displacement of its molecule from its equilibrium position, under the action of stress, is called strain energy.

Consider a wire of length L, cross sectional area A and modulus of elasticity E, whose one end is attached to a fixed support, is stretched vertically by connecting a weight at its lower end. The work done for extension l_1 by a certain force F_1 will be equal to the area under force–extension curve, which is equal to the area of triangle OAB.

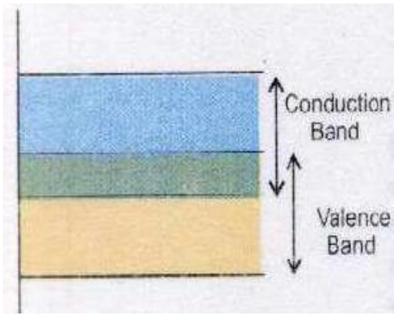
Therefore, Work done = Area of triangle OAB

Work done = $\frac{1}{2}$(base) (altitude) = $\frac{1}{2}$ (l_1) (F_1)

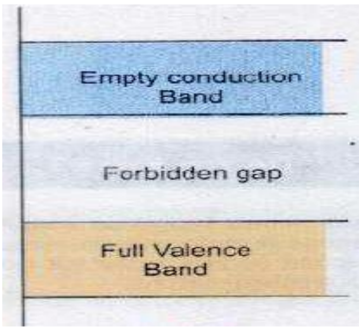
This work done is appeared as strain energy inside the wire. It can also be expressed as following:-

Work done = $\frac{1}{2}\frac{(E\,A\,l_1^2)}{L}$.

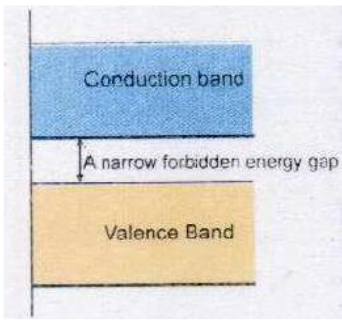
Question 17.6:- Describe formation of energy bands in solids. Explain the difference amongst electrical behavior of conductors, insulators and semi-conductors in terms of energy band theory.



Answer:- **Energy Band** When the numbers of atoms are brought together, as in a crystal, they interact with one another. As the result, each energy level splits up into several sub-levels. The energy levels are so closely spaced that appear to be continuous. A group of such energy sub-levels is called an energy band.



Conductors In conductors, valence and conduction bands largely overlap each other. There is no physical distinction between the two bands which ensures the availability of a large number of free electrons.

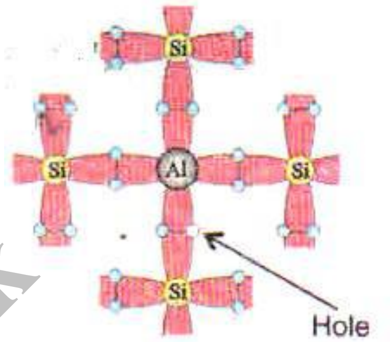


Insulators In insulators, valence electrons are tightly bound to their atoms and are not free to move. An insulator has an empty conduction band, completely filled valence band and a large energy gap in between them.

<u>Semi-conductors</u> At room temperature, the semiconductors have partially filled conduction band, partially filled valence band and very narrow forbidden gap between valence and conduction band.

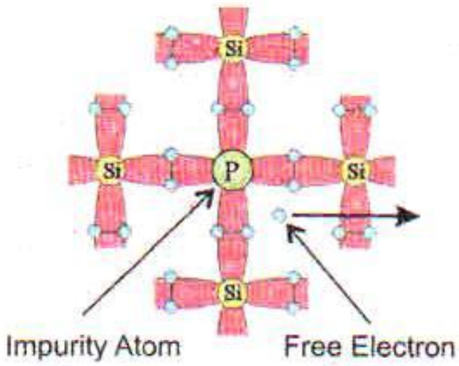
Question 17.7:- Distinguish between intrinsic and extrinsic semi-conductors. How would you obtain n-type and p-type material from pure silicon? Illustrate it by schematic diagram.

Answer:- <u>Intrinsic Semiconductors</u> A semiconductor in its extremely pure form is known as intrinsic semiconductors such as Silicon and Germanium in pure form.



<u>Extrinsic Semiconductors</u> The doped semi-conducting materials are called extrinsic semi-conductors such as Silicon or Germanium doped with impurity atoms such as Nitrogen and Aluminum.

<u>P-type Semiconductor</u> These materials are obtained by doping semi-conductor with atoms of a trivalent impurity such as Aluminum. It creates a vacancy of an electron (having net positive charge) called a hole. The majority charge carriers are holes in P-type semiconductors.

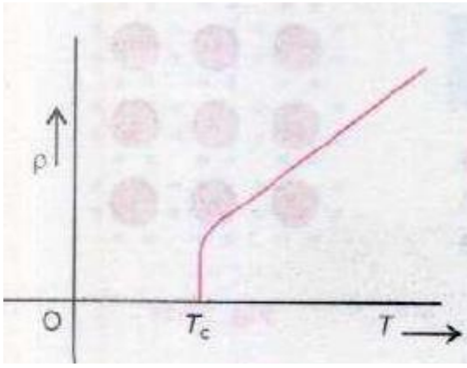


<u>P-type Semiconductor</u> The N-type materials are obtained by doping semi-conductor with atoms of a pentavalent impurity such as Phosphorous. It leaves a free electron. The majority charge carriers are electrons in N-type semiconductors.

Question 17.8:- Discuss the mechanism of electrical conduction by holes and electrons in a pure semi-conductor element.

Answer:- In a pure (or intrinsic) semi-conductor, the number of holes and free electrons is equal and both contribute to the flow of current through it. When voltage is applied across the semi-conductor, an electric field is produced. Due to this electric field, electrons get a drift velocity opposite to the electric field and holes in the direction of the electric field. The electronic current and the hole current add up together to give the current through semiconducting material.

Question 17.9:- Write a note on superconductors.



Answer:- The materials whose resistivity becomes zero below a certain temperature are called superconductors. And the temperature at which the resistivity of a material falls to zero is called critical temperature.

Any superconductor having a critical temperature above 77K (the boiling point of liquid Nitrogen) is referred as high temperature superconductor. Superconductors can be used in magnetic resonance imaging (MRI), magnetic levitation trains, powerful but small electric motors and in fast computer chips.

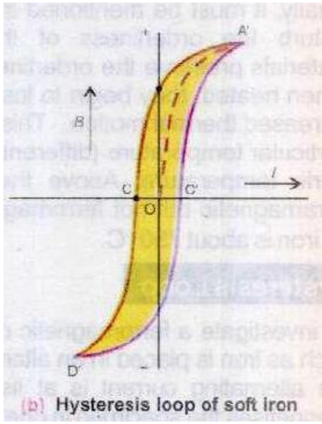
Question 17.10:- What is meant by para, dia and ferromagnetic substances? Give examples for each.

Answer:- __**Paramagnetic Substances**__ If the spin and orbital axis of electrons in an atom are oriented in such a way that their fields support each other and the atom behaves like a tiny magnet. Such substances are called Paramagnetic substances. The examples are Manganese, Aluminum and Platinum.

__**Diamagnetic Substances**__ The substances in which the magnetic field produced by orbital and spin motion of the electrons may cancel each other's effects are called diamagnetic substances. The examples are water, Copper (Cu), Bismuth (Bi) and Antimony (Sb).

__**Ferromagnetic Substances**__ Ferromagnetic substances are those substances in which atoms co-operate with each other in such a way as to show strong magnetic effects. The examples are Iron (Fe), Cobalt (Co), Nickel (Ni), Chromium dioxide and Alnico.

Question 17.11:- What is meant by hysteresis loss? How is it used in construction of a transformer?



(b) Hysteresis loop of soft iron

Answer:- The energy required to magnetize and demagnetize a substance in an AC cycle is called hysteresis loss. This energy is dissipated in form of heat, which is called hysteresis loss. It can be measured by estimating the area of hysteresis loop which is a graph between magnetizing current and magnetization. The materials, for which hysteresis loss is small, are used to form the core of transformers.