STEP Classes

Sanjeev Sir

Class 11 Notes Physics Chapter 9

Mechanical Properties of Solids

Deforming Force: A deforming force can be defined as a force that produces a change in the configuration (size or shape) of the object on application.

Perfectly Elastic Body: The bodies which have the capability to regain their original configuration immediately and completely after having the deforming force removed are termed perfectly elastic bodies. Quartz fibre can be considered as a perfectly elastic body.

Plasticity: When a body does not have the capability to regain its original size and shape completely and immediately after having the deforming force removed, it is called a plastic body and this property is termed as plasticity.

Perfectly Plastic Body: A body that does not regain its original configuration at all on the removal of deforming force is known as a perfectly plastic body. Putty and paraffin wax can be considered nearly perfectly plastic bodies.

Inter molecular Force: In a solid, atoms and molecules are arranged in such a way that each molecule is acted upon by the forces due to the neighbouring molecules. These forces are known as inter molecular forces.

Elasticity : The property of the body to regain its original configuration (length, volume or shape) when the deforming forces are removed, is called elasticity.
→ The change in the shape or size of a body when external forces act on it is determined by the forces between its atoms or molecules. These short range atomic forces are called elastic forces.

Perfectly elastic body : A body which regains its original configuration immediately and completely after the removal of deforming force from it, is called perfectly elastic body. Quartz and phospher bronze are the examples of nearly perfectly elastic bodies.

Plasticity : The inability of a body to return to its original size and shape even on removal of the deforming force is called plasticity and such a body is called a plastic body.

Stress : Stress is defined as the ratio of the internal force F, produced when the substance is deformed, to the area A over which this force acts. In equilibrium, this force is equal in magnitude to the externally applied force. In other words,

$$\text{Stress} = \frac{F}{A}$$

The SI unit of stress is Nm^{-2}

CGS unit is dyne cm^{-2}

Dimensional Formula is $[ML^{-1}T^{-2}]$

Stress is of two types:
(i) Normal stress: It is defined as the restoring force per unit area perpendicular to the surface of the body. Normal stress is of two types: tensile stress and compressive stress.
(ii) Tangential stress: When the elastic restoring force or deforming force acts parallel to the surface area, the stress is called tangential stress.

Strain: It is defined as the ratio of the change in size or shape to the original size or shape. It has no dimensions, it is just a number.
Strain is of three types:
(i) Longitudinal strain: If the deforming force produces a change in length alone, the strain produced in the body is called longitudinal strain or tensile strain. It is given as:

(ii) Volumetric strain: If the deforming force produces a change in volume alone, the strain produced in the body is called volumetric strain. It is given as:

$$\text{Volumtric Strain} = \frac{\text{Change in volume } \Delta V}{\text{Original volume V}}$$

(iii) Shear strain: The angle tilt caused in the body due to tangential stress expressed is called shear strain. It is given as:

$$\text{Shear Strain } \theta = \frac{\Delta L}{L}$$

→ The maximum stress to which the body can regain its original status on the removal of the deforming force is called elastic limit.

Hooke's Law : Hooke's law states that, within elastic limits, the ratio of stress to the corresponding strain produced is a constant. Thus

$$\text{Stress} \propto \text{strain}$$
$$\text{Stress} = K.\ \text{strain}$$

where K is the constant of proportionality known as the 'modulus of elasticity' of the material.

$$\text{Modulus of elasticity} = \frac{\text{Stress}}{\text{Strain}}$$

Since Strain is a pure number, and unit of Modulus of elasticity is Nm^{-2}

Young's Modulus : For a solid, in the form of a wire or a thin rod, Young's modulus of elasticity within elastic limit is defined as the ratio of longitudinal stress to longitudinal strain. It is given as:

Young's Modulus $Y = \frac{F/A}{\Delta L/L} = \frac{F\,L}{A.\Delta L} = \frac{mg\,L}{\pi r^2.\Delta L}$

Bulk Modulus: Within elastic limit the bulk modulus is defined as the ratio of longitudinal stress and volumetric strain. It is given as:

Bulk Modulus B = $\frac{F/A}{\Delta V/V} = -\frac{P}{\Delta V/V}$

– ve indicates that the volume variation and pressure variation always negative each other.

Compressibility: The compressibility of a material refers to the reciprocal of its bulk modulus of elasticity. Mathematically, it is given by

$C = \frac{1}{\kappa}$

It is also defined as the fractional change in volume per unit change in pressure.

Shear Modulus or Modulus of Rigidity: It is defined as the ratio of the tangential stress to the shear strain.
Modulus of rigidity is given by

Modulus of Rigidity = η $= \frac{\text{Tangential stress}}{\text{Shear strain}} = \frac{F/A}{\theta}$

Poisson's Ratio : The ratio of change in diameter (ΔD) to the original diameter (D) is called lateral strain. The ratio of change in length (Δl) to the original length (l) is called longitudinal strain. The ratio of lateral strain to the longitudinal strain is called **Poisson's ratio**.

Poisson's ratio σ $= \frac{\text{Lateral strain}}{\text{Longitudinal strain}} = -\frac{\Delta D/D}{\Delta L/L}$

→ The value of σ lies between 0.2 to 0.4

→ For a perfectly incompressible body σ is maximum and equal to 0.5

Elastic after Effect: Objects return to their original state when deforming force is removed. Certain objects return to their original state immediately after the removal of the deforming force, whereas some objects take longer to do so. The delay in attaining back the original state by an object on the removal of the deforming force is termed an elastic after effect.

Elastic Fatigue: It is the property of an elastic body by virtue of which its behaviour becomes less elastic under the action of repeated alternating deforming forces.

Ductile Materials:

The materials that have a large plastic range of extension are known as ductile materials. These materials undergo an irreversible rise in their lengths before snapping. Thus, they can be drawn into thin wires. Some examples of ductile materials are copper, silver, iron and aluminium.

Brittle Materials: The materials that have a very small range of plastic extension are known as brittle materials. These materials break as soon as the stress is increased beyond the elastic limit. Some examples of brittle materials are cast iron, glass etc.

Elastomers: The materials for which the strain produced is much larger than the stress applied, within the limit of elasticity, are termed elastomers. Some examples of elastomers are rubber, the elastic tissue of the aorta and the large vessel carrying blood from the heart. They have no plastic range.

Elastic Potential Energy of Stretched Wire: When a wire is made to stretch, interatomic forces come into play, which opposes the change. Work has to be done against these restoring forces. The work done in stretching the wire is stored in it as its elastic potential energy.

→ Relations between Elastic Moduli

For isotropic materials (i.e., materials having the same properties in all directions), only two of the three elastic constants are independent. For example, Young's modulus can be expressed in terms of the bulk and shear moduli.

Breaking Stress: The ultimate tensile strength of a material is the stress required to break a wire or a rod by pulling on it. The breaking stress of the material is the maximum stress which a material can withstand. Beyond this point breakage occurs.

When a wire of original length L is stretched by a length l by the application force F at one end ,

then work done to stretch wire $= \frac{1}{2}$ x stretching force x extension

$$= \frac{1}{2}\frac{\text{YAl2}}{\text{L}}$$

work done per unit volume of wire = W = $\frac{1}{2}$ x stress x strain

The elastic potential energy of a wire (energy density) is equal to half the product of its stress and strain.