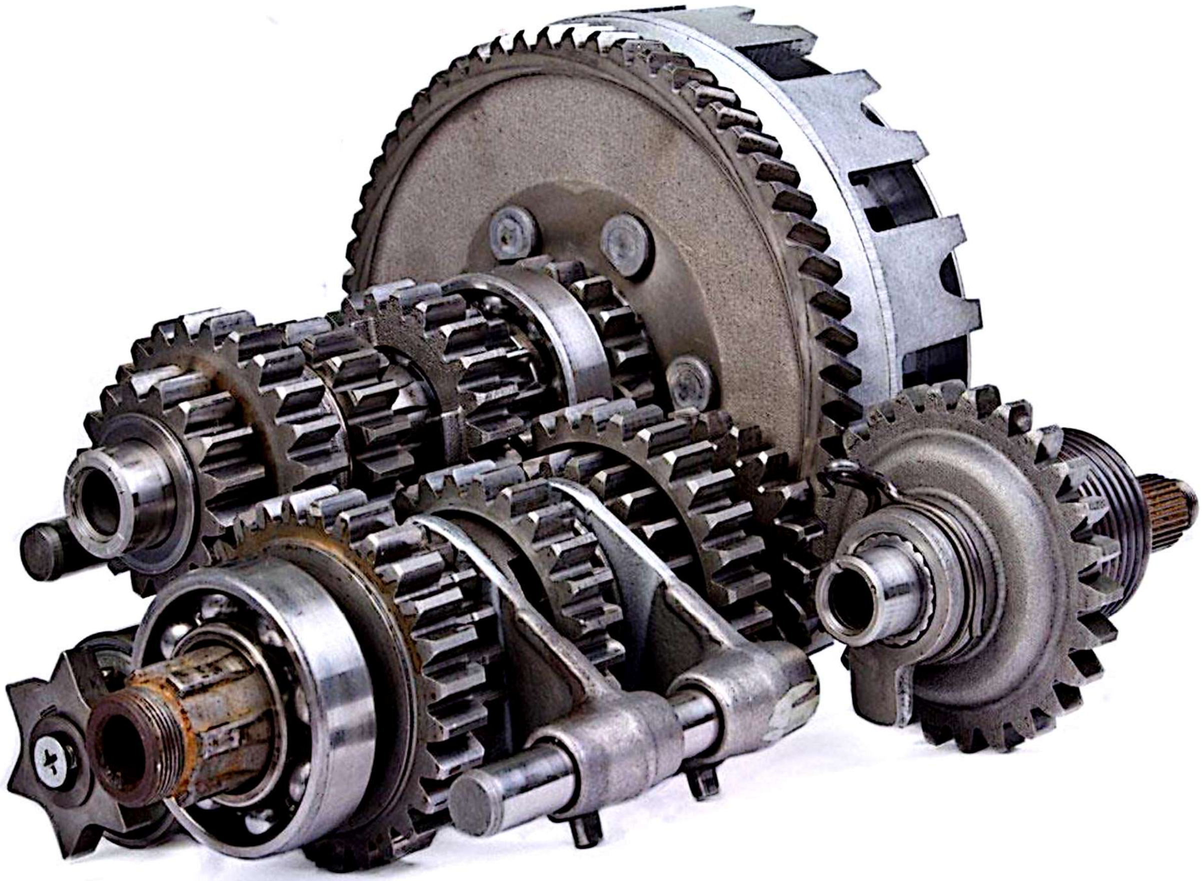
Chapter–9:

Mechanical Properties of Solids



CBSE CLASS XI NOTES

Dr. SIMIL RAHMAN

Mechanics of solids

Matter :- Three different states of matter solid, liquid and gas.

Solids

* Rigid within limit
* They have definite size and shape
* Average seperation between the molecules does no change

Liquids

* Liquids do not have definite shape and size but have definite volume.
* Seperation between the molecules greater than that of solids

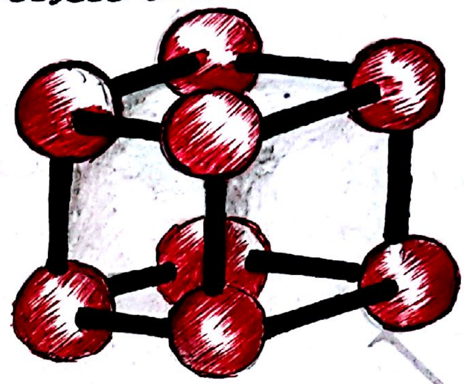
Gases

* Intermolecular forces are very weak.
* Average K.E > Average PE of molecules.

Types of Solids

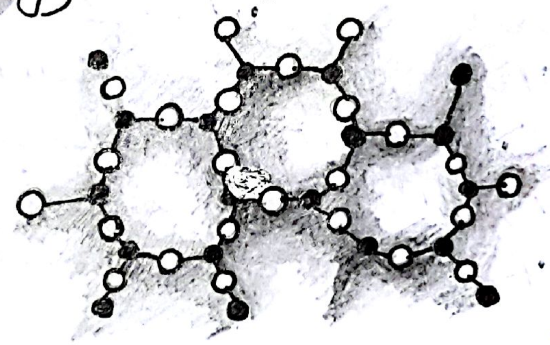
1. crystalline solids
2. Amorphous solids

1. crystalline solids :- Atoms are arranged regularly (periodic array of atoms) over large distances.



2. Glassy or Amorphous solids

If atoms or molecules are arranged in irregular fashion, then it is called amorphous.
eg. Glass, wood etc.



Deforming Force

A force that changes the shape and size of a body is called deforming force.

Restoring Force.

It is the internal force of a body which tries to bring the body back to it's initial size and shape

eg; Mud, paraffin wax etc.

Elasticity

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

***When a body is said to be perfectly elastic. Give examples?**

If a body regains its original shape and size immediately and perfectly when the deforming force is removed, it is said to be perfectly elastic body.

eg; Quartz, steel, glass etc.

*** When a body is said to be perfectly plastic. Give examples?**

If a body has no tendency to regain its original shape and gets permanently deformed, it is said to be perfectly plastic body

*** Define stress?**

The restoring force per unit area of a deforming body is called stress.

$$\text{stress} = \frac{\text{Restoring force}}{\text{Area}}$$

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

SI unit of stress is N/m^2 or Pascal (Pa)

* Dimensional formula $ML^{-1}T^{-2}$

*** What is meant by tensile or expansive stress?**

If a stress causes an increase in length or volume, the restoring force per unit area in this case is called tensile stress.

*** What is meant by compressive stress?**

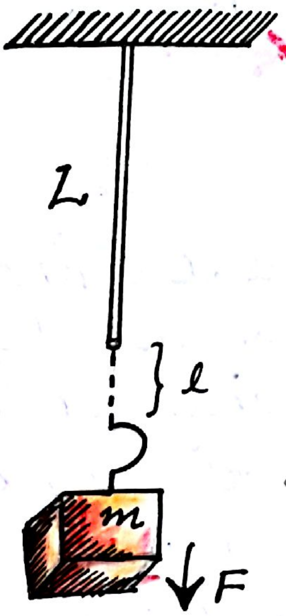
If a stress causes a decrease in length or volume of the solid, the restoring force per unit area in this case is called compressive stress.

* What are the types of stress? Explain?

1. Linear stress
2. Volume or (Bulk) stress
3. shearing stress

1. Linear stress

Linear stress → Tensile / compressive stress



when a wire of radius 'r' is suspended from a rigid support carries a load of mass m.

$$\text{Linear stress} = \frac{F}{A} = \frac{F}{\pi r^2}$$

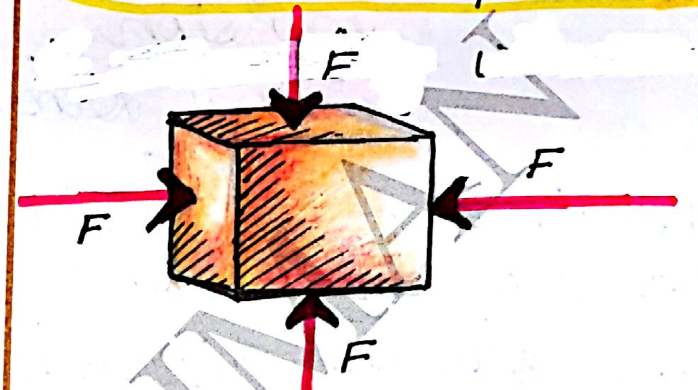
$$\text{Linear stress} = \frac{mg}{\pi r^2}$$

2. Volume (Bulk stress)

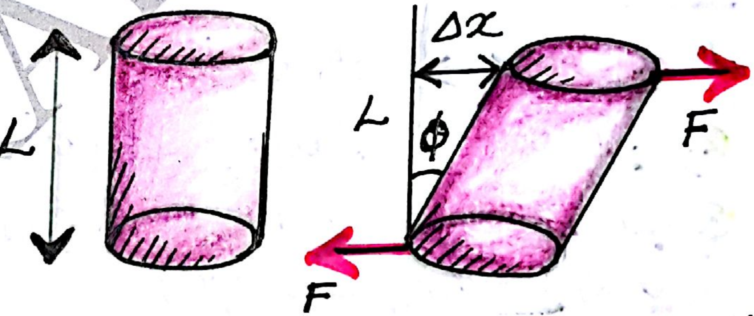
when deforming force (F) acts perpendicularly and uniformly on all surfaces, then

$$\text{Bulk stress} = \frac{\text{Normal force}}{\text{Area}}$$

$$\text{Bulk stress} = dp = \text{change in } P$$



(3) shearing stress



when two equal and opposite deforming forces are acting tangentially on the surface of a body (opposite faces), there is a change in the shape of the body.

$$\text{Shearing stress} = \frac{\text{Tangential force}}{\text{Area}}$$

* Define Strain?

strain may be defined as the ratio between change in dimension and the original dimension of a body

$$\text{strain} = \frac{\text{change in Dimension}}{\text{Original Dimension}}$$

* strain has no unit and no dimension.

* What are the different types of strain? Explain?

1. Linear strain
2. Volume (Bulk) strain
3. shearing strain (angle of shear)

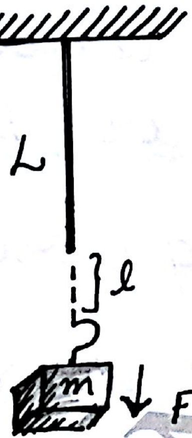
1. Linear strain

when a wire of length 'L' suspended from a rigid support, subjected to linear stress, it increases lengthwise

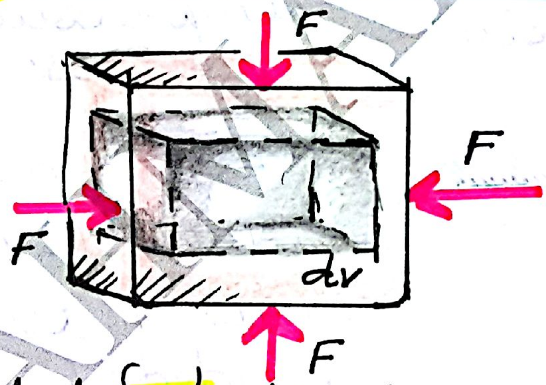
Let 'l' be the increase in length

$$\text{Linear strain} = \frac{\text{change in length}}{\text{original length}}$$

$$\text{Linear strain} = \frac{l}{L}$$



(2) Volume (Bulk) strain



Let 'V' be the original volume of the body. when deforming force 'F' applied ⊥rly and uniformly (volume stress), its volume changes by dV.

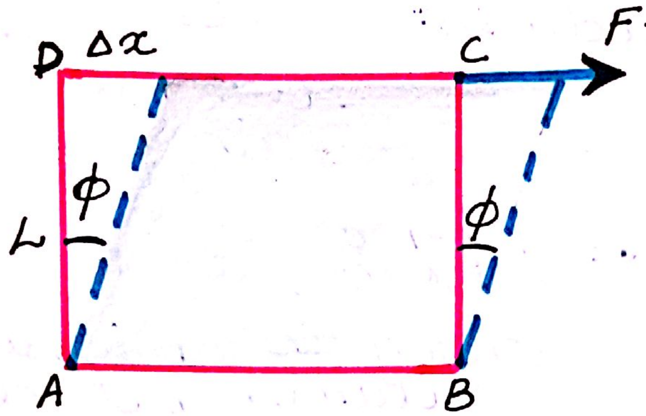
$$\text{volume strain} = \frac{\text{change in volume}}{\text{original volume}}$$

$$\text{volume strain} = \frac{dV}{V}$$

3. shearing strain (angle of shear)

when two equal and opposite

deforming forces acts tangentially on the opposite faces of a body, there is a change in the shape of the body, no change in volume.



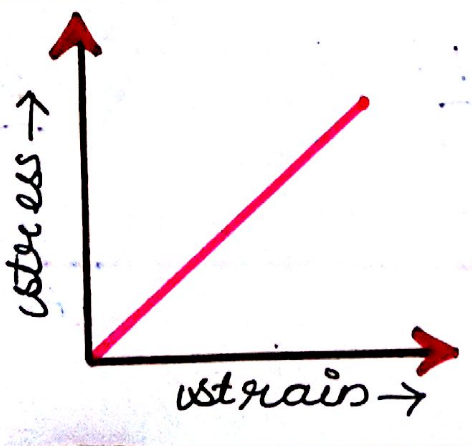
shearing strain

$$\phi = \frac{\Delta x}{L}$$

* Define Elastic Limit?

The maximum stress upto which a body exhibits the property of elasticity is called elastic limit.

* State Hookes Law?



Hookes law states that within the elastic limit stress is directly proportional to strain.

* Define modulus of Elasticity?

Modulus of elasticity of a substance is defined as the ratio of stress to strain within the limit of elasticity.

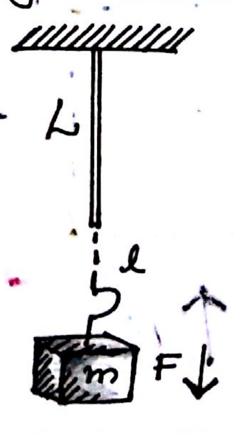
→ Its SI unit is Pa

→ Dimensions : $ML^{-1}T^{-2}$

* What are the different modulii of elasticity. Explain?

1. youngs modulus (Y)
2. Bulk modulus (B)
3. Rigidity modulus (shear modulus) 'η'

1. Youngs Modulus (Y)



Consider a uniform wire of radius 'r', area of cross section A, suspended from a rigid support. A force 'F' is applied by suspending a mass 'm'.

$l \rightarrow$ Increase in length

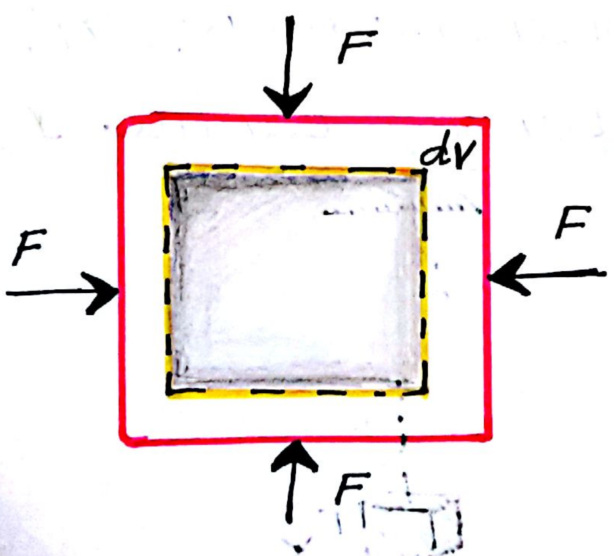
$$\text{Youngs Modulus} = \frac{\text{Linear stress}}{\text{Linear strain}}$$

$$Y = \frac{\frac{F}{A}}{\frac{l}{L}} = \frac{F}{A} \times \frac{L}{l}$$

$$Y = \frac{FL}{Al} = \frac{mgL}{\pi r^2 l}$$

$$Y = \frac{mgL}{\pi r^2 l}$$

2. Bulk modulus (B)



Consider a body of volume V. When a force 'F' is applied on all surfaces normally and uniformly, its volume changes by dV.

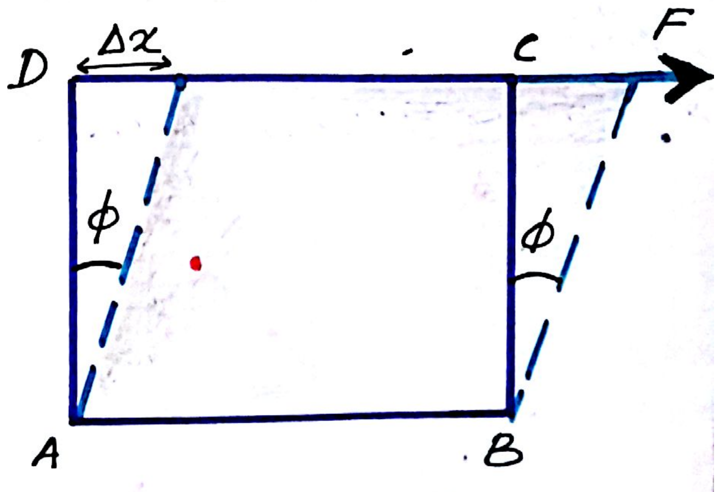
$$\text{Bulk Modulus} = \frac{\text{Volume stress}}{\text{Volume strain}}$$

$$B = \frac{\text{Normal Force / area}}{\text{change in Volume / original volume}}$$

$$B = \frac{\frac{F}{A}}{\frac{dV}{V}} = \frac{dP}{\frac{dV}{V}}$$

$$B = V\frac{dP}{dV} \quad \text{or} \quad B = \frac{FV}{AdV}$$

3. Rigidity modulus (shear modulus)

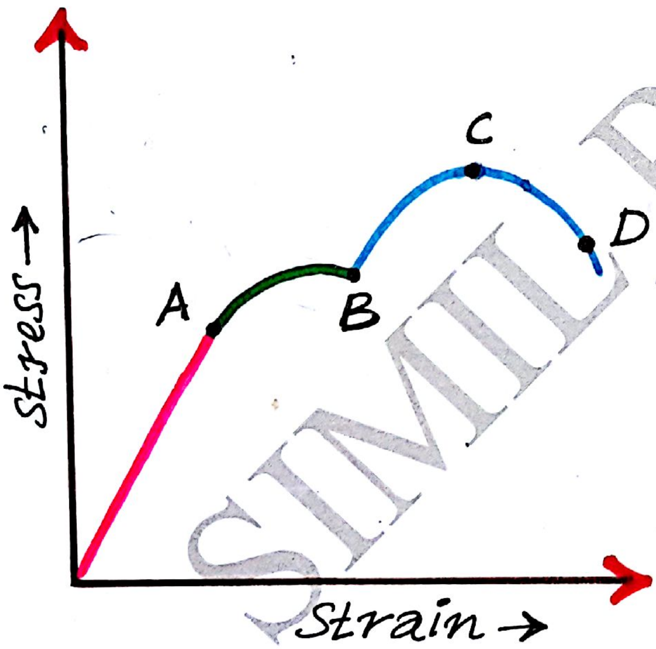


Rigidity modulus = shearing stress / shearing strain

$$n = \frac{Force/Area}{\Delta x / L}$$

$$\eta = \frac{FL}{A \Delta x}$$

* Elastic behaviour of Solids – stress-strain graph.



OA → obeys Hookes law
stress ∝ strain

D – Breaking stress

B – yield point

* C – ultimate stress

* Application of Elasticity

→ In the construction of metal ropes (In cranes)

→ In the construction of girders (I-section)

* Elastomers

substances which can be elastically stretched to large values of strain

eg; Elastic tissue of aorta

* Elastic fatigue

A substance temporarily loses its elasticity when it is continuously subjected to strain

* Elastic hysteris

The non-coincidence of the curves for Increasing and decreasing stress.