

1 VSAQ + 1 SAQ = 2M + 4M = 6 MARKS

9. MECHANICAL PROPERTIES OF SOLIDS

• Elasticity • Plasticity • Stress - types • Hooke's law • Elastic moduli
• Strain - types • Poisson's ratio • Strain energy

SMART SYNOPSIS

1. **Elasticity** is the property of a body, by virtue of which, it regains its original size and shape when the deforming force is removed.

Examples of Elastic bodies: Steel springs, rubber bands, wire, bow, quartz fibre,...

In physics, Elasticity refers to the opposition of a body to deformation. Thus, greater rigidity generally implies greater elasticity. That is why, Steel is more Elastic than Rubber. [VSAQ]

2. **Plasticity** is the property of a body by virtue of which, it does not regain its original size and shape on the removal of deforming force.

- Examples of Plastic bodies :** Wet clay, wax, chewing gum

Note: The elastic bodies that we use in everyday life exhibit both elastic and plastic properties at different stages. They are elastic under small forces and plastic beyond their elastic limit.

3. **Stress** is defined as the internal restoring force developed within the body per unit area.

Formula: $\text{Stress} = \frac{\text{restoring force}}{\text{Area}} = \frac{F}{A}$

[VSAQ]

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

Dimensional Formula : $[M^1L^{-1}T^{-2}]$

3 Types of Stress :

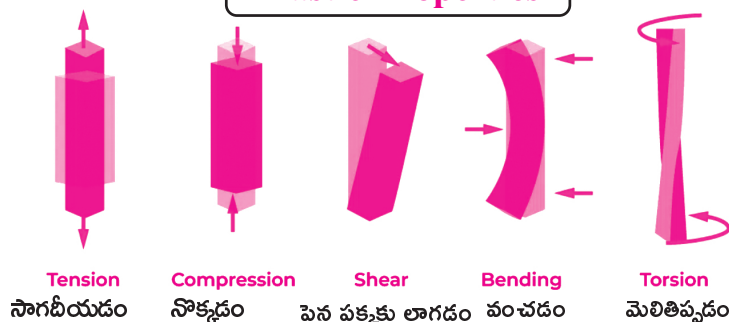
[SAQ]

- 3.1 **Longitudinal stress or Tensile stress:** It is the stress produced within the body, when its length is changed by applying a force normal (perpendicular) to its surface .

- 3.2 **Shear stress or Tangential stress:** It is the stress produced with in the body ,when its shape is changed by applying a tangential force on its surface.

- 3.3 **Bulk stress or Volume stress:** It is the stress produced with in the body ,when its volume is changed by applying force normally and uniformly all over its surfaces.

Elastic Properties



4. **Strain** is the ratio of change in dimension of a body to the original dimension .

$$\text{Formula : Strain} = \frac{\text{Change in dimension}}{\text{Original dimension}}$$

[VSAQ]

Note: Strain has no Units & no Dimensions being a ratio of same quantities.

Types of Strain :

[SAQ]

- 4.1 **Longitudinal strain** is defined as, change in length per unit original length, when deformed by an external force.

$$\text{Longitudinal strain} = \frac{\text{change in length}}{\text{original length}} = \frac{\Delta l}{l}$$

This is two types . (a) Tensile strain - occurs when the object is stretched

(b) Contraction strain - occurs when the object is compressed.

- 4.2 **Shear strain** is defined as the angular distortion caused by a tangential force.

It is calculated as the displacement of a surface relative to the height of the object.

- 4.3 **Volume strain (or) Bulk strain** is defined as, change in volume per unit original volume, when deformed by external forces.

$$\text{Volume strain} = \frac{\text{Change in volume}}{\text{Original volume}} = \frac{\Delta V}{V}$$

- 4.4 **Poisson's ratio(σ)** is the ratio of lateral contraction strain to the longitudinal strain.

$$\sigma = \frac{\text{contraction strain}}{\text{longitudinal strain}} = \frac{(d - d^1) / d}{(l^1 - l) / l} \Rightarrow \sigma = -\frac{\Delta d / d}{\Delta l / l}$$

Note 1 : Poisson's ratio (σ) has no units.

Note 2 : Theoretical limits of Poisson's ratio are -1 to 0.5

Note 3 : Practical limits of Poisson's ratio are 0.2 to 0.4

Note 4 : **For Steel**, Poisson's ratio lies between **0.27 and 0.30**

5. **Elastic limit** is the maximum value of stress upto which the body completely regains its original size and shape when the deforming force is removed.

Note: i) For a perfectly elastic body, the elastic limit is very high.

ii) For a perfectly plastic body, the elastic limit is very low.

6. **Hooke's law of Elasticity :** Within the elastic limit, stress is directly proportional to the strain produced.

Thus, $\text{Stress} \propto \text{Strain} \Rightarrow \text{Stress} = E \times \text{Strain}$.

[VSAQ]

7. **Stress - Strain curve- Behaviour of a wire under gradually increasing load :** [SAQ]

The elastic behaviour of the material of a wire can be studied by plotting a graph between stress (on y-axis) and strain (on x-axis). By using this curve we can study the behaviour of a wire under gradually increasing load.

8. **Elastic moduli:** From Hooke's law, $\text{Stress} \propto \text{Strain} \Rightarrow \text{Stress} = E (\text{Strain})$.

This proportionality constant E is called the **modulus of elasticity**.

Modulus of Elasticity (E) is defined as the ratio of Stress and Strain

$$\therefore E = \frac{\text{Stress}}{\text{Strain}} \quad \text{SI unit: Pascal or Nm}^{-2}$$

9. **3 Types of Elastic moduli :**

[SAQ]

9.1 **Young's Modulus (Y):** It is the ratio of **longitudinal stress** to **longitudinal strain**.

- Y measures the resistance of a material to change in length.
- It is applicable only to solids.

$$\text{Formula: } Y = \frac{\text{Longitudinal Stress}}{\text{Longitudinal Strain}} = \frac{(F/A)}{(\Delta L/L)} = \frac{FL}{A\Delta L} \quad \text{SI Unit: Pascal (Pa) or Nm}^{-2}$$

9.2 **Shear or Modulus of Rigidity (G):** It is the ratio of **shearing stress** to **shearing strain**.

- G measures the resistance of a material to change in shape.
- It is applicable only to solids.

$$\text{Formula: } G = \frac{\text{Shearing Stress}}{\text{Shearing Strain}} = \frac{(F/A)}{(\Delta x/L)} = \frac{FL}{A\Delta x}$$

9.3 **Bulk Modulus (B):** It is the ratio of **bulk stress (hydraulic pressure)** to **volume strain**.

- B measures resistance to change in volume.
- It is applicable to solids, liquids and gases.

$$\text{Formula: } B = \frac{\text{Bulk Stress}}{\text{Volume Strain}} = -\frac{p}{\Delta V/V}$$

Note 1: The negative sign indicates that volume decreases when pressure increases.

Note 2: $B_{\text{Solids}} > B_{\text{Liquids}} > B_{\text{Gases}}$

10. **Compressibility** is the reciprocal of the bulk modulus (B) of a material.

Compressibility indicates how easily a material can be compressed.

$$\text{Compressibility} = \frac{1}{B} \quad \text{SI unit : Pa}^{-1} \text{ or m}^2/\text{N};$$

[VSAQ]

D.F: $[M^{-1}L^1T^2]$ It has negative dimension in mass.

11. **Elastic Potential Energy & Strain Energy :**

The total amount of work done in deforming a body is called "Potential Energy" and

the amount of work done per unit volume of a body is called "strain energy".

- **Strain Energy** $E = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{Volume of the wire} = \frac{1}{2} F \Delta L$
- **Strain Energy per unit volume** $= \frac{1}{2} \times \text{Stress} \times \text{Strain}$

For better concept clarity refer **PHYSI BEATS P.No: 266**

