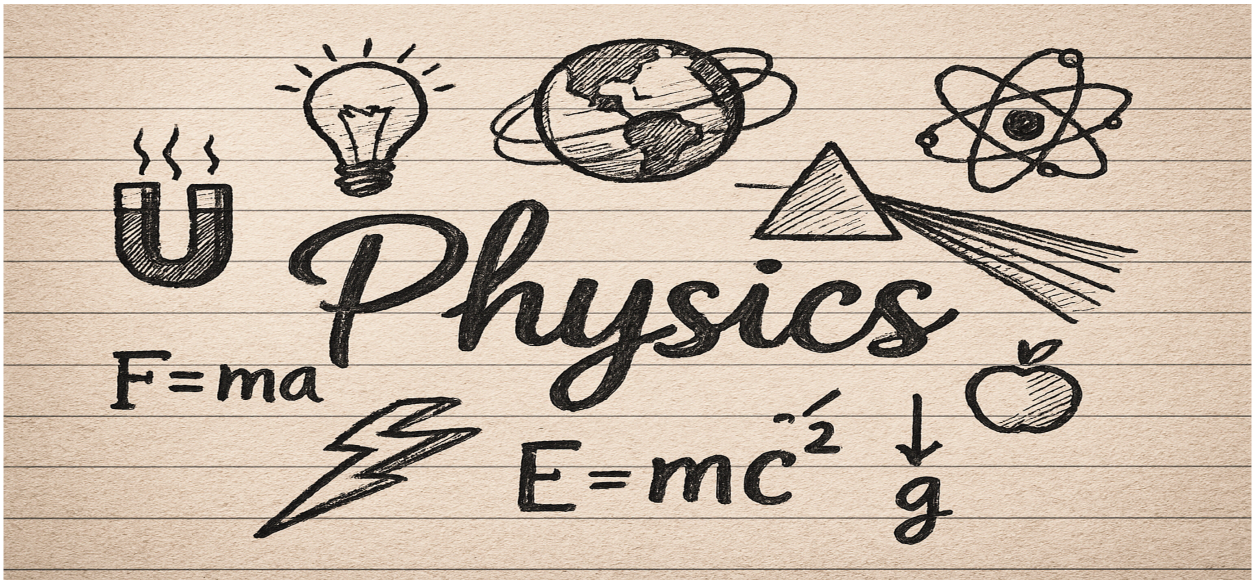


Class: 12th

Subject: Physics

Chapter 17: PHYSICS OF SOLIDS

🩸 Important Short Questions (From Key Points)

1. Crystalline solids are those in which:

(a) Molecules are randomly arranged

(b) Molecules are loosely packed

(c) Molecules are arranged in a regular pattern ✅

(d) Molecules behave like liquids

2. Amorphous solids are more like liquids because they:

(a) Have high melting point

(b) Have ordered structure

(c) Have disordered structure frozen in ✅

(d) Are transparent

3. Polymers are classified as:

(a) Perfectly crystalline solids

(b) Completely amorphous solids

(c) Partially or poorly crystalline solids ✅

(d) Liquid materials

4. The smallest repeating three-dimensional structure of a crystal is called:

(a) Lattice

(b) Unit cell ✅

(c) Grain

(d) Domain

5. Stress is defined as:

(a) Force × area

(b) Change in length

(c) Force per unit area ✅

(d) Change in volume

6. Stress produced due to pulling a wire is called:

(a) Shear stress

(b) Volume stress

(c) Tensile stress ✅

(d) Compressive stress

7. Stress produced when a body is compressed is called:

(a) Tensile stress

(b) Shear stress

(c) Compressive stress ✅

(d) Elastic stress

8. Stress produced by tangential force causing twisting is known as:

(a) Tensile stress

(b) Compressive stress

(c) Shear stress ✅

(d) Volume stress

9. Strain is defined as:

(a) Force per unit area

(b) Change in volume

(c) Fractional change in length ✅

(d) Force applied

10. Strain has:

(a) Unit of metre

(b) Unit of newton

(c) Unit of pascal

(d) No unit ✅

11. The ratio of stress to strain is called:

(a) Elastic limit

(b) Modulus of elasticity ✅

(c) Strain energy

(d) Yield strength

12. Strain energy stored in a material can be obtained from:

(a) Stress–strain ratio

(b) Length of wire

(c) Area of force–extension graph ✅

(d) Volume of material

13. The process of adding impurity to a pure semiconductor is called:

(a) Ionization

(b) Neutralization

(c) Doping ✅

(d) Polarization

14. When silicon is doped with a pentavalent impurity, it becomes:

(a) p-type semiconductor

(b) Intrinsic semiconductor

(c) n-type semiconductor ✅

(d) Insulator

15. Substances which show strong magnetic effect due to cooperative atomic behavior are called:

(a) Diamagnetic

(b) Paramagnetic

(c) Ferromagnetic ✅

(d) Superconductors

🩸 Important MCQs:

1. Crystalline solids are characterized by:

(a) Random arrangement of particles

(b) Short-range order only

(c) Regular and repeating arrangement of particles ✅

(d) No definite shape

2. The majority of solids such as metals and ionic compounds are:

(a) Amorphous

(b) Polymeric

(c) Glassy

(d) Crystalline ✅

3. In crystalline solids, atoms or molecules:

(a) Remain completely at rest

(b) Move freely like gases

(c) Vibrate about fixed positions ✅

(d) Flow like liquids

4. The melting point of a crystalline solid is:

(a) Not fixed

(b) Gradual

(c) Definite and sharp ✅

(d) Very low

5. Amorphous solids differ from crystalline solids because they:

(a) Have long-range order

(b) Have regular lattice

(c) Lack regular arrangement of particles ✅

(d) Are always transparent

6. Ordinary glass is an example of:

(a) Crystalline solid

(b) Metallic solid

(c) Amorphous (glassy) solid ✅

(d) Ionic solid

7. Amorphous solids on heating:

(a) Melt suddenly at one temperature

(b) Show no change

(c) Gradually soften over a range of temperature ✅

(d) Directly change into gas

8. Polymers are best described as solids having:

(a) Perfect order

(b) Complete disorder

(c) Structure between order and disorder ✅

(d) Only liquid properties

9. Polythene, polystyrene and nylon are examples of:

(a) Ceramics

(b) Metals

(c) Polymers ✅

(d) Ionic compounds

10. A unit cell is defined as:

(a) The whole crystal

(b) The smallest repeating three-dimensional structure ✅

(c) The surface of a crystal

(d) The melting point of a solid

11. Deformation in a solid is produced when the body is:

(a) Heated

(b) Cooled

(c) Subjected to an external force ✅

(d) Left free

12. The ability of a body to regain its original shape after removal of force is called:

(a) Plasticity

(b) Ductility

(c) Elasticity ✅

(d) Brittleness

13. Stress is defined as:

(a) Force × area

(b) Force per unit volume

(c) Force per unit area ✅

(d) Change in length per unit length

14. The SI unit of stress is:

(a) Dyne

(b) Joule

(c) Pascal (Pa) ✅

(d) Watt

15. Stress which causes change in length is called:

(a) Volume stress

(b) Shear stress

(c) Tensile stress ✅

(d) Bulk stress

16. Strain is defined as:

(a) Force applied

(b) Change in length

(c) Change in length / original length ✅

(d) Force per unit area

17. Strain has:

(a) Unit of metre

(b) Unit of pascal

(c) Unit of newton

(d) No unit ✅

18. Volumetric strain is equal to:

(a) ΔL / L

(b) $\Delta V / V_0$ ✅

(c) F / A

(d) tan θ

19. Shear strain (γ) for small angles is equal to:

(a) sin θ

(b) cos θ

(c) tan θ

(d) θ (in radians) ✅

20. The ratio of stress to strain is called:

(a) Elastic limit

(b) Strain energy

(c) Modulus of elasticity ✅

(d) Yield strength

21. The ratio of tensile stress to tensile strain is known as:

(a) Bulk modulus

(b) Shear modulus

(c) Young's modulus ✅

(d) Poisson's ratio

22. Bulk modulus is related to:

(a) Change in length

(b) Change in shape

(c) Change in volume ✅

(d) Change in mass

23. The point up to which Hooke's law is obeyed is called:

(a) Yield point

(b) Proportional limit ✅

(c) Breaking point

(d) Ultimate stress

24. The maximum stress a material can withstand is called:

(a) Elastic limit

(b) Fracture stress

(c) Ultimate tensile strength (UTS) ✅

(d) Yield strength

25. Substances which undergo large plastic deformation before breaking are called:

(a) Brittle

(b) Elastic

(c) Ductile ✅

(d) Rigid

26. The fundamental electrical property of a solid is its ability to:

(a) Absorb heat

(b) Reflect light

(c) Conduct electric current ✅

(d) Change shape

27. Metals are good conductors because they have conductivity of the order of:

(a) 10^{-10} $(\Omega\cdot m)^{-1}$

(b) 10^{-4} $(\Omega\cdot m)^{-1}$

(c) 10^{7} $(\Omega\cdot m)^{-1}$ ✅

(d) 10^{20} $(\Omega\cdot m)^{-1}$

28. Materials like wood and diamond are classified as insulators because they have:

(a) High conductivity

(b) Moderate conductivity

(c) Very low conductivity ✅

(d) Overlapping bands

29. Solids having conductivity between conductors and insulators are called:

(a) Superconductors

(b) Insulators

(c) Semiconductors ✅

(d) Dielectrics

30. The theory which successfully explains electrical behaviour of solids is:

(a) Bohr atomic model

(b) Free electron theory

(c) Energy band theory ✅

(d) Rutherford model

31. The energy band which contains the valence electrons is called:

(a) Forbidden band

(b) Conduction band

(c) Valence band ✅

(d) Free band

32. The band in which electrons move freely and conduct current is known as:

(a) Valence band

(b) Forbidden band

(c) Conduction band ✅

(d) Lower band

33. In insulators, the energy gap between valence and conduction band is:

(a) Zero

(b) Very small

(c) Moderate

(d) Very large ✅

34. In conductors, the valence and conduction bands:

(a) Are separated by a large gap

(b) Do not overlap

(c) Slightly overlap

(d) Largely overlap each other ✅

35. At room temperature, semiconductors have:

(a) Empty conduction band

(b) Full valence band only

(c) Partially filled valence and conduction bands ✅

(d) No forbidden gap

36. The vacancy created in the valence band is called:

(a) Proton

(b) Neutron

(c) Hole ✅

(d) Ion

37. A pure semiconductor without impurity is called:

(a) Extrinsic semiconductor

(b) n-type semiconductor

(c) p-type semiconductor

(d) Intrinsic semiconductor ✅

38. The process of adding impurity to a pure semiconductor is called:

(a) Ionization

(b) Neutralization

(c) Doping ✅

(d) Polarization

39. When silicon is doped with a pentavalent impurity, it becomes:

(a) p-type semiconductor

(b) Intrinsic semiconductor

(c) n-type semiconductor ✅

(d) Insulator

40. In semiconductors, electric current is carried by:

(a) Electrons only

(b) Holes only

(c) Ions only

(d) Both electrons and holes ✅

41. A material whose electrical resistivity becomes zero below a certain temperature is called:

(a) Semiconductor

(b) Insulator

(c) Superconductor ✅

(d) Perfect resistor

42. The temperature below which a material becomes superconducting is known as:

(a) Melting temperature

(b) Room temperature

(c) Critical temperature ✅

(d) Curie temperature

43. Once current is established in a superconductor, it:

(a) Gradually decreases

(b) Produces heat

(c) Continues indefinitely without energy loss ✅

(d) Needs external emf continuously

44. The first superconductor was discovered in 1911 by:

(a) Bohr

(b) Ampere

(c) Kamerlingh Onnes ✅

(d) Faraday

45. Mercury becomes a superconductor below the temperature of:

(a) 7.2 K

(b) 3.72 K

(c) 1.18 K

(d) 4.2 K ✅

46. A superconductor with critical temperature above 77 K is called:

(a) Low temperature superconductor

(b) Ceramic conductor

(c) High temperature superconductor ✅

(d) Perfect conductor

47. Superconductors are used in:

(a) Electric heaters

(b) Magnetic resonance imaging (MRI) ✅

(c) Incandescent bulbs

(d) Resistors

48. According to modern theory, magnetism in substances is mainly due to:

(a) Protons in nucleus

(b) Neutrons in nucleus

(c) Orbital and spin motion of electrons ✅

(d) Atomic vibrations

49. Substances whose atoms have a resultant magnetic moment are called:

(a) Diamagnetic

(b) Paramagnetic ✅

(c) Non-magnetic

(d) Superconducting

50. Water, copper and bismuth are examples of:

(a) Ferromagnetic substances

(b) Paramagnetic substances

(c) Diamagnetic substances ✅

(d) Superconductors

51. Strongly magnetic substances like iron, cobalt and nickel are called:

(a) Diamagnetic

(b) Paramagnetic

(c) Ferromagnetic ✅

(d) Antimagnetic

52. In an unmagnetized ferromagnetic material, magnetic domains are:

(a) Perfectly aligned

(b) Randomly oriented ✅

(c) Absent

(d) Fixed in one direction

53. The temperature above which a ferromagnetic material becomes paramagnetic is called:

(a) Critical temperature

(b) Boiling temperature

(c) Curie temperature ✅

(d) Saturation temperature

54. The phenomenon in which magnetism lags behind magnetizing current is known as:

(a) Saturation

(b) Retentivity

(c) Coercivity

(d) Hysteresis ✅

55. The area of the hysteresis loop represents:

(a) Magnetic field strength

(b) Coercive force

(c) Energy loss per cycle ✅

(d) Magnetic flux

🩸 Important Short Questions (Form Key points)

1. What are crystalline solids?

Answer:

👉 Crystalline solids are those solids in which molecules are arranged in a regular and repeating pattern.

2. What are amorphous solids?

Answer:

👉 Amorphous solids are solids in which molecules do not have a regular arrangement and their structure is disordered.

3. What are polymers?

Answer:

👉 Polymers are solids having a structure intermediate between order and disorder and are partially crystalline.

4. What is a unit cell?

Answer:

👉 A unit cell is the smallest three-dimensional repeating unit that forms the crystal lattice.

5. What is stress?

Answer:

👉 Stress is the force applied per unit area to produce a change in shape, length, or volume of a body.

6. What is tensile stress?

Answer:

👉 Tensile stress is the stress produced when a body is stretched by a pulling force, causing an increase in length.

7. What is compressive stress?

Answer:

👉 Compressive stress is the stress produced when forces act inward on a body, resulting in a decrease in length.

8. What is shear stress?

Answer:

👉 Shear stress is produced when a force is applied tangentially to a surface, causing change in shape.

9. What is strain?

Answer:

👉 Strain is the fractional change in length of a body produced due to applied stress.

10. What is the modulus of elasticity?

Answer:

👉 Modulus of elasticity is the ratio of stress to strain, provided the elastic limit is not exceeded.

🩸 Important Short Questions:

1. What are crystalline solids?

Answer:

👉 Crystalline solids are solids in which molecules, atoms, or ions are arranged in a regular, repeating pattern throughout the solid.

2. What is meant by long-range order?

Answer:

👉 Long-range order is the regular arrangement of particles over large distances in a crystalline solid.

3. Why do crystalline solids have a definite melting point?

Answer:

👉 Because their particles are arranged in a fixed regular pattern, they melt abruptly at a specific temperature.

4. What are amorphous solids?

Answer:

👉 Amorphous solids are solids with no regular arrangement of molecules, having disordered structure like liquids.

5. Why are amorphous solids called glassy solids?

Answer:

👉 Because their disordered structure is frozen in and they have no definite melting point.

6. What are polymeric solids?

Answer:

👉 Polymeric solids are materials with long-chain molecules, having structure intermediate between order and disorder.

7. Give examples of polymeric solids.

Answer:

👉 Examples include polythene, polystyrene, nylon, and natural rubber.

8. What is a unit cell?

Answer:

👉 A unit cell is the smallest three-dimensional repeating structure in a crystalline solid.

9. What is a crystal lattice?

Answer:

👉 A crystal lattice is the complete three-dimensional arrangement of unit cells repeated throughout the solid.

10. How does the structure affect the properties of solids?

Answer:

👉 The structure and bonding of atoms determine properties like hardness, ductility, malleability, conductivity, and melting point.

11. What is deformation in solids?

Answer:

👉 Deformation is the change in shape, length, or volume of a solid when an external force is applied.

12. What is elasticity?

Answer:

👉 Elasticity is the ability of a solid to regain its original shape after the removal of the applied force.

13. Define stress.

Answer:

👉 Stress is the force applied per unit area on a body to produce a change in shape, volume, or length.

14. What are the SI units of stress?

Answer:

👉 The SI unit of stress is pascal (Pa), which is equal to newton per square metre (N/m^2).

15. Differentiate between tensile, compressive, and shear stress.

Answer:

👉 Tensile stress changes length, compressive stress reduces length, and shear stress twists or deforms the shape.

16. Define strain.

Answer:

👉 Strain is the measure of deformation of a solid, defined as fractional change in length (or volume) per unit length.

17. What is tensile strain and compressive strain?

Answer:

👉 Tensile strain occurs due to stretching, compressive strain occurs due to compression of a solid.

18. What is the modulus of elasticity?

Answer:

👉 Modulus of elasticity is the ratio of stress to strain for a material, provided the applied force is within elastic limits.

19. What is bulk modulus?

Answer:

👉 Bulk modulus is the ratio of applied stress to the volumetric strain when the volume of a body changes.

20. What is shear modulus?

Answer:

👉 Shear modulus is the ratio of shear stress to the shear strain when a body is twisted or deformed.

21. What is electrical conductivity of a solid?

Answer:

👉 Electrical conductivity is the ability of a solid to conduct electric current when an electric field is applied.

22. What are insulators?

Answer:

👉 Insulators are solids which have very low electrical conductivity because their electrons are tightly bound.

23. What are conductors?

Answer:

👉 Conductors are materials that have a large number of free electrons and can easily conduct electric current.

24. What are semiconductors?

Answer:

👉 Semiconductors are solids whose electrical conductivity lies between that of conductors and insulators.

25. What is energy band theory?

Answer:

👉 Energy band theory explains the electrical behaviour of solids on the basis of allowed and forbidden energy bands.

26. What is a forbidden energy gap?

Answer:

👉 Forbidden energy gap is the range of energy between valence band and conduction band where no electron can exist.

27. What is a valence band?

Answer:

👉 Valence band is the highest occupied energy band that contains valence electrons.

28. What is a conduction band?

Answer:

👉 Conduction band is the energy band in which electrons move freely and conduct electric current.

29. What is doping in semiconductors?

Answer:

👉 Doping is the process of adding a small amount of impurity to a pure semiconductor to change its conductivity.

30. What is an intrinsic semiconductor?

Answer:

👉 An intrinsic semiconductor is a pure semiconductor without any impurity, such as pure silicon or germanium.

31. What is a superconductor?

Answer:

👉 A superconductor is a material whose electrical resistivity becomes zero below a certain temperature.

32. What is critical temperature?

Answer:

👉 The critical temperature is the temperature below which a material becomes superconducting.

33. Who discovered the first superconductor and when?

Answer:

👉 The first superconductor was discovered by Kamerlingh Onnes in 1911.

34. What is meant by high temperature superconductor?

Answer:

👉 A superconductor having critical temperature above 77 K is called a high temperature superconductor.

35. Give two applications of superconductors.

Answer:

👉 Superconductors are used in MRI machines and magnetic levitation trains.

36. What is the source of magnetism in an atom?

Answer:

👉 Magnetism in an atom is due to the spin and orbital motion of electrons.

37. What is a magnetic dipole?

Answer:

👉 An atom having a resultant magnetic field behaves like a tiny magnet and is called a magnetic dipole.

38. What are paramagnetic substances?

Answer:

👉 Paramagnetic substances are those in which the magnetic fields of electrons support each other.

39. What are diamagnetic substances?

Answer:

👉 Diamagnetic substances are those in which the magnetic effects of electrons cancel each other.

40. What are ferromagnetic substances?

Answer:

👉 Ferromagnetic substances are materials whose atoms cooperate to produce a strong magnetic effect.

🩸 Important Long Questions:

🌟 Q1. Explain the classification of solids in detail.

❖ **Answer:**

Solids are classified on the basis of the arrangement of atoms, molecules or ions present in them. This internal arrangement determines their physical and mechanical properties such as shape, melting point, hardness and conductivity. On this basis, solids are classified into crystalline solids, amorphous solids and polymeric solids.

1. Crystalline Solids

Crystalline solids are those in which atoms, molecules or ions are arranged in a regular, repeating and well-ordered three-dimensional pattern throughout the solid.

Properties

- Long-range orderly arrangement of particles
- Definite geometrical shape
- Sharp and fixed melting point
- Hard and rigid structure
- Can be studied by X-ray diffraction

Examples

- Metals: iron, copper, zinc
- Ionic compounds: sodium chloride (NaCl)
- Ceramics: zirconia

2. Amorphous (Glassy) Solids

Amorphous solids are those solids in which particles are arranged in an irregular and random manner, similar to liquids. The word amorphous means without definite shape.

Properties

- No long-range order
- No definite geometrical shape
- No sharp melting point
- Soften gradually on heating
- Behave like supercooled liquids

Examples

- Glass
- Rubber
- Certain plastics

3. Polymeric Solids

Polymeric solids are materials whose structure is intermediate between crystalline and amorphous solids. They consist of very long chain molecules formed by polymerization.

Properties

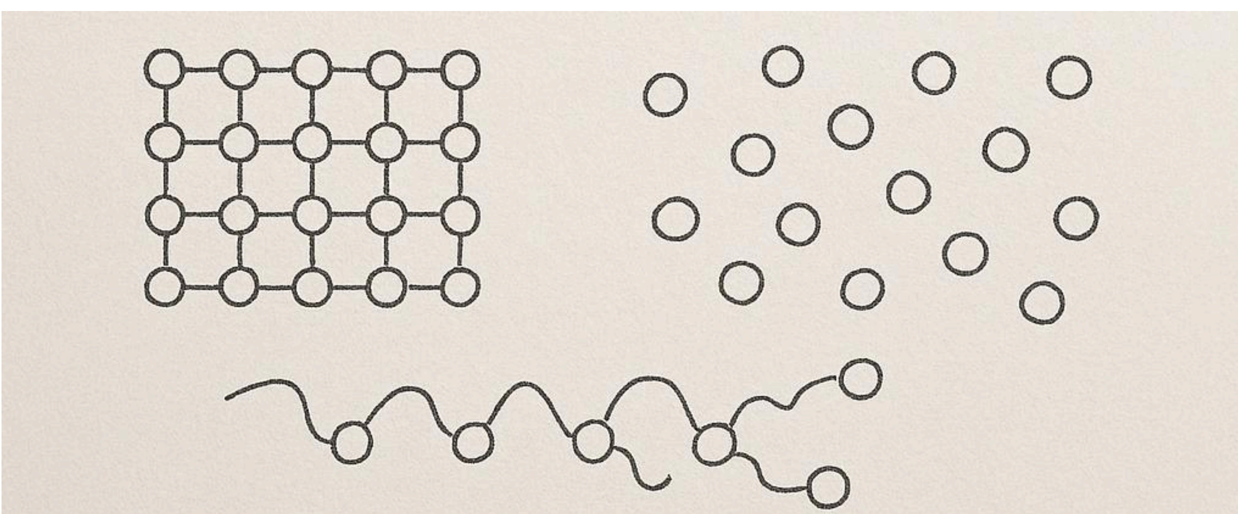
- Partially or poorly crystalline
- Low density
- High strength-to-weight ratio
- Flexible and durable

Examples

- Polythene
- Nylon
- Polystyrene
- Natural rubber

✦ Diagram Concept (For Board Exam)

👉 **Crystalline Solid Diagram Concept:**



✦ **Summary:**

Solids are classified into crystalline, amorphous and polymeric solids based on the internal arrangement of their particles. Crystalline solids have a regular structure and fixed melting point, amorphous solids have a disordered structure and no definite melting point, while polymeric solids show intermediate behavior. This classification helps in understanding the properties and applications of different materials in science and technology.

🌟 **Q2. Describe deformation in solids and explain stress and strain.**

❖ **Answer:**

When an external force is applied to a solid body, its shape, size or volume may change. This change produced in a solid due to the applied force is called deformation. The study of deformation helps us understand how materials behave under different forces.

Deformation in Solids

Deformation is the change in length, shape or volume of a solid body when an external force acts on it. If the force is small, the body may return to its original shape after removal of the force. If the force is large, permanent deformation may occur.

✦ Stress

Stress is defined as the force applied per unit area of a body.

Stress = Force / Area = F / A

Unit of Stress

- SI unit: Pascal (Pa) or N m^{-2}

Types of Stress

1. Tensile Stress

- When a force is applied to stretch a body, the stress produced is called tensile stress.

Example:

- Stretching a wire by pulling it from both ends.

2. Compressive Stress

- When a force acts to compress or shorten a body, the stress produced is called compressive stress.

Example:

- Pressing a spring or squeezing a rubber ball.

3. Shear Stress

- When a force is applied parallel (tangential) to the surface of a body causing it to twist or change shape, it is called shear stress.

Example:

- Twisting a cube or cutting paper with scissors.

✦ Strain

Strain is the measure of deformation and is defined as the ratio of change in dimension to the original dimension of a body.

Strain = Change in length / Original length

Unit of Strain

- Strain has no unit because it is a ratio.

Types of Strain

1. Tensile Strain

- Strain produced due to tensile stress when a body is stretched.

Example:

- Increase in length of a stretched wire.

2. Compressive Strain

- Strain produced due to compressive stress when a body is compressed.

Example:

- Decrease in length of a compressed rod.

3. Shear Strain

- Strain produced due to shear stress when a body is twisted or deformed sideways.

Example:

- Angular deformation of a cube.

Relation Between Stress and Strain

For small deformations, stress is directly proportional to strain:

Stress $\propto$ Strain

This relationship leads to the concept of modulus of elasticity.

✦ **Summary:**

Deformation in solids occurs when an external force changes the shape or size of a body. Stress is the force applied per unit area, while strain measures the resulting deformation. Stress is of three types: tensile, compressive and shear. Similarly, strain is also classified into tensile, compressive and shear strain. Understanding stress and strain is essential in designing safe and durable materials.

🌟 **Q3. Explain Modulus of Elasticity and describe different elastic constants.**

❖ **Answer:**

When a force is applied to a solid body, it undergoes deformation. If the applied force is within the elastic limit, the body regains its original shape after the force is removed. The modulus of elasticity helps us measure how much a material resists deformation.

Modulus of Elasticity

The modulus of elasticity is defined as the ratio of stress to the corresponding strain within the elastic limit of a material.

Modulus of Elasticity = Stress / Strain

Unit

- SI unit: Pascal (Pa) or N m^{-2}

It shows the stiffness of a material. A higher value of modulus means the material is more rigid and less easily deformed.

Types of Elastic Constants

There are three important elastic constants:

1. Young's Modulus (Y)

Definition:

Young's modulus is the ratio of tensile stress to tensile strain.

Y = Tensile stress / Tensile strain

Unit

- Pascal (Pa)

Explanation:

It measures the ability of a material to resist change in length when stretched or compressed.

Example:

- Steel has a high Young's modulus, so it stretches very little under force, while rubber has a low Young's modulus.

2. Bulk Modulus (K)

Definition:

- Bulk modulus is the ratio of volumetric stress to volumetric strain.

K = Change in pressure / Volumetric strain

Unit

- Pascal (Pa)

Explanation:

- It measures the resistance of a material to change in volume when subjected to pressure from all sides.

Example:

- Liquids have a high bulk modulus because they are difficult to compress.

3. Shear Modulus (G)

Definition:

- Shear modulus is the ratio of shear stress to shear strain.

G = Shear stress / Shear strain

Unit

- Pascal (Pa)

Explanation:

- It measures the resistance of a material to change in shape without change in volume.

Example:

- Shear modulus is important in materials used for shafts and beams.

✦ **Summary:**

The modulus of elasticity expresses how a material responds to applied stress within the elastic limit. It is the ratio of stress to strain. There are three elastic constants: Young's modulus, which deals with change in length; bulk modulus, which relates to change in volume; and shear modulus, which concerns change in shape. These constants help engineers select suitable materials for different structural and mechanical applications.

🌟 Q4. Explain the Stress–Strain Curve of a Ductile Material.

❖ Answer:

When a gradually increasing force is applied to a ductile material (like mild steel), its deformation is not uniform. The relationship between stress and strain can be studied with the help of a stress–strain curve. This curve helps us understand the mechanical behavior of the material at different stages of loading.

Stress–Strain Curve Explanation

A ductile material can undergo large deformation before breaking. The stress–strain curve for such materials consists of different regions or points which represent various stages of deformation.

1. Proportional Limit (Point A)

At the beginning, stress is directly proportional to strain, i.e., Stress ∝ Strain

Up to this point, the graph is a straight line.

If the load is removed here, the material returns completely to its original shape.

👉 **Example**: Elastic spring action.

2. Elastic Limit (Point B)

Beyond the proportional limit, stress and strain are no longer exactly proportional.

However, the material can still return to its original shape if the load is removed.

The elastic limit is the maximum stress that the material can bear without permanent deformation.

👉 **Beyond this point,** plastic deformation begins.

3. Yield Point (Point C)

At this stage, a small increase in stress causes a large increase in strain.

The material starts to deform permanently, even if the load is removed.

The stress corresponding to this point is called yield stress.

This is the beginning of plastic deformation.

👉 The metal appears to “yield” without any additional load.

4. Ultimate Tensile Strength (UTS) (Point D)

As the load is increased further, the material resists deformation up to a maximum point.

The maximum stress the material can withstand before necking occurs is called Ultimate Tensile Strength (UTS).

Beyond this point, the material starts to weaken.

👉 This shows the maximum strength of the material.

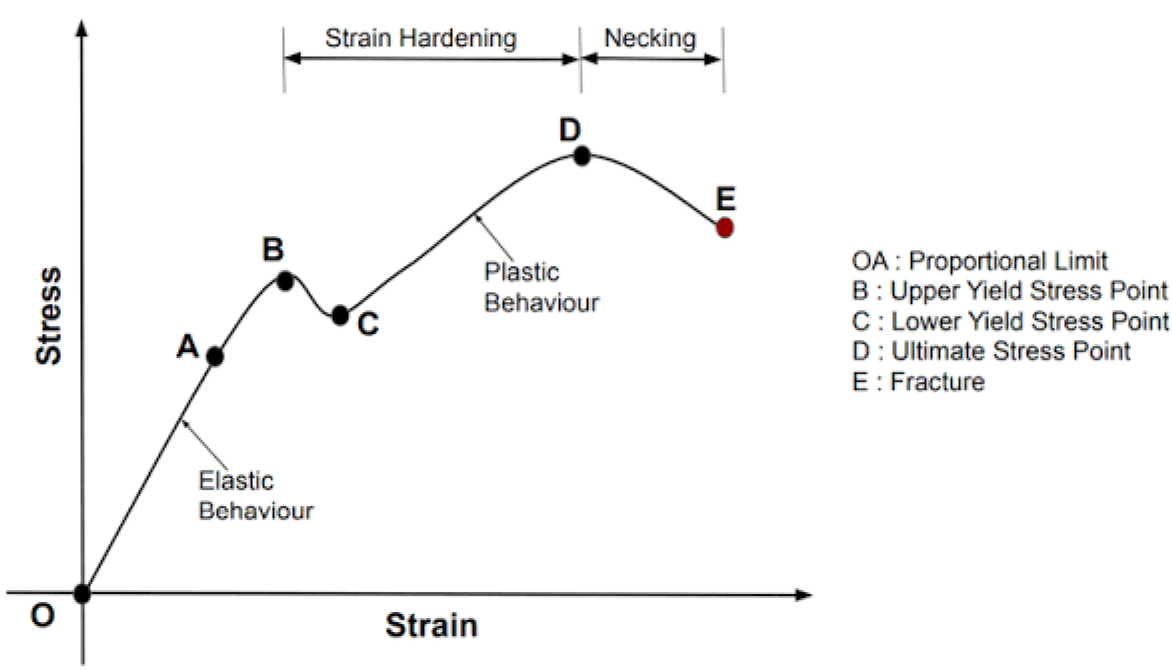
5. Fracture Point (Point E)

After reaching UTS, the material starts to narrow (neck) and finally breaks.

The point at which the material fractures or breaks completely is called the Fracture Point.

👉 Permanent damage occurs — the material cannot be restored.

✦ Diagram:



✦ **Summary:**

- The stress–strain curve for a ductile material shows how it behaves under tension.
- In the proportional region, stress and strain obey Hooke's Law.
- Up to the elastic limit, the material returns to its original shape.
- Beyond the yield point, plastic deformation begins.
- The ultimate tensile strength marks the highest stress before necking.
- **Finally**, at the fracture point, the material breaks.

This curve helps engineers determine the strength, ductility, and elasticity of materials used in mechanical and structural designs.

🌟 Q5. Describe Strain Energy and Explain How It Is Obtained from the Force–Extension Graph

❖ **Answer:**

Strain Energy

When a solid body such as a wire, spring, or rod is stretched, compressed, or twisted within its elastic limit, work is done on the body. This work done is stored in the body in the form of strain energy.

👉 Strain energy is the energy stored in a body due to elastic deformation.

This energy is stored only as long as the deformation remains elastic. When the applied force is removed, the body returns to its original shape and the stored energy is released.

Strain Energy in a Stretched Wire

Consider a wire of original length L stretched by a force F, producing an extension ΔL.

- The applied force gradually increases from 0 to F.
- The extension also increases gradually from 0 to ΔL.
- The average force acting on the wire during stretching is:

Average force = F / 2

Expression for Strain Energy

Work done = Average force × Extension

Strain Energy = (1/2) * F * ΔL

This work is stored in the wire as strain energy.

Force–Extension Graph

To understand strain energy graphically, we draw a force–extension graph.

- Force (F) is plotted along the y-axis
- Extension (ΔL) is plotted along the x-axis

Within the elastic limit, the graph is a straight line passing through the origin, showing that force is directly proportional to extension.

Strain Energy from the Graph

- The strain energy stored in the body is equal to the area under the force–extension graph up to the point of extension.
- Since the graph is a straight line, the area under the graph is a triangle.

Strain Energy = Area of triangle

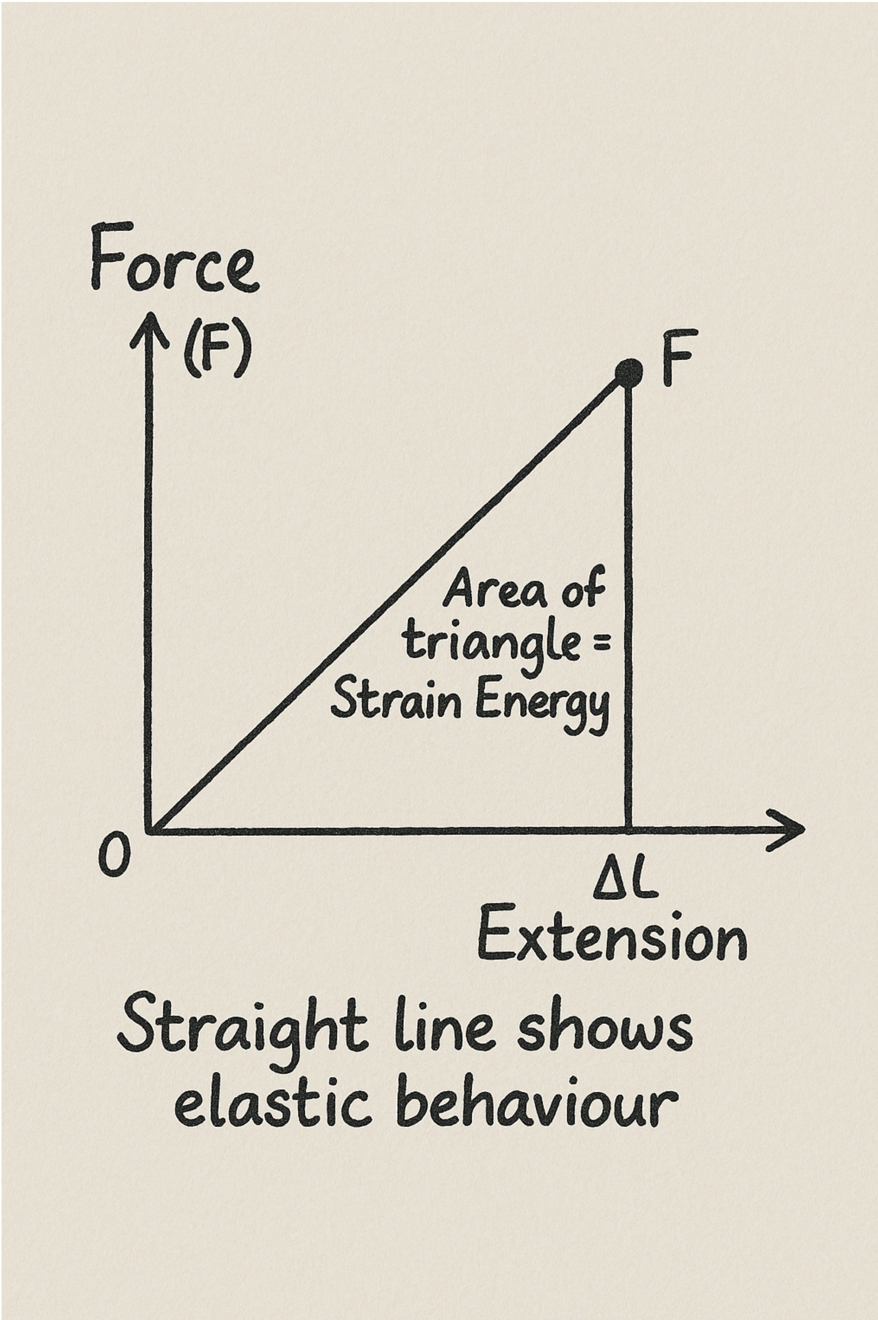
Area of triangle = (1/2) * Base * Height

Strain Energy = (1/2) * ΔL * F

Thus, the strain energy stored in the body is:

Strain Energy = (1/2) * F * ΔL

✦ **Diagram (Force–Extension Graph)**



Important Points

- Strain energy exists only within the elastic limit.

- If the elastic limit is exceeded, energy is lost as heat and permanent deformation occurs.

The concept of strain energy is widely used in:

- Springs
- Shock absorbers
- Bridges and buildings
- Mechanical and structural designs

✦ **Summary:**

Strain energy is the energy stored in a body due to elastic deformation. It is equal to the work done in stretching or compressing the body. Graphically, strain energy is obtained from the area under the force–extension graph. For elastic deformation, this area is triangular, and the strain energy is given by:

Strain Energy = (1/2) * F * ΔL

This concept is essential in understanding the elastic behavior and energy storage capacity of materials.

🌟 Q6. Explain Energy Band Theory and Classify Solids on its Basis

❖ **Answer:**

Energy Band Theory

According to energy band theory, electrons in an isolated atom can occupy only discrete energy levels. However, when a very large number of atoms come close together to form a solid, the interaction between neighbouring atoms causes each discrete energy level to split into a very large number of closely spaced energy levels.

These closely **spaced energy** levels form a continuous range of energies, called an energy band.

Between two consecutive energy bands, there exists a region in which no electron is allowed to exist. This region is called the forbidden energy gap or band gap.

Important Energy Bands

1. Valence Band

The energy band that contains valence electrons (outermost shell electrons) is called the valence band.

- It is normally filled or partially filled
- Electrons in this band are bound to atoms
- It plays a major role in determining electrical properties

2. Conduction Band

The energy band just above the valence band is called the conduction band.

- Electrons in this band are free to move
- These electrons conduct electric current
- It may be empty, partially filled, or overlapped with valence band

✦ Classification of Solids on the Basis of Energy Band Theory

On the basis of the arrangement of valence band, conduction band, and forbidden energy gap, solids are classified into conductors, semiconductors, and insulators.

1. Conductors

Conductors are materials that allow electric current to flow easily.

Energy Band Description

- Valence band and conduction band overlap
- There is no forbidden energy gap
- A large number of free electrons are available

Result

Electrons move freely even under a small electric field, so conductivity is very high.

Examples

- Copper

- Silver
- Aluminium

2. Semiconductors

Semiconductors have electrical conductivity between conductors and insulators.

Energy Band Description

- Valence band is almost full
- Conduction band is almost empty
- A small forbidden energy gap (~1 eV) exists

Result

At room temperature, some electrons gain enough energy to cross the band gap and enter the conduction band, making the material conductive.

Examples

- Silicon (Si)
- Germanium (Ge)

3. Insulators

Insulators are materials that do not allow electric current to flow.

Energy Band Description

- Valence band is completely full
- Conduction band is completely empty
- A large forbidden energy gap (several eV) exists

Result

Electrons cannot jump to the conduction band even at high temperatures, so no current flows.

Examples

- Glass
- Rubber
- Diamond
- Wood

✦ Comparison (Conceptual)

Conductors: No band gap ⟶ high conductivity

Semiconductors: Small band gap ⟶ moderate conductivity

Insulators: Large band gap ⟶ negligible conductivity

✦ Summary:

Energy band theory explains the electrical behavior of solids by considering the arrangement of energy bands. In conductors, the valence and conduction bands overlap, allowing free movement of electrons. In semiconductors, a small forbidden energy gap exists, enabling limited conduction at room temperature. In insulators, a large energy gap prevents electrons from reaching the conduction band, making them poor conductors of electricity. Thus, energy band theory successfully explains the electrical properties of different solids.

🌟 Q7. Explain Intrinsic and Extrinsic Semiconductors

❖ Answer:

Semiconductors

Semiconductors are materials whose electrical conductivity lies between conductors and insulators. Their conductivity depends strongly on temperature and purity.

1. Intrinsic Semiconductors

Definition

An intrinsic semiconductor is a pure semiconductor without any intentional impurity added.

Explanation

- Pure silicon (Si) and germanium (Ge) are intrinsic semiconductors
- Each atom has four valence electrons
- In crystal form, each atom shares its four electrons with four neighbouring atoms forming covalent bonds
- At 0 K, all electrons are bound → no conduction
- At room temperature, some electrons gain enough energy to break covalent bonds and move to the conduction band

Electron–Hole Pair

- When an electron leaves the valence band, it creates a hole
- A hole behaves like a positive charge
- Both electrons and holes contribute to current flow

Properties

- Equal number of electrons and holes
- Low conductivity compared to extrinsic semiconductors

Examples

- Pure Silicon
- Pure Germanium

2. Extrinsic Semiconductors

Definition

An extrinsic semiconductor is a semiconductor whose conductivity is increased by adding a small amount of impurity.

This process is called doping.

Doping

Definition

Doping is the process of adding a controlled amount of impurity atoms to a pure semiconductor to increase its conductivity.

Ratio of impurity ≈ 1 atom in 10^6–10^8 atoms

Two types:

- n-type
- p-type

A. n-Type Semiconductor

Formation

- Formed by doping silicon or germanium with a pentavalent impurity

Examples: Phosphorus (P), Arsenic (As), Antimony (Sb)

Explanation

- Pentavalent atom has 5 valence electrons
- Four electrons form covalent bonds
- The fifth electron becomes free

Donor Atom

- The impurity atom donates a free electron
- Hence called a donor atom

Charge Carriers

- Majority carriers: Electrons
- Minority carriers: Holes

B. p-Type Semiconductor

Formation

- Formed by doping silicon or germanium with a trivalent impurity

Examples: Boron (B), Aluminium (Al), Gallium (Ga), Indium (In)

Explanation

- Trivalent atom has 3 valence electrons
- Three covalent bonds are formed
- One bond is incomplete $\longrightarrow$ hole is created

Acceptor Atom

- The impurity atom accepts an electron
- Hence called an acceptor atom

Charge Carriers

- Majority carriers: Holes
- Minority carriers: Electrons

Comparison of n-Type and p-Type (Conceptual)

n-type $\longrightarrow$ Donor impurity $\longrightarrow$ Free electrons

p-type $\longrightarrow$ Acceptor impurity $\longrightarrow$ Holes

✦ **Summary:**

Intrinsic semiconductors are pure materials like silicon and germanium in which conduction occurs due to thermally generated electron–hole pairs. Their conductivity is low. Extrinsic semiconductors are formed by doping intrinsic semiconductors with suitable impurities. Doping with pentavalent elements produces n-type semiconductors where electrons are the majority charge carriers, while doping with trivalent elements produces p-type semiconductors where holes are the majority carriers. The controlled addition of impurities greatly increases the conductivity of semiconductors.

🌟 Q8. What are superconductors? Describe their properties and applications.

❖ Definition:

Superconductors are materials whose electrical resistivity becomes zero when cooled below a certain temperature called the critical temperature (Tc).

- Below Tc, current flows indefinitely without energy loss
- They are perfect conductors

1. Critical Temperature (Tc)

It is the temperature below which a material becomes superconducting

Example:

- Mercury → Tc = 4.2 K
- Aluminium → Tc = 1.18 K
- Lead → Tc = 7.2 K

- High-temperature superconductors (ceramics) → Tc up to 125 K or higher

2. Properties of Superconductors

1. Zero Electrical Resistance

- No energy dissipation
- Current can flow indefinitely

2. Perfect Diamagnetism (Meissner Effect)

- Expel magnetic fields from the interior
- Magnetic levitation is possible

3. Critical Current & Magnetic Field

- Each superconductor has maximum current and magnetic field it can withstand

4. Abrupt Transition

- Resistivity drops suddenly to zero at Tc

3. Example

- Mercury (Hg), Lead (Pb), Tin (Sn) – Low-temperature superconductors
- Yttrium-Barium-Copper-Oxide ($YBa_2Cu_3O_7$) – High-temperature superconductor

4. Applications

1. Magnetic Resonance Imaging (MRI)

- Superconducting magnets create strong magnetic fields

2. Magnetic Levitation (Maglev) Trains

- Trains float above tracks using superconductors

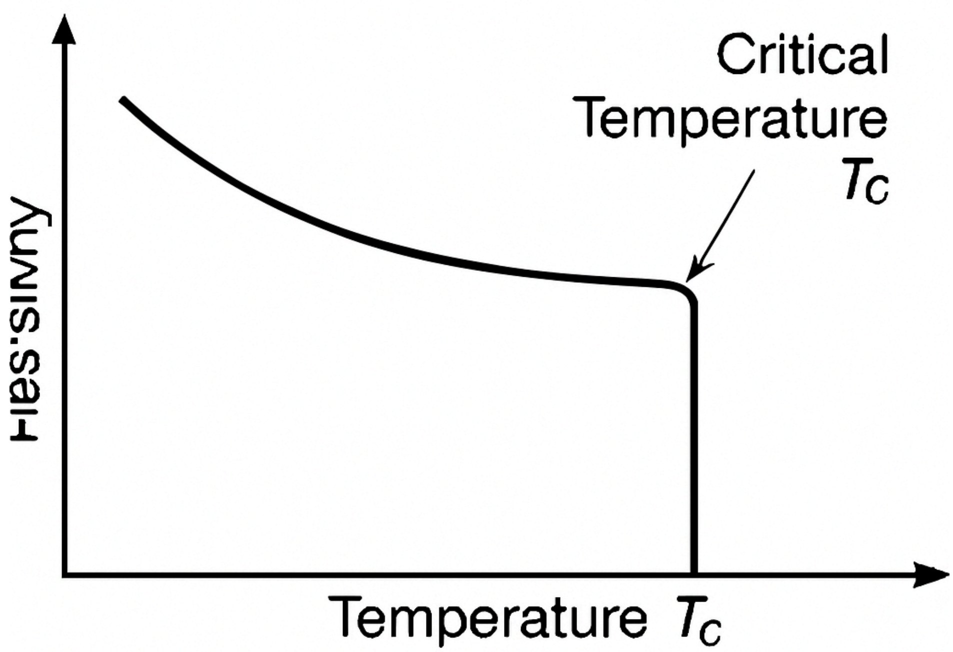
3. Power Cables & Electric Motors

- Lossless energy transmission
- High-efficiency motors

4. Faster Computers & Electronics

- Superconducting circuits allow rapid signal transmission

✦ Diagram:



Resistivity drops suddenly to zero at T_C

✦ Summary:

Superconductors are materials that lose all electrical resistance below a critical temperature and can maintain current indefinitely. They also exhibit perfect diamagnetism. Their applications include MRI machines, magnetic levitation trains, high-efficiency motors, and faster electronic circuits. Superconductivity represents a revolution in energy-efficient technology.

🌟 **Q9. Explain magnetic properties of solids.**

❖ **Definition:**

Magnetism in solids arises due to motion of electrons in atoms. The magnetic field of an atom comes from:

1. Orbital motion of electrons around the nucleus

2. Spin of electrons

- Atoms with a resultant magnetic field act like tiny magnets called magnetic dipoles.
- Magnetic properties of solids depend on alignment of these dipoles.

1. Classification of Magnetic Materials

A. Paramagnetic Substances

- Atoms have unpaired electrons whose magnetic fields support each other
- Weakly attracted by external magnetic field

Examples: Aluminium (Al), Platinum (Pt)

B. Diamagnetic Substances

- Magnetic fields of electrons cancel each other
- Weakly repelled by external magnetic field

Examples: Copper (Cu), Bismuth (Bi), Water (H_2O)

C. Ferromagnetic Substances

- Atoms cooperate strongly, aligning their magnetic moments in same direction
- Strongly attracted by external magnetic field

Examples: Iron (Fe), Cobalt (Co), Nickel (Ni), Chromium dioxide

Domains: Small regions where atoms are aligned

- In unmagnetized state ⟶ domains randomly oriented ⟶ net magnetism = 0
- In magnetized state ⟶ domains align ⟶ material becomes strongly magnetic

Curie Temperature: Temperature above which ferromagnetic materials lose their magnetism

- Iron $T_c \approx 750$ °C

2. Hysteresis Loop

- Represents magnetization vs magnetizing current

Key features:

1. Hysteresis: Magnetism lags behind current

2. Saturation: Maximum magnetization reached

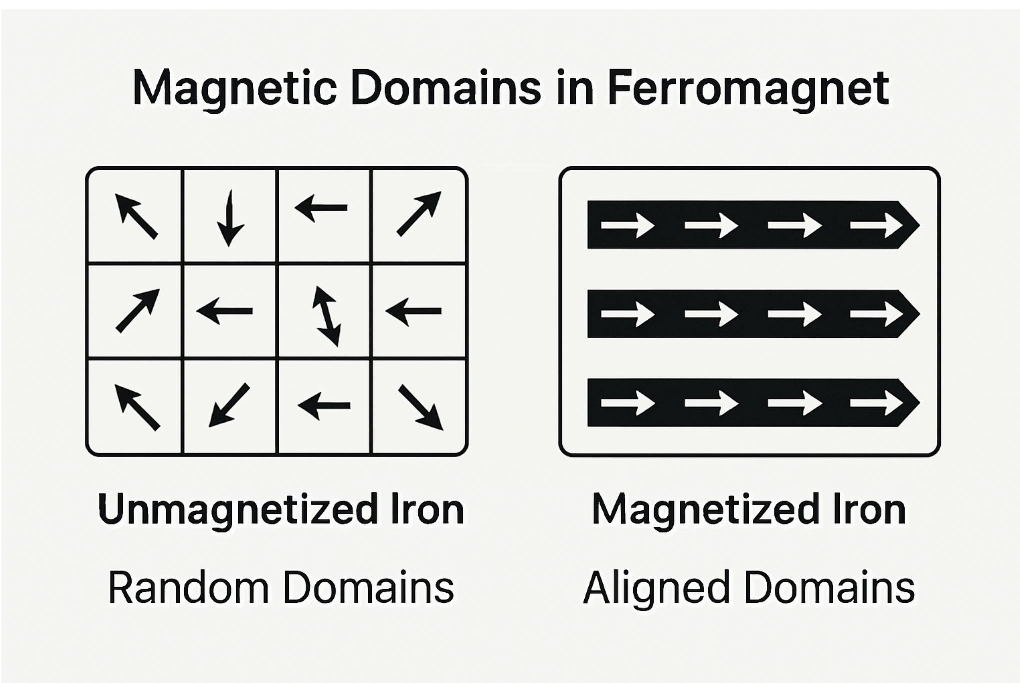
3. Retentivity (Remanence): Remaining magnetization when current = 0

4. Coercivity: Current required to reduce magnetization to 0

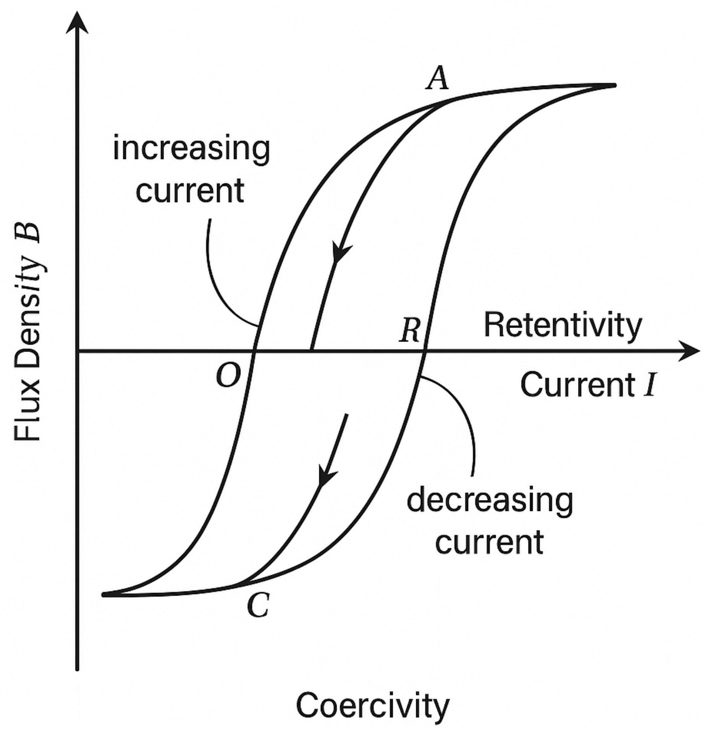
5. Loop Area: Energy lost per cycle (hysteresis loss)

- Hard magnetic materials (e.g., steel) ⟶ large coercivity ⟶ good permanent magnets
- Soft magnetic materials (e.g., iron) ⟶ small coercivity ⟶ good for electromagnets

✦ **Diagram:**



Hysteresis Loop (Flux Density vs Magnetizing Current)



✦ Summary:

- Magnetism arises from electrons: orbital motion + spin
- Materials can be paramagnetic, diamagnetic, or ferromagnetic
- Ferromagnetic substances have domains ⟶ can be magnetized
- Hysteresis loop shows energy loss and magnetic behavior of materials

- Hard materials → permanent magnets, soft materials → electromagnets

🌟 **Q10. Describe magnetic domains and explain the process of magnetization.**

❖ **Answer: Magnetic Domains and Magnetization**

1. Magnetic Domains

Definition:

- Magnetic domains are small regions within a ferromagnetic material in which the magnetic fields of all atoms are aligned in the same direction.
- Each domain behaves as a tiny magnet with a north and south pole.
- In an unmagnetized ferromagnetic material, the domains are oriented randomly, so the net magnetic effect of the material is zero.

Example: Iron, cobalt, nickel, chromium dioxide, Alnico alloys.

2. Process of Magnetization

1. Applying an External Magnetic Field

- When a ferromagnetic material (like iron) is placed in a magnetic field (e.g., solenoid), the domains begin to reorient parallel to the field.

2. Alignment of Domains

- Domains that are already partially aligned with the field grow at the expense of misaligned domains.
- **Gradually**, most domains line up with the external field, producing a net magnetic effect in the material.

3. Magnetic Saturation

- When all domains are aligned, the material is said to be magnetically saturated.
- Beyond this point, further increase in the external field does not increase magnetization.

4. Removing the External Field

- Some materials, like iron, lose most of their alignment and become unmagnetized (soft magnetic materials).
- Materials like steel retain most alignment and remain permanently magnetized (hard magnetic materials).

✦ **Summary:**

- **Magnetic domains:** Small regions with aligned atomic magnetic moments.
- **Magnetization:** Process of aligning domains in a ferromagnetic material by applying an external field.
- **Saturation:** Maximum alignment of domains.
- **Soft vs Hard magnetic materials:** Iron $\longrightarrow$ soft, Steel $\longrightarrow$ hard.

🌟 **Q11. Explain hysteresis loop and its importance.**

❖ **Answer: Hysteresis Loop and Its Importance**

1. Hysteresis

Definition:

- Hysteresis is the phenomenon in which the magnetization of a ferromagnetic material lags behind the applied magnetizing field.
- This occurs because magnetic domains do not immediately follow changes in the external magnetic field.

2. Hysteresis Loop

A hysteresis loop is obtained by plotting magnetic flux density (B) versus magnetizing force (H) during a complete cycle of magnetization.

Key points on the loop:

1. Saturation (S):

- Maximum magnetization when all domains are aligned.

2. Retentivity / Remanence (R):

- Residual magnetism left in the material after removing the external field.

3. Coercivity (C):

- The reverse magnetizing field required to bring net magnetization to zero.

4. Energy Loss:

- The area of the hysteresis loop represents energy dissipated per cycle in the form of heat due to internal friction of domains.
- Materials with narrow loops have low energy loss (e.g., soft iron).
- Materials with wide loops have high energy loss but retain magnetization longer (e.g., steel).

3. Importance of Hysteresis Loop

1. Selection of Magnetic Materials:

- Soft magnetic materials → narrow loop → used in transformers, electromagnets.
- Hard magnetic materials → wide loop → used in permanent magnets.

2. Understanding Energy Loss:

- Helps in minimizing energy loss in AC magnetic applications.

3. Design of Magnetic Devices:

- Hysteresis characteristics determine the efficiency and performance of motors, generators, and magnetic storage devices.

✦ Summary:

- Hysteresis = lag of magnetization behind applied field.
- **Key features:** Saturation, Retentivity, Coercivity.
- Loop area = energy loss.
- Helps in choosing magnetic materials for soft vs hard applications.

🩸 Exercise Questions:

🌟 17.1 Distinguish between crystalline, amorphous and polymeric solids.

❖ **Answer:**

1. Crystalline Solids:

- Molecules, atoms, or ions are arranged in a regular, repeating three-dimensional pattern.
- They have an ordered structure that extends throughout the solid.
- Possess a definite geometric shape.
- Exhibit a sharp and definite melting point.
- Usually hard and brittle due to strong interatomic or ionic bonds.

Examples: Metals like copper (Cu), iron (Fe); ionic compounds like sodium chloride (NaCl); ceramics like zirconia (ZrO_2).

2. Amorphous Solids:

- Molecules are arranged randomly; there is no long-range order.
- The structure is more like a frozen liquid.
- No definite melting point; they gradually soften over a range of temperatures.
- Generally soft or flexible.

Examples: Glass, rubber, gels.

3. Polymeric Solids:

- Made up of long-chain molecules with structure intermediate between order and disorder.
- Partially crystalline or poorly crystalline.
- Softening occurs gradually; may have partial melting points.
- Flexible and lightweight, with good strength-to-weight ratio.

Examples: Polythene, nylon, natural rubber, plastics.

✦ **Summary:**

- **Crystalline solids:** Ordered, sharp melting point, hard.
- **Amorphous solids:** Disordered, gradual softening, flexible.
- **Polymeric solids:** Long chains, intermediate properties, flexible and strong.

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

❖ **Answer:**

1. Stress:

Stress is defined as the force applied per unit area of a body to produce any change in its shape, volume, or length.

Mathematically:

Stress (σ) = Force (F) / Area (A)

2. Strain:

Strain is the measure of deformation produced in a body when stress is applied.

In one dimension (length):

Strain (ε) = Change in length (ΔL) / Original length (L)

Strain due to volume change:

Volumetric strain = $\Delta V / V_0$

3. Types of Stress and Strain:

A. Tensile Stress and Tensile Strain:

- **Tensile Stress:** Stress applied to stretch a body.
- **Tensile Strain:** Fractional increase in length due to tensile stress.

Example: Stretching a wire.

B. Compressive Stress and Compressive Strain:

- **Compressive Stress**: Stress applied to compress or shorten a body.
- **Compressive Strain:** Fractional decrease in length due to compressive stress.

Example: Pressing a cylinder from both ends.

C. Shear Stress and Shear Strain:

- **Shear Stress:** Stress applied tangentially to deform a body by twisting or sliding layers.
- **Shear Strain**: Ratio of angular displacement produced to the perpendicular length.

Example: Twisting a cube or sliding one layer over another.

✦ **Summary:**

Tensile: Pulling ⟶ elongation ⟶ stress = F/A, strain = ΔL/L

Compressive: Pushing ⟶ shortening ⟶ stress = F/A, strain = ΔL/L

Shear: Tangential ⟶ twisting ⟶ stress = F/A, strain = θ (angle in radian)

🌟 **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:**

1. Modulus of Elasticity (E):

Modulus of elasticity is the ratio of stress to strain.

Formula:

Stress ÷ Strain = E

2. Units of Modulus of Elasticity:

Stress = Force ÷ Area

Strain = $\Delta L \div L$ (dimensionless)

Therefore:

$E = (F / A) \div (\Delta L / L) = (F \times L) \div (A \times \Delta L)$

Units of E = same as stress = Pascal (Pa)

3. Three Types of Modulus of Elasticity:

A. Young's Modulus (Y):

Formula: Y = Tensile Stress ÷ Tensile Strain

$Y = (F / A) \div (\Delta L / L) = (F \times L) \div (A \times \Delta L)$

B. Bulk Modulus (K):

Formula: K = Volumetric Stress ÷ Volumetric Strain

$K = (F / A) \div (\Delta V / V) = (F \times V) \div (A \times \Delta V)$

C. Shear Modulus (G):

Formula: G = Shear Stress ÷ Shear Strain

$G = (F / A) \div \theta \approx F \div (A \times \theta)$

✦ **Summary:**

- Modulus of elasticity = stress ÷ strain ⟶ measures stiffness.
- Units = Pascal (Pa).

- **Types**: Young’s (tensile), Bulk (volumetric), Shear (tangential).

🌟 **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:**

1. Stress-Strain Curve for a Ductile Material:

A stress-strain curve shows how a material deforms under applied force.

- On the x-axis ⟶ Strain (ε)
- On the y-axis ⟶ Stress (σ)

2. Key Terms:

A. Elastic Limit:

- The maximum stress a material can withstand without permanent deformation.

- Within this limit, if the stress is removed, the material returns to its original shape.

Example: Wire stretched slightly within this region returns to original length.

B. Yield Point:

- The point at which material starts to deform plastically.
- Beyond this stress, permanent deformation occurs even if stress is removed.
- Yield stress is denoted as σy.
- In ductile materials, it is the transition from elastic to plastic region.

C. Ultimate Tensile Stress (UTS):

- The maximum stress a material can withstand before it starts to neck and finally breaks.
- Denoted as σUTS or σmax.
- **After UTS,** material starts to weaken until fracture occurs.

✦ **Summary:**

Stress-strain curve helps visualize elastic and plastic behavior.

- Elastic limit → no permanent deformation
- Yield point → start of plastic deformation
- UTS → maximum stress before failure

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

❖ **Answer:**

1. Definition of Strain Energy:

- Strain energy is the energy stored in a deformed body due to applied stress.
- When a material is stretched or compressed, work is done on it, and this work is stored as potential energy in the material.
- It depends on the amount of force applied and extent of deformation.
- Denoted by U.

2. Determination from Force–Extension Graph:

- Consider a wire or spring being stretched by a force F, producing an extension ΔL.
- On plotting Force (F) on the y-axis and Extension (ΔL) on the x-axis, the area under the curve represents the work done or strain energy.

Formula (for linear elastic region):

Strain Energy, U = (1/2) * F * ΔL

F = (E * A * ΔL) / L

⇒ U = (1/2) * (E * A * (ΔL)^2) / L

✦ **Summary:**

Strain energy = Energy stored in a body due to deformation

Can be calculated from the area under force-extension graph

Formula:

U = (1/2) * F * ΔL = (1/2) * (E * A * (ΔL)^2) / L

🌟 **17.6 Describe the formation of energy bands in solids. Explain the difference amongst electrical behaviour of conductors, insulators and semi-conductors in terms of energy band theory.**

❖ **Answer:**

1. Formation of Energy Bands in Solids

- **Isolated atoms:** Electrons in an isolated atom occupy discrete energy levels.
- When atoms come together to form a solid (large number of atoms, N):
  - Each atomic energy level splits into N closely spaced sub-levels due to interaction between atoms.
  - These sub-levels appear as a continuous energy band.

Forbidden energy gap (band gap):

- The range of energies not allowed for electrons is called a forbidden energy gap.

Valence and conduction bands:

- **Valence band:** Highest occupied band by electrons.
- **Conduction band:** Band above valence band; electrons here move freely and conduct electricity.

2. Electrical Behaviour of Solids

(a) Conductors (Metals)

- Valence band and conduction band overlap, so many electrons are free to move.
- **Band gap:** Zero (or negligible)
- **Conductivity**: Very high (~10^7 $\Omega^{-1}m^{-1}$)

Examples: Copper, Silver, Aluminum

(b) Insulators

- Valence band: Completely filled
- Conduction band: Empty
- **Band gap:** Large (several eV), electrons cannot jump easily
- **Conductivity**: Very low (~10^{-10} to 10^{-20} $\Omega^{-1}m^{-1}$)
- **Examples:** Diamond, Glass, Wood

(c) Semiconductors

- **Valence band:** Filled at 0 K
- **Conduction band:** Empty at 0 K, but small band gap (~1 eV) allows electrons to jump at higher temperatures
- **Electrical behaviour:** Moderate, increases with temperature
- **Examples**: Silicon (Si), Germanium (Ge)
- **Holes**: Vacancies in valence band behave like positive charges

✦ **Summary:**

- Energy bands form due to splitting of atomic energy levels in solids.
- **Conductors:** Overlapping bands ⟶ free electrons ⟶ high conductivity
- **Insulators**: Large band gap ⟶ no free electrons ⟶ low conductivity
- **Semiconductors**: Small band gap ⟶ conductivity depends on temperature, can be enhanced by doping

🌟 **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:**

1. Intrinsic Semiconductors

Definition: Extremely pure semiconductors without any impurity are called intrinsic semiconductors.

Examples: Pure silicon (Si), pure germanium (Ge)

Properties:

- Electrical conductivity is very low at room temperature.
- Conductivity increases slightly with temperature.
- Charge carriers are electrons and holes generated thermally.

2. Extrinsic Semiconductors

Definition: Semiconductors obtained by adding a small amount of impurity to intrinsic semiconductors are called extrinsic semiconductors. This process is called doping.

Purpose: Increase electrical conductivity.

Types of doping:

- a. n-type semiconductor $\longrightarrow$ doped with pentavalent elements (5 valence electrons) like Phosphorus (P), Arsenic (As), Antimony (Sb)
- b. p-type semiconductor $\longrightarrow$ doped with trivalent elements (3 valence electrons) like Boron (B), Aluminium (Al), Gallium (Ga)

3. Formation of n-type Semiconductor

- **Doping element:** Pentavalent (5 valence electrons) e.g., Phosphorus

Mechanism:

- Four valence electrons of impurity form covalent bonds with neighboring Si atoms.
- Fifth electron remains free $\longrightarrow$ increases electron concentration $\longrightarrow$ majority carriers = electrons, minority carriers = holes

4. Formation of p-type Semiconductor

Doping element: Trivalent (3 valence electrons) e.g., Boron

Mechanism:

- Three valence electrons of impurity form covalent bonds with neighboring Si atoms.
- One missing electron (hole) appears in the bond ⟶ acts as positive charge carrier
- Majority carriers = holes, minority carriers = electrons

✦ **Summary:**

- Intrinsic vs Extrinsic Semiconductors
- **Intrinsic**: Pure, low conductivity, electrons & holes generated thermally
- **Extrinsic**: Doped, higher conductivity, electrons or holes as majority carriers
- **n-type:** Pentavalent dopant ⟶ free electrons ⟶ negative carriers
- **p-type**: Trivalent dopant ⟶ holes ⟶ positive carriers

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

❖ **Answer:**

1. Introduction

Pure semiconductor: Examples – silicon (Si) or germanium (Ge) in its pure form.

Electrical conduction: Carried out by electrons (negative charge) and holes (positive charge).

2. Mechanism of Conduction

Step 1: Formation of electron-hole pairs

- At room temperature, thermal energy excites some electrons from the valence band to the conduction band.
- When an electron leaves its covalent bond in the valence band, it creates a hole (vacancy).
- Electron = negative charge carrier
- Hole = positive charge carrier

Step 2: Movement of electrons

- Free electrons in the conduction band can move under the influence of an applied electric field.
- This movement constitutes electrical current.

Step 3: Movement of holes

- A hole is a vacancy in the covalent bond of the valence band.
- Neighboring electrons move to fill the hole, causing the hole to appear to move in the opposite direction of electrons.
- This movement of holes also contributes to electrical conduction.

Step 4: Current flow

- Both electrons (−) and holes (+) move simultaneously.
- **In a semiconductor under applied voltage:**
  - Electrons drift towards positive terminal
  - Holes drift towards negative terminal
- Total current = contribution of electrons + contribution of holes

✦ **Summary:**

- **Electrons:** Negative charge carriers in conduction band
- **Holes**: Positive charge carriers in valence band
- **Current in semiconductor:** Result of combined motion of electrons and holes
- Mechanism explains why pure semiconductors have low conductivity at 0 K, increasing with temperature.

🌟 **17.9 Write a note on superconductors.**

❖ **Answer:**

Superconductors are special materials whose electrical resistivity becomes exactly zero when cooled below a certain temperature known as the critical temperature (T_c). This means that below T_c, superconductors offer no resistance to the flow of electric current, allowing it to circulate indefinitely without any energy loss.

Key Properties of Superconductors:

1. Zero Resistance: Below the critical temperature, the material conducts electricity perfectly with no energy dissipation.

2. Critical Temperature (T_c): The specific temperature at which a material becomes superconducting. Different materials have different T_c values.

Example: Mercury → 4.2 K, Lead → 7.2 K, Aluminium → 1.18 K

3. Perfect Conductivity: Once current starts flowing in a superconductor, it can continue without any external power source.

4. High Temperature Superconductors: Certain ceramic materials can become superconducting at temperatures as high as 125 K or above 77 K (liquid nitrogen temperature), making them more practical for applications.

Applications of Superconductors:

- MRI machines (Magnetic Resonance Imaging)
- Maglev trains (magnetic levitation trains)
- High-speed, powerful, and compact electric motors

- Faster and efficient computer chips
- Particle accelerators and scientific research instruments

✦ **Summary:**

Superconductors are materials that exhibit zero electrical resistance below a critical temperature, enabling highly efficient energy transfer and advanced technological applications.

🌟 **Q17.10: What is meant by para, dia and ferromagnetic substances? Give examples for each.**

❖ **Answer:**

The magnetic properties of solids depend on the behavior of electrons in their atoms, particularly the spin and orbital motion of electrons. Based on this, solids can be classified as paramagnetic, diamagnetic, and ferromagnetic.

1. Paramagnetic Substances:

- These are materials in which the orbits and spin axes of electrons in atoms support each other, producing a small net magnetic field.

- Such materials behave like tiny magnets and are attracted weakly by an external magnetic field.

Examples: Aluminium (Al), Oxygen (O_2), Magnesium (Mg).

2. Diamagnetic Substances:

- In these substances, the magnetic fields produced by orbital and spin motions of electrons cancel each other, resulting in no net magnetic moment.
- They are repelled weakly by an external magnetic field.

Examples: Copper (Cu), Bismuth (Bi), Water (H_2O), Antimony (Sb).

3. Ferromagnetic Substances:

- These are materials in which atoms cooperate to produce a strong magnetic effect, showing permanent magnetism.
- They contain magnetic domains, which align in the direction of an external magnetic field.

Examples: Iron (Fe), Cobalt (Co), Nickel (Ni), Alnico alloys.

✦ **Summary:**

- **Paramagnetic:** Weakly attracted, net atomic magnetic field present.
- **Diamagnetic:** Weakly repelled, net atomic magnetic field zero.
- **Ferromagnetic**: Strongly magnetic, permanent magnetism, domain alignment.

🌟 **Q17.11: What is meant by hysteresis loss? How is it used in the construction of a transformer?**

❖ **Answer:**

Hysteresis Loss:

- Hysteresis loss is the energy dissipated as heat when a ferromagnetic material is repeatedly magnetized and demagnetized during each cycle of an alternating current (AC).
- When a magnetic material such as iron is placed in an AC solenoid, the magnetization lags behind the applied magnetizing current, forming a hysteresis loop on a flux density (B) versus magnetizing force (H) graph.

- The area of the hysteresis loop represents the energy lost per unit volume per cycle.
- This loss occurs due to the internal friction of magnetic domains as they reorient themselves in response to the changing magnetic field.

Use in Transformer Construction:

- In transformers, cores are made of soft magnetic materials like silicon steel.
- Soft magnetic materials have narrow hysteresis loops and low hysteresis loss, which minimizes energy dissipation as heat.
- Choosing such materials ensures that transformers are efficient, reducing wastage of electrical energy during continuous magnetization and demagnetization cycles.

✦ Summary:

- Hysteresis loss = energy lost in magnetizing a ferromagnetic core.
- Minimizing it improves transformer efficiency.
- Soft iron cores ⟶ small hysteresis loop ⟶ less energy loss.

Note:

This chapter is designed to provide a solid foundation of knowledge, with the goal of deepening understanding and encouraging further exploration of the subject. The content has been carefully selected to support effective learning and inspire students to engage with the topic more deeply.

Author: Muhammad Asghar

Purpose: To contribute to education by offering insightful, valuable content that enhances learning and understanding.

Copyright & Usage Policy