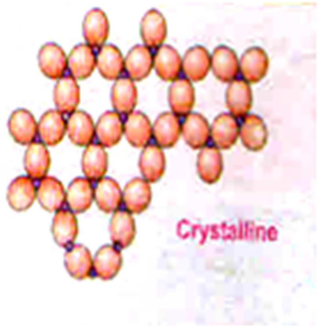
IMPORTANT QUESTIONS WITH ANSWERS

Q # 1. What do you know about crystalline solids? Describe its properties.

Ans. The solids in which the atoms, ions and molecules are arranged periodically are called crystalline solids.



Examples:

- Metals such as copper, zinc, iron etc.
- Ionic compounds such as sodium chloride
- Ceramics such as zirconia

are the examples of crystalline solids.

Properties of Crystalline Solids

1. The crystalline solids show the phenomenon of X-ray diffraction.
2. Every crystalline solid has sharp melting point i.e., for every crystal there is a temperature at which the thermal vibrations becomes so great that the structure suddenly breaks up, and the solid melts.

Q # 2. Write a note on amorphous or glassy solids?

Ans. The word amorphous means shapeless. Thus in amorphous solids, there is no regular arrangement of molecules like that in crystalline solids.

Examples:

The ordinary glass is an example of amorphous solids.

Properties of Amorphous Solids

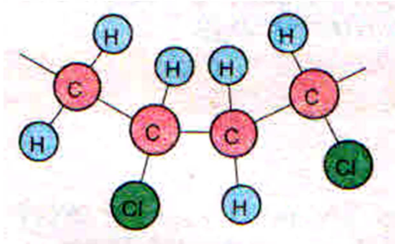
1. As the atom, ions and molecules are not arranged periodically in amorphous solids, so these solids don't show the phenomenon of X-ray diffraction.
2. The amorphous solids don't have sharp melting point. For example, a glass passes through a paste like state on heating and becomes a very viscous liquid at almost 800^0C.

Q # 3. What are Polymeric Solids? Describe its properties.

Ans. Polymeric solids are formed by polymerization reaction in which relatively simple molecules are chemically combined into massive long chain molecules. Polymers may be said to be more or less solid materials with a structure that is intermediate between order and disorder.

Example:

Plastics, synthetic rubber, polythene and nylon etc. are the examples of polymers.



Properties of Polymeric Solids

Polymeric solids have low specific gravity, but yet they exhibit good strength to weight ratio.

Q # 4. Define following:

- **i) Unit Cell**
- **ii) Crystal Lattice**

Ans.

Unit Cell

A crystalline solid consists of three dimensional pattern that repeat itself over and over again. This smallest three dimensional basic structure is called unit cell.

Crystal Lattice

The whole structure obtained by the repetition of unit cell is known as crystal lattice.

Q # 5. What do you know about deformation? Also describe the phenomenon of deformation in crystalline solids.

Ans. Deformation

Any change in shape, volume and length of an object when it is subjected to some external force is called deformation.

Deformation in Crystalline Solids

In crystalline solids atoms are arranged in a certain order. When external force is applied on such a body, a distortion results because of displacement of the atoms from their equilibrium position and the body is said to be in state of deformation.

In deformed crystalline solid, the atoms return to their equilibrium position after the removal of external force. This ability of the body to return to its original shape is called elasticity.

Q # 6. What do you know about mechanical properties of solids?

Ans. The properties shown by the solid material under the action of external force are called mechanical properties. Physical quantities such as stress, strain and modulus of elasticity are used to describe the mechanical properties of solids.

Q # 7. Define the term Stress. Also describe its different types.

The force applied on unit area to produce any change in the shape, volume or length of a body is called stress. Mathematically, it is described as:

$$Stress\,(\sigma) = \frac{Force\ (F)}{Area\ \ (A)}$$

The SI unit of stress is newton per square meter, which is given the name pascal (Pa).

Types of Stress

Tensile Stress: A stress that causes the change in length of an object is called tensile stress.

Shear Stress: A stress that causes the change in shape of an object is called shear stress.

Volume Stress: A stress that causes the change in volume of an object is called volume stress.

Q # 8. Define the term Strain. Also describe its different types.

Ans. Strain is the measure of deformation of a solid when stress is applied to it. For the case of one dimensional deformation, strain is defined as the fractional change in length.

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If Δl is the change in length and l is the original length, then the strain is given by:

$$Strain\ (\varepsilon) = \frac{\Delta l}{l}$$

Since strain is the ration of lengths, it is dimensionless, and therefore, has no units.

Types of Strain

Tensile Strain: If the strain is due to tensile stress, it is called tensile strain.

Shear Strain: A strain produced in the object when it is subjected to shear stress is called shear strain. When the opposite faces of a rigid body are subjected to shear stress, the shear strain produced is given by:

$$Shear\ \ Strain = \frac{\Delta a}{a} = \tan\theta$$

Volumetric Strain: When the applied stress changes the volume, then the change in volume per unit volume is called volumetric strain. Thus

$$Volumetric\ \ Strain = \frac{\Delta V}{V}$$

Q # 9. What do you know about Modulus of Elasticity? Describe its different types.

Ans. Modulus of Elasticity The ratio of stress to strain is a constant for a given material, provided the external applied force is not too great, called modulus of elasticity. Mathematically, it is described as:

$$Modulus\ \ of\ \ Elasticity = \frac{Stress}{Strain}$$

Since the strain is a dimensionless quantity, the units of modulus of elasticity are the same as that of stress, i.e., Nm^{-2} or Pa.

Types of Elastic Constants

Young Modulus: For the case of linear deformation, the ration of tensile stress to tensile strain is called Young Modulus (Y):

$$Y = \frac{F/A}{\Delta l/l}$$

Shear Modulus: When the shear stress **τ =(F/A)** and shear strain **($\gamma = \tan\theta$)** are involved, then their ratio is called shear modulus (G):

$$G = \frac{F/A}{\tan\theta}$$

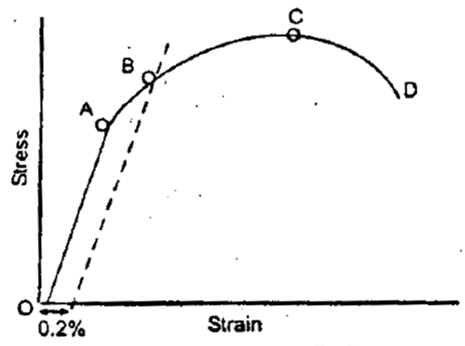
Bulk Modulus: For three dimensional deformations, when volume is involved, then the ratio of applied stress to volumetric strain is called bulk modulus (K):

$$K = \frac{F/A}{\Delta V/V}$$

Where ΔV is the change in original volume V.

Q # 10. How the mechanical properties of a wire are determine in Tensile Test.

In tensile test, metal wire is extended at a specified deformation rate. The stresses generated in the wire during deformation are continuously measured by a suitable electronic device fitted in the mechanical testing machine. Stress-strain curve is plotted automatically on XY chart recorder. A typical stress strain curve for a ductile material is shown in the figure:



In the initial stages of deformation, stress is increased linearly with strain till point A on stress-strain curve. This is called proportional limit.

Proportional Limit (Definition):

Proportional limit is the greatest stress that a material can endure without losing straight line proportionality between stress and strain.

From A to B, the stress and strain are not proportional, but nevertheless, if the load is removed at any point between O and B, the curve will be retraced and the material will return to its original length. The point B is called yield point and the value of stress at this point is known as yield stress or elastic limit.

Yield Stress or Elastic Limit (Definition):

Elastic limit is the greatest stress that a material can endure without any permanent deformation.

If the stress is increased beyond elastic limit, the specimen becomes permanently deformed. This kind of behavior is called plasticity. The region of plasticity is represented by the portion of the curve from B to C. The point C represents ultimate tensile strength (UTS).

Ultimate Tensile Stress (UTS), (Definition):

Ultimate tensile stress is the maximum stress that a material can withstand.

Once point C corresponding to UTS is crossed, the material breaks at point D, responding to fracture stress.

Q # 11. Describe the classification of solids on the basis of plastic deformation of solids.

Ductile Substances

Substances that undergo plastic deformation until they break are called ductile substances. Lead, copper and wrought iron are ductile.

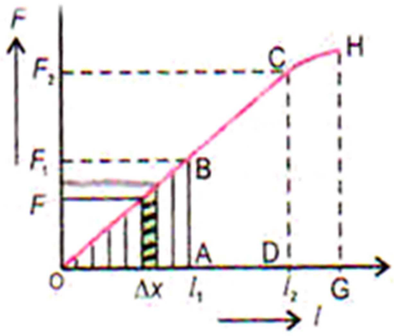
Brittle Substance

The substances which break just after the elastic limit is reached, are known as brittle substances. Glass and high carbon steel are brittle.

Q # 12. Define the term Strain Energy. Also derive its expression of strain energy by considering force-elongation graph obtained during the tensile test of a wire.

Ans. Strain Energy. The amount of P.E stored in a material due to displacement of its molecule from its equilibrium position, under the action of stress, is called strain energy.

Derivation of the expression of Strain Energy



Energy in stretched wire

Ans. Consider a wire whose one end is attached to a fixed support, is stretched vertically by connecting a weight at its lower end. The suspended weight acts as a stretching force. The extension in the wire is increased by increasing the stretching force. The graph plotted between extension l for the different value of stretching force is shown in the figure:

It is clear from the figure that the force is constant in producing extension l_1 but is changing linearly from 0 to F_1. In order to calculate the work done for extension l_1 by a certain force F_1, it is convenient to find the work done by graphical method.

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

$$\text{Work Done} = \frac{1}{2}(\text{base})(\text{altitude})$$

$$\text{Work Done} = \frac{1}{2}(\overline{OA})(\overline{AB})$$

$$\text{Work Done} = \frac{1}{2}(l_1)(F_1)$$

This work done is appeared as strain energy inside the wire. So

$$\text{Strain Energy} = \frac{1}{2}(l_1)(F_1) \quad \text{----------} \quad (1)$$

Expression of Strain Energy in terms of Elastic Modulus

If A is the cross-sectional area of the wire of length L, then the modulus of elasticity E of the wire can be described as:

$$Modulus\ of\ Elasticity = \frac{Stress}{Strain}$$

$$E = \frac{F_1 / A}{l_1 / L}$$

$$E = \frac{F_1 L}{A l_1} \Rightarrow F_1 = \frac{E A l_1}{L}$$

Putting value in equation (1), we get:

$$\text{Strain Energy} = \frac{1}{2}(l_1)\left(\frac{E A l_1}{L}\right)$$

$$\Rightarrow \text{Strain Energy} = \frac{1}{2}\left(\frac{E A l_1^2}{L}\right)$$

Q # 12. What do you mean by electrical properties of solids? Also write a short note on energy band theory of solids.

Ans. The electrical properties of solids determine its ability to conduct electric current. The conventional free electron theory based on Bohr Model failed to explain completely the vast diversity in the electrical behavior of solids. On the other hand, the energy based on wave mechanical model has been found successful in resolving this problem.

Q # 13. Define following:

i. **Energy Band**
ii. **Forbidden Band**
iii. **Valance Band**
iv. **Conduction Band**

Ans.

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. A group of such energy sub-levels are called an energy band.

Forbidden Bands

The energy bands are separated by gaps in which there is no energy level. Such energy gaps are called forbidden bands.

Valence Bands

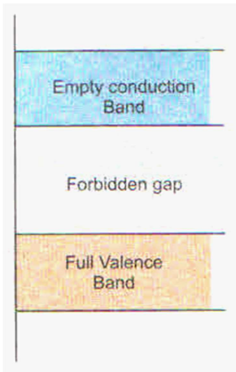
The electrons in the outermost shell of an atom are called valance electrons. Therefore, the energy band occupied by valance electrons is called the valance band. The valance band may be either completely filled or partially filled with the electrons but can never be empty.

Conduction Band

The energy band next to the valance band is called the conduction band. The valance and conduction bands are separated by forbidden energy gaps. The conduction band may be empty or partially filled. The electrons in the conduction band can drift freely in the materials and are called free or conduction electrons.

Q # 14. Differentiate among conductors, insulators and semiconductors on the basis of band theory of solids.

Ans. The width of forbidden energy gap between valance and conduction band decide whether a material is a conductor, insulator or a semiconductor.

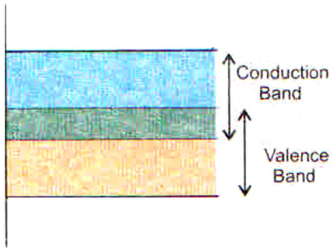


Insulators

Insulators are those materials in which valance electrons are bound very tightly to their atoms and are not free. In terms of energy bands, it means that an insulator has:

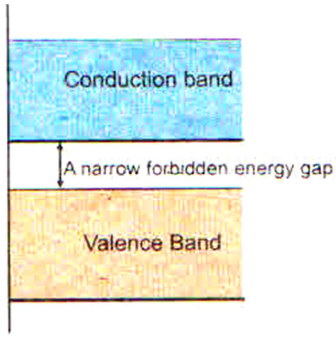
a) An empty conduction band (no free electron)
b) A full valence band
c) A large energy gap (several eV) between them.

Conductor



Conductors are those which have plenty of free electrons for electrical conduction. In terms of energy bands, conductors are those materials in which valence and conduction band largely overlap each other. There is no physical distinction between the two band which ensures the availability of free electrons. That is why, the conductions are good conductors of electricity.

Semiconductors



In terms of energy bands, semiconductors are those materials which at room temperature have

i) A partially filled conduction band

ii) A partially filled valence band

iii) A very narrow forbidden energy gap (of the order of 1 eV) between the conduction and valence bands.

Q # 15. Describe the variation in conductivity of semi-conductors due to effect of temperature.

Ans. At 0 K, there are no electrons in the conduction band and their valence band is completely filled. It means at 0 K a piece of Ge or Si is a perfect insulator.

However, with the increase of temperature, some electrons posses sufficient energy to jump across the small energy gap from the valance band to conduction band. This transfers some free electrons in the conduction band and create some holes in the valance band. The vacancy of electron in the valence band is known as a hole. It behave like a positive charge. Thus at room temperature, Ge or Si crystals becomes a semiconductor.

Q # 16. Differentiate among intrinsic and extrinsic semi-conductor materials.

Intrinsic Semiconductor

A semiconductor in its extremely pure form is known as intrinsic semiconductors.

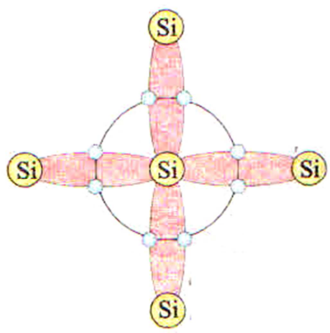
Extrinsic Semi-conductors

The doped semi-conducting materials are called extrinsic semi-conductors.

Q # 17. Define the term Doping.

Ans. The electrical behavior of semiconductors is extremely sensitive to the purity of the material. It is substantially changed on introducing a small impurity into pure semi-conductor. This process is called doping.

Q # 18. Write a note on Crystal Structure of Intrinsic Semi-conductors.



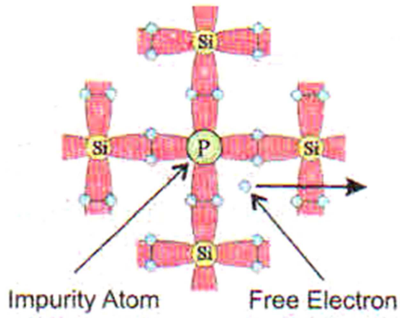
Ans. Pure elements of silicon and germanium are intrinsic semi-conductors. These semi-conductor elements have atoms with four valence electrons. In solid crystalline form, the atoms of these elements arrange themselves in such a pattern that each atom has four equidistant neighbors. Each atom with its four valence electrons, shares an electrons from its neighbors. This effectively allocates eight electrons in the outermost shell of each atom, which is a stable state.

Q # 19. Describe the different types of extrinsic semi-conducting materials.

The conductivity of silicon and germanium can be drastically increased by the controlled addition of impurities to the intrinsic (pure) semiconductive material.

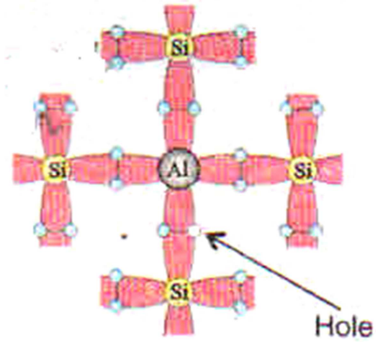
N-Type Semi-conductors

When a silicon crystal is doped with a pentavalent element, e.g., arsenic, antimony or phosphorous etc., four valance electrons of impurity atom form covalent bond with the four neighboring Si atoms, while the fifth valence electron provides a free electron in the crystal. This extra electron becomes a conduction electron because it is not attached to any atom. Such a doped extrinsic semi-conductor is N-type semi-conductor.



P-Type Semi-conductors

When a silicon crystal is doped with the trivalent element, e.g., aluminum, boron, gallium or indium etc., three valence electrons of the impurity atom form covalent bond with three neighboring Si atoms, while the one missing electron in the covalent bond with the forth neighboring Si atom, is called a hole which in fact is vacancy where an electron is accommodated. Such a semi-conductor is called P-Type Semi-conductor.



Q # 20. What is effect of battery on the motion of charge carrier in a semi-conductor crystal?

Ans. When a battery is connected to a semi-conductor, it establishes an electric field across it due to which a directed flow of electrons and holes takes place. The electrons drift towards the positive end whereas the holes drift towards the negative end of the semi conductor. The current flowing through the semi-conductor is carried by both electrons and holes. It may be noted that the electronic current and charge the hole current add up together to give the current I.

Q # 21. Define following:

i. **Superconductors**
ii. **Critical Temperature**
iii. **High Temperature Superconductors**

Superconductors

The materials whose resistivity becomes zero below a certain temperature are called superconductors.

Critical Temperature

The temperature at which the resistivity of a material falls to zero is called critical temperature.

High Temperature Superconductors

Any superconductor having a critical temperature above 77K (the boiling point of liquid nitrogen) is referred as high temperature superconductor.

Q # 22. Describe the applications of superconductors.

Superconductors can be used in

a) Magnetic Resonance Imaging (MRI)
b) Magnetic Levitation Trains
c) Powerful but small electric motors
d) Fast computer chips

Q # 23. What is the reason of magnetic behavior of solids?

The magnetism produced by electrons within an atom can arise from two motions:

i) Electron orbiting the nucleus behaves like an atom sized loop of current that generate small magnetic field.

ii) The spin motion of electron also gives rise to a magnetic field.

The net magnetic field generated by the electrons within an atom is due to combined field created by their orbital and spin motion.

Q # 24. Differentiate among the paramagnetic and diamagnetic substances.

Paramagnetic Substances

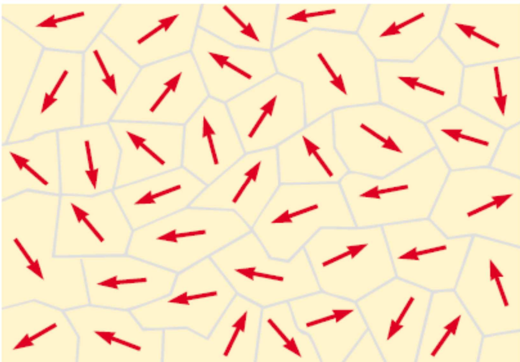
The solids in which the orbital and spin axes of the electrons in an atom are so oriented that their fields support each other are called paramagnetic substances. In these solids, each atom behaves like a tiny magnet.

Diamagnetic Substance

In diamagnetic substance, there is no resultant field as the magnetic field produced by both orbital and spin motions of the electron might add up to zero. For example, the atoms of water copper, bismuth and antimony are diamagnetic.

Q # 25. Write a note on Ferromagnetic Substances. Also describe its different types.

In ferromagnetic substances, e.g., Fe, Co, Ni, Chromium dioxide and Alnico, the atoms cooperate with each other in such a way so as to exhibit a strong magnetic effect. In ferromagnetic substance, there exist small regions called domains (contain 10^{12} to 10^{16} atoms). Within each domain, the magnetic fields of all spinning electrons are parallel to one another, i.e., each domain is magnetized to saturation. Each domain behaves as a small magnet with its own north and south poles.



Types of Ferromagnetic Substances

Soft Ferromagnetic Substances

In soft ferromagnetic substances, the domains are easily oriented on applying an external field and also readily return to random positions when the field is removed. This is desirable in an electromagnet and also in transformers. Iron is a soft magnetic material.

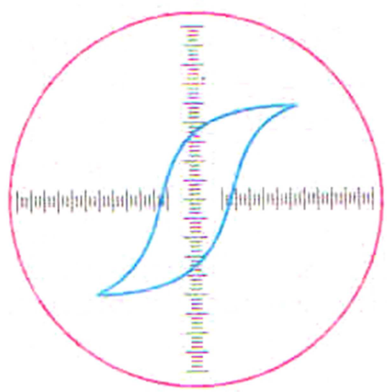
Hard Ferromagnetic Substances

In hard ferromagnetic materials, domains are no so easily oriented to order. They required very strong external fields, but once oriented, retain the alignment. These solids are used to make permanent magnet. Steel is an example of hard ferromagnetic material.

Q # 26. What do you know about the Curie temperature in Ferromagnetic Substances?

The thermal vibrations in ferromagnetic solids tends to disturb the orderliness of domains. Ferromagnetic materials preserve the orderliness at ordinary temperatures. When heated, they begin to lose their orderliness due to increased thermal motion. This process begins to occur at a particular temperature called Curie temperature. Above the Curie temperature iron is paramagnetic but not ferromagnetic. The curie temperature of iron is about 750^0C.

Q # 27. How the Hysteresis Loop of a magnetic material is obtained?



To investigate a ferromagnetic material, a bar of that material such as iron is placed in an alternating current solenoid. When the alternating current is at the positive peak value, it fully magnetizes the specimen in one direction and when the current is at its negative peak, it fully magnetized it in opposite direction. Thus an alternating current changes from its positive peak value to its negative peak value and then back to its positive peak value, the specimen undergoes a complete cycle of magnetization, called hysteresis loop.

Q # 28. Define the following properties of Hysteresis Loop:

i. **Hysteresis**
ii. **Saturation**
iii. **Remanence or Retaintivity**
iv. **Coercivity**
v. **Area of Hysteresis Loop**

Hysteresis

The value of flux density for any value of current is always greater when the current is decreasing, then when it is increasing, i.e., magnetism lags behind the magnetizing current. This phenomenon is known as hysteresis.

Saturation

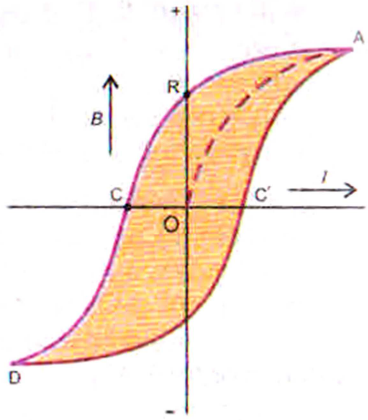
The alignment of all domains of magnetic materials under the influence of external magnetic field is called saturation. The magnetic flux density increases from zero and reaches a maximum value. At this stage, the material is said to be magnetically saturated.

Remanence or Retaintivity

When the current is reduced to zero, the material still remain strongly magnetized represented by point R on the curve. It is due to the tendency of domains to stay partially in line, once they have been aligned.

Coercivity

To demagnetize the material, the magnetizing current is reversed and increased to reduce the magnetization to zero. This is known as coercive current, represented by C on curve. The Coercivity of steel is more than that of iron, as more current is needed to demagnetize it.

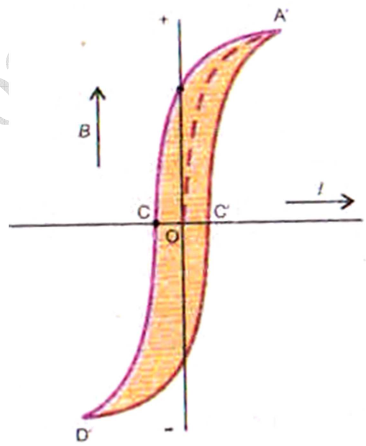


(a) Hysteresis loop of steel

Area of the loop (Measure of Hysteresis Loss)

The area of the loop is the measure of the energy needed to magnetize and demagnetize the specimen during each cycle of the magnetizing current. This is the energy required to do work against internal friction of the domains. This work is dissipated as heat. It is called hysteresis loss.

Hard magnetic material like steel cannot be easily magnetized and demagnetized, so they have large loop area as compared to soft magnetic materials such as iron which can easily be magnetized. The energy dissipated per cycle, thus, for iron is less than for steel.



(b) Hysteresis loop of soft iron

OR = Retentivity
OC = Coercivity

Q # 29. Describe the advantages of Hysteresis Loop.

Suitability of magnetic material for different purposes can be studied by taking the specimen through a complete cycle and drawing the hysteresis loop.

- A material with high Retaintivity and large coercive force would be most suitable to make a permanent magnet.
- The cores of electromagnets used for alternating current where the specimen repeatedly undergoes magnetization and demagnetization should have narrow hysteresis curve of small area to minimize the waste of energy.

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