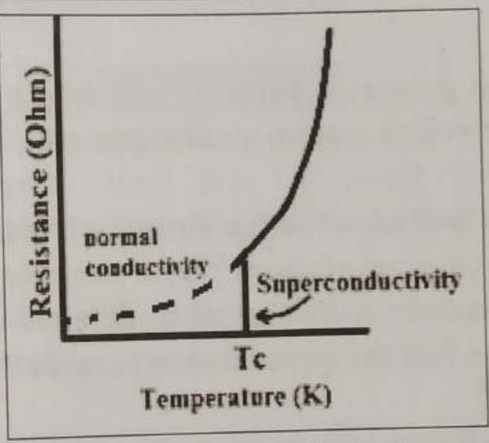
CONCEPTUAL QUESTIONS

Q1. Evaluate the importance of strength and stiffness in a design context?

Ans: Stiffness is a measure of a system's resistance to deformation. Strength of a material denotes the largest stress that a material can sustain. Knowledge of strength is important to evaluate bearing capacity of the material for construction. If a structural system has low strength then it may not exist under high stresses and hence may fail.

Stiffness largely determines the strains of the material, as it is loaded and unloaded. High stiffness means the material exhibits low deformation under loading. Stress, moisture content and temperature influence both strength and stiffness. Both strength and stiffness provide the material the structure with the ability to maintain its shape and dimensions under loading.

2. Discuss the superconductivity of a conductor with the help of a curve.



Ans There is a special class of materials whose resistance falls to zero when their temperature is significantly lowered. Such materials are called superconductors and the phenomena is called superconductivity. In the figure, resistance is plotted as a function of time for a typical material that shows no resistance (superconductivity) at a temperature, called critical temperature Tc. As the temperature is lowered from higher values, the curve approaches smaller values of resistance till it becomes zero at T_c. The dashed curve also shows resistance of ordinary material that is not superconductor. Magnetic resonance imaging (MRI) and magnetic levitation trains are some of the applications of superconductors.

3. Distinguish between crystalline, amorphous and polymer solids.

Ans:

Crystalline solids

In a crystalline solid, the particles (atoms, irons or molecules) are arranged in definite geometric pattern in the three dimensional network, known as long chain order. The arrangement repeats itself periodically over the entire crystal. Crystalline solids have fixed melting point and their particles vibrate about a fixed position. Their arrangement can be studied using X-rays and electron microscope. Examples are diamond, sugar and rock salt. All metals are also crystalline in nature for instance iron, copper and zinc are crystalline.

Amorphous solids (Glassy solids)

Amorphous (non-crystalline) solid is composed of randomly oriented atoms, ions or molecules that do not form defined patterns or lattice structures. So these are the substances whose constituent particles do not possess a regular orderly arrangement. There is a very small periodicity in amorphous solids that breaks soon. This behavior is called short range order. In contrast with crystalline solids, amorphous solids do not have fix melting point. Glass, which is also called fused silica, is an example of amorphous solids.

Polymers

This class of solids contains long chain (up to 10,000) of molecules. They are mostly organic (carbon containing) compounds. Polymers have both crystalline and amorphous regions. After some periodicity, the arrangement changes but keeps continue again. Polymers are of two types; natural polymers and synthetic polymers. Rubber, wool, cellulose and proteins are natural polymers that exist naturally. Synthetic polymers are prepared by chemical reaction, called as polymerization. These include plastics such as polythene and fibers such as nylon and polyester etc.

4. Define unit cell, basis and space lattice

Ans

Unit cell

The smallest geometric figure or unit whose periodic repetition in two or three dimensions forms a crystal, is called unit cell.

Basis

Geometrical analysis of crystal structure is made by associating a lattice point to a single atom or group of atoms. These atoms or group of atoms are called basis. The group may contain similar atoms or different atoms. Basis must be identical in all respects such that the crystal appears exactly the same at every lattice point.

Space lattice

Lattice is collection of infinite number of points in a periodic arrangement. Space lattice is a skeleton upon which crystal structure is built by placing atoms on the lattice points. Or it is the repeating pattern of geometrical points that extend throughout the space. When a basis is associated with each lattice site, the crystal structure is obtained.

Crystal lattice + Basis structure = Crystal

5. Differentiate between paramagnetic diamagnetic and ferromagnetic materials with suitable examples.

Ans:

PARAMAGNETIC MATERIALS

In these substances, the orbital and spin axis of the electrons in an atom are so oriented that their field support each other and the atom behaves like a tiny magnet. When a paramagnetic substance is placed in a magnetic field, the substance is weakly magnetized in the direction of the applied field. Therefore, a paramagnetic substance is weakly attracted by a strong magnet. Examples of such materials are aluminum and antimony.

DIAMAGNETIC MATERIALS

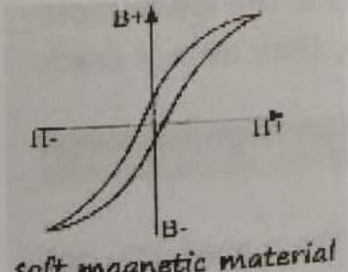
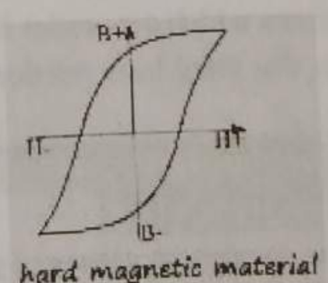
The substances in which the orbital and spin axis of the electron in an atom are so oriented that their fields cancel the effect of each other so that their resultant field is zero. When a diamagnetic substance is placed in a magnetic field, the substance is weakly magnetized in a direction opposite to that of the applied field. Therefore, a diamagnetic substance is weakly repelled by a strong magnet. Examples of such materials are copper, zinc and bismuth.

FERROMAGNETIC MATERIALS

In these substance the individual atoms act like tiny magnets. The interaction between these tiny atomic magnets is so strong that they line up parallel to each other even when no external magnetic field is present. These tiny magnets are called magnetic domains. Each domain acts like a small magnet with its own north and South Pole. When a ferromagnetic substance is placed in a magnetic field, the substance is strongly magnetized in the direction of the applied field. Therefore, ferromagnetic material is strongly attracted by a magnet. Examples of such materials are iron, nickel and cobalt.

6. Distinguish between soft and hard substance by drawing their curves.

Ans

SOFT MATERIALS	HARD MATERIALS
1. Soft materials such as pure iron have very narrow magnetic hysteresis loop and they can be easily magnetized and de-magnetized.	**1.** Hard magnetic materials such as tungsten steel, are not easily de-magnetized once they are magnetized.
2. The coercivity of soft magnetic materials is small while the retentivity is greater.	**2.** Hard materials have high value of coercivity while small Retentivity.
3. Soft materials have higher relative permeability.	**3.** hHard materials have small relative permeability.
4. Area of hysteresis loop is small for soft materials.  soft magnetic material	**4.** Their hysteresis loop is very fat.  hard magnetic material

7. Explain Hook's Law and Modulus of Elasticity ?

Ans: Hook's law states that under elastic limits (small deformations), stress and strain are directly proportional. Mathematically

$$\text{Stress} \propto \text{Strain}$$

$$\text{Stress} = k\ \text{Strain}$$

Where k = constant of proportionality and is known as modulus of elasticity. Its unit is same as that of stress as strain has no unit. Those materials which obey Hook's law show linear behavior between applied stress and resulting strains. Also Hook's law is valid within elastic limits and for small strains.

8. Is there any difference in the length of a 20 meter steel girder when standing vertically or horizontally?

Ans: First we must identify the force acting on it which is its weight W. If the steel girder is placed horizontally then the force acting on it will distribute itself on the wider area of girder and hence there will be no change in the length of the steel girder. But if it is placed vertically, then the same force will act along its length on its cross sectional area which is smaller than horizontal case. Now in this case, there might be a very small decrease in the length of the girder because of larger stress. Hence there will be a difference in the length of the 20 mm steel girder when placed in vertical position but not in horizontal position.

9. Steel reinforcing is used in concrete beams to prevent cracking. Explain where the steel reinforcing should be placed in a concrete beam?

Ans: Properties of concrete are as follows:

i. Strong,
ii. stiff and
iii. brittle

Properties of steel are as follows:

i. Strong,
ii. elastic and
iii. has higher value of Young's modulus.

As the concrete beams are subjected to higher stresses, they need to be strong and also they must have some elasticity which they do not have if acting alone. Their strength is higher while elasticity is negligible. So in order to achieve some elasticity and to prevent cracking of the beams, we reinforce steel bars. These steel bars are introduced in those regions which are under high state of stress i.e, the lower most face of the beam. With the steel bars reinforced in the beams, they do not crack readily.

10. (a) What is meant by the elastic limit of a material? (b) In what way does a material behave if it obeys Hook's Law?

Ans: (a) Elastic limit is the maximum values of stress up to which the material do not show permanent deformations. It can regain its actual shape when deforming forces are removed. When the stress reaches the value of elastic limit, Hook's law is no more valid since proportionality between stress and strain has been lost.

(b) If a material obeys Hook's law then its stress strain curve shows linear behavior as stress and strain are directly proportional for such material.
When stress is removed, the material gains its actual shape.

11. Cast-iron beams are used in bridge and building construction. The lower part of the beam is thicker than the upper part. Why is it better for the lower part of the

beam to be thicker than the upper part? Given reason for your answer including reference to the tensile and compressive strength.

Ans: Bridge and building construction are those cases in which the beams used are simultaneously under tensile as well as compressive stress. The upper part of the beams when subjected to load, is in the state of compression while the lower part is under tension. Now if the beams are made uniform then strains may be produced which can damage the structure. In order to reduce this discrepancy, beams are made in such a way that their lower part is thicker than upper part. With this geometry, the beams can tolerate load easily.