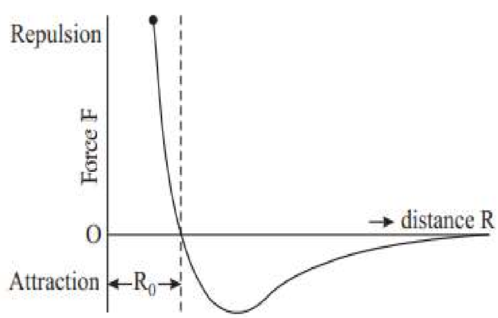
8

ELASTIC PROPERTIES OF SOLIDS

MOLECULAR THEORY OF MATTER : INTER-MOLECULAR FORCES

- matter is made up of atoms and molecules.
- The forces which act between them are responsible for the structure of matter.
- The interaction forces between molecules are known as inter-molecular forces.



- When the separation is large, the force between two molecules is attractive and weak. As the separation decreases, the net force of attraction increases up to a particular value and beyond this, the force becomes repulsive.
- a distance R = R0 the net force between the molecules is zero. This separation is called **equilibrium separation.**
- In solids, molecules are very close to each other at their equilibrium separation
- In liquids, the average separation between the molecules is somewhat larger
- In gases, the intermolecular separation is significantly larger and the molecular force is very weak (almost negligible). Molecules of a gas are almost free to move inside a container

ELASTICITY

- when an external force is applied on an object, its shape or size (or both) change, i.e. deformation takes place. The extent of deformation depends on the material and shape of the body and the external force. When the deforming forces are withdrawn, the body tries to regain its original shape and size.
- The property of matter to regain its original shape and size after removal of the deforming forces is called elasticity.

Elastic and Plastic Bodies

- A body which regains its original state completely on removal of the deforming force is called perfectly elastic.
- if it completely retains its modified form even on removing the deforming force, i.e. shows no tendency to recover the deformation, it is said to be perfectly plastic.

Molecular Theory of Elasticity

- Due to inter-atomic forces, solid takes such a shape that each atom remains in a stable equilibrium
- When the body is deformed, the atoms are displaced from their

original positions and the inter-atomic distances change.

- If in deformation, the separation increases beyond their equilibrium separation (i.e., R >R0), strong attractive forces are developed. However, if inter–atomic separation decreases (i.e. R < R0), strong repulsive forces develop. These forces, called **restoring forces,**

Stress

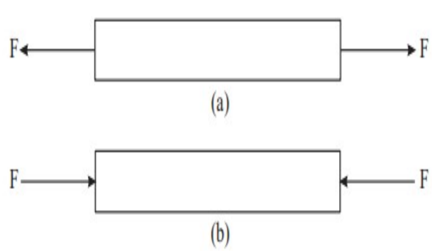
- The internal restoring force acting per unit area of cross-section of a deformed body is called stress.

Stress = restoring force area = deforming force ( ) area ( ) F A or Stress = F A

The unit of stress is Nm–2

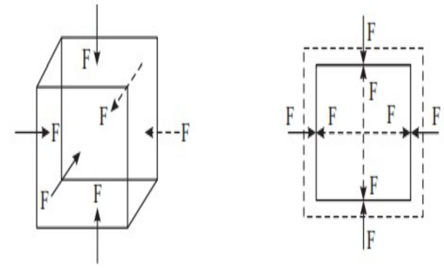
Longitudinal Stress

- If the deforming forces are along the length of the body, we call the stress produced as **longitudinal stress,**



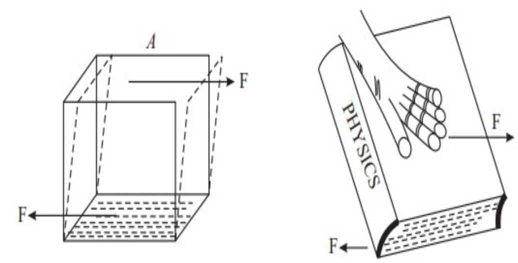
Normal Stress

- If the deforming forces are applied uniformly and normally all over the surface of the body so that the change in its volume occurs without change in shape . we call the stress produced as **normal stress.**



Shearing Stress :

- If the deforming forces act tangentially or parallel to the surface (Fig 8.5a) so that shape of the body changes without change in volume, the stress is called **shearing stress**.

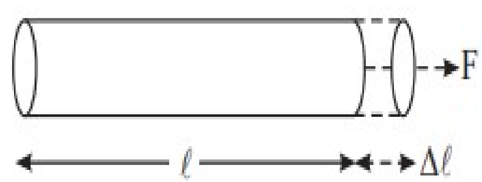


Strain

- Strain is defined as the change in dimension (e.g. length, shape or volume) per unit dimension of the body.

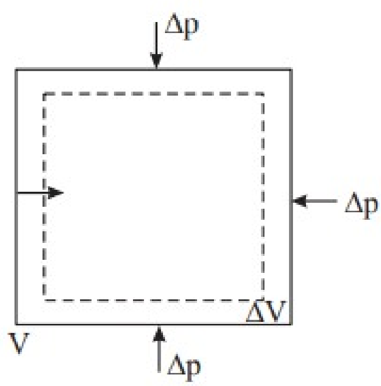
Linear Strain :

- If on application of a longitudinal deforming force, the length l of a body changes by Δl (Fig. 8.6), then linear strain = change in length /original length



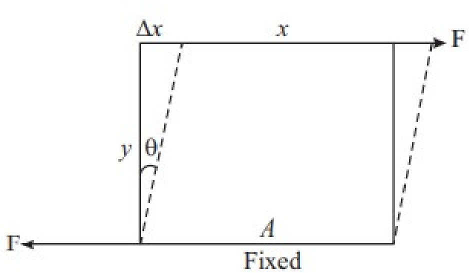
Volume Strain :

- If on application of a uniform pressure Δp, the volume V of the body changes by ΔV without change of shape of the body, then Volume strain = change in volume /original volume

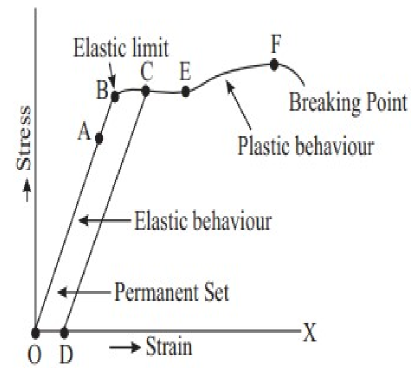


Shearing strain:

- When the deforming forces are tangential the shearing strain is given by the angle θ through which a line perpendicular to the fixed plane is turned due to deformation.



Stress-strain Curve for a Metallic Wire



- Region of Proportionality
- Elastic Limit
- Point C
- Breaking point F
  - The stress corresponding to breaking point F is called breaking stress or tensile strength.

Within the elastic limit, the maximum stress which an object can be subjected to is called working stress and the ratio between working stress and breaking stress is called factor of safety.

Stress-Strain Curve for Rubber

Steel is more Elastic than Rubber

HOOKE'S LAW

- Within elastic limit, stress is directly proportional to corresponding strain. i.e. stress α strain or stress strain = constant (E
- This constant of proportionality E is a measure of elasticity of the substance and is called modulus of elasticity

Modulus of Elasticity

Young's Modulus:

The ratio of the longitudinal stress to the longitudinal strain is called Young's modulus for the material of the body.

Bulk Modulus:

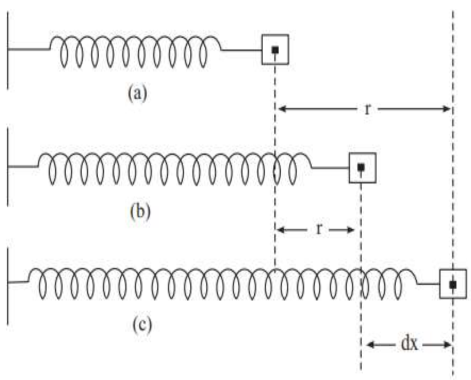
The ratio of normal stress to the volume strain is called bulk modulus of the material of the body.

Modulus of Rigidity or Shear Modulus:

The ratio of the shearing stress to shearing strain is called modulus of rigidity of the material of the body.

Elastic Energy

- When a spring is either compressed or extended, it undergoes a change in its configuration and is capable of performing work.



Elastic energy

- It is a kind of potential energy and it is the energy which is associated with the state of compression or extension of an elastic object like a spring

Check yourself

1. The stress may be
   a) Longitudinal
   b) Normal
   c) Shearing
   d) All the above
2. A load of 100 kg is suspended by a wire of length 1.0 m and cross sectional area $0.10cm^2$. wire is stretched by 0.20 cm. tensile stress is
   a) $9.8x10^7$nm
   b) $9.8x10^7nm^{-2}$
   c) $9.8x10^7$n/m
3. S. I. unit of young modules is
   a) NM^{-2}
   b) Nm^{-3}
   c) $N^{-1}m^{-2}$
   d) NM
4. Which one of the following is correct
   A. $\sigma = \frac{l}{d}\frac{\Delta d}{\Delta l}$
   B. $\sigma = \frac{d}{l}\frac{\Delta d}{\Delta l}$
   C. $\sigma = \frac{d}{l}\frac{\Delta l}{\Delta d}$
   D. $\sigma = \frac{l}{d}\frac{\Delta d}{\Delta l}$
5. Elastic potential energy is
   A. $U = \frac{1}{2}kr$
   B. $U = \frac{1}{2}kr^2$
   C. $U = \frac{k}{2r^2}$
   D. $U = \frac{k}{2r}$

Stretch yourself

1. Is steel is more elastic than rubber, explain
2. Why gas have no fixed shape and size then solid. Explain
3. How much force is required to have an increase of 0.5% in the length of a metallic wire of radius 0.1mm.Given $\gamma = 9 \times 10^{10}\ Nm^{-2}$
4. Why poission ratio have no units? Explain
5. What is Young Modulus? Derive expression for Young Modulus