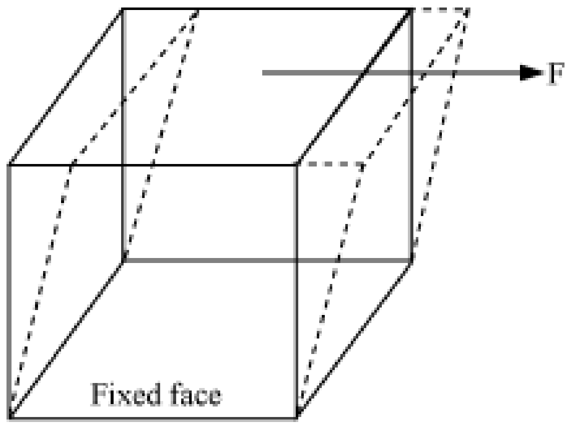
Mechanical Properties Of Solids

- **Elasticity:** It is the property of a body by virtue of which it tends to regain its original size and shape after the applied force is removed.
- **Plasticity:** It is the inability of a body in regaining its original status on the removal of the deforming forces.
- **Elastic deformation:** After withdrawal of force, the material regains its original shape and size.
  - **Plastic deformation:** After withdrawal of force, the material does not regain its original size and shape.
  - **Stress:** Restoring force per unit area

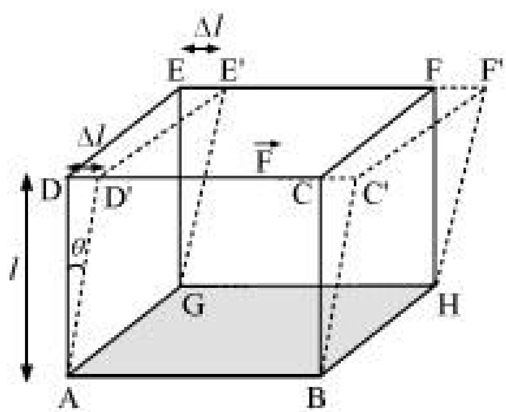
Types of Stress

- **Normal Stress:** When the elastic restoring force or deforming force acts perpendicular to the area, the stress is called normal stress. Normal stress can be sub-divided into the following categories:
  - **Tensile Stress:** When there is an increase in the length or the extension of the body in the direction of the force applied, the stress set up is called tensile stress.
  - **Compressive Stress:** When there is a decrease in the length or the compression of the body due to the force applied, the stress set up is called compressive stress.
- **Tangential or Shearing Stress:** When the elastic restoring force or deforming force acts parallel to the surface area, the stress is called tangential stress.



- **Strain** : Deformation amount/original dimension $\left(\frac{\Delta L}{L}, \frac{\Delta V}{V}\right)$

Shear strain = $\frac{\Delta l}{l}$



Within elastic limits, θ is small.

Therefore, Shear strain = tan $\theta \approx \approx \theta$

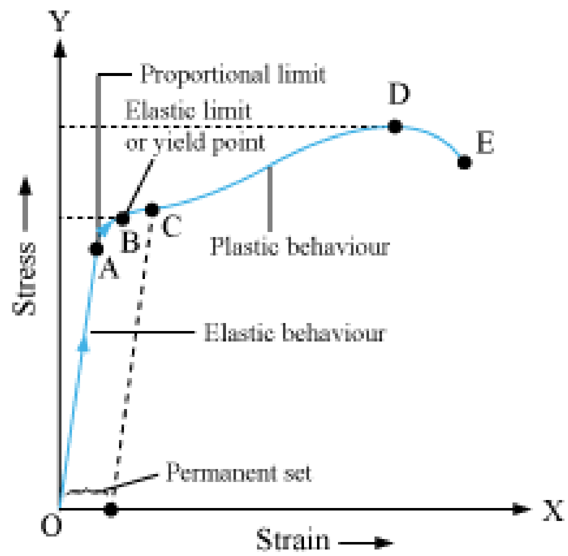
- **Hooke's law:** Stress is proportional to Strain

Stress = $k \times$ Strain

[Where, k = Modulus of elasticity]

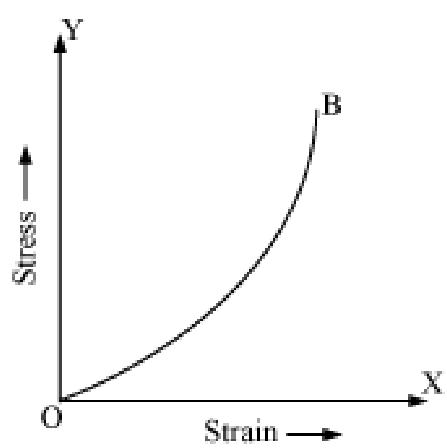
Stress-strain graph

- For a wire



- When the material does not regain its original dimension, it is said to have a permanent set, and the deformation is said to be plastic deformation.

- Stress-strain curve for elastomers:



- They do not obey Hooke's law, and always return to their original shape.

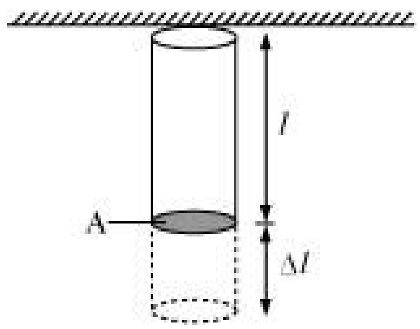
- **Young's modulus of elasticity (*Y*)**

$$Y = \frac{\text{Longitudinal stress}}{\text{Longitudinal strain}}$$

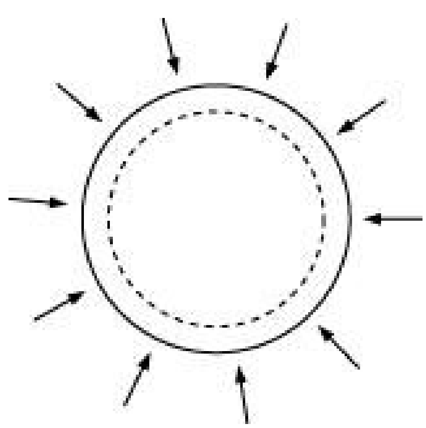
$$Y = \frac{\frac{F}{A}}{\frac{\Delta l}{l}} = \frac{Fl}{A\Delta l}$$

The Young's modulus of an experimental wire is given by

$\therefore Y = \frac{MgL}{\pi r^2 l}$ ∴Y=MgLπr2l.



- **Bulk modulus of elasticity (*B*)**



$$B = \frac{\text{Normal stress}}{\text{Volumetric strain}} = \frac{\Delta P}{-\frac{\Delta V}{V}} = -V\frac{\Delta P}{\Delta V}$$

- **Compressibility:** It is the reciprocal of bulk modulus.

- **Modulus of rigidity ($\eta\eta$)**

$\eta = \frac{\text{Tangential stress}}{\text{Shear strain}} = \frac{\frac{F}{A}}{\frac{\Delta l}{l}}$ η=Tangential stressShear strain=FAΔll⇒η=FAθ orη=FAθ

$\Rightarrow \eta = \frac{\frac{F}{A}}{\theta}$ or

$\eta = \frac{F}{A\theta}$

- Poisson's ratio(σ) = lateral strain/longitudinal strain
- Poisson's ratio(σ) is a unitless and dimensionless quantity.
- A metallic rod expands on heating and the thermal strain developed in the rod is given by $\frac{L-L_0}{L_0} = \alpha\,\Delta\,t$ L-L0L0=αΔt.
- When a rod, fixed at both the ends by supports, is heated, it exerts a force on both the supports. The force exerted on the supports is given by F= Y$\alpha\Delta t$× ×A.

Application of Elasticity

- The metallic parts in machinery are never subjected to stress beyond their elastic limits; else, they may get permanently deformed.

- The thickness of the metallic rope used in cranes depends on the elastic limit of the material of the rope and the factor of safety.

- Bridges are designed in such a way that they do not bend much or break under the load of heavy traffic, force of strong wind or their own weights.

Poisson's ratio

$$\sigma = \frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \frac{\frac{\Delta d}{d}}{\frac{\Delta l}{l}}$$ σ=Lateral strainLongitudinal strain=ΔddΔll

- Elastic energy stored in the wire on elongating it by a length $l = \frac{1}{2}$ l =12 × (load) × (extension)