To join our WhatsApp Group contact:- 9508550281

Chapter - 2

Properties of Matter...

* **Deforming Force :-**

When an external force applied on an object or body it changes its shape and size then the applied external force is called as deforming force.

* **Restoring Force :-**

When an external force is applied on an object or body at the same time internal restoring force develop within the body or object with opposes any change in shape and size of the object. This internal force is called restoring force.

* **Elasticity :-**

It is the property of solid material by virtue of which it regain its original shape and size after the removal of deforming force.

Diplomawallah.in

To join our WhatsApp Group contact:- 9508550281

* Classification of object according to Elastic Property :-

(I) Perfectly Elastic body :- When a body or object completly regain it original shape and size after the removal of deforming force is called Perfectly Elastic body. Ex:- Quartz, Phosphor, Bronze etc.

(II) Perfectly Plastic (in elastic body) :-

When a body or object do not have any tendency to regain original shape and size after the removal of deforming force is called ~~def~~ Perfectly Plastic or in elastic body. Ex:- Wet clay, Paraffin wax etc.

* There is no object or body in universe which is perfectly elastic or plastic

(III) Elastic body :- When a body or object regain its original shape and size after the removal of deforming force is elastic body. Ex:- steel, Rubber etc.

Diplomawallah.in

To join our WhatsApp Group contact:- 9508550281

4. Plastic or Inelastic body :— When a body or object do not regain its original shape and size after the removal of deforming force is called plastic or Inelastic body.
Ex:— Grease, Snow, Putty etc.

5/10/24

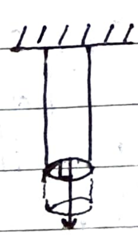
Stress :— The internal restoring force acting per unit area of the deformed body is called stress.
In equilibrium the restoring force in is equal to magnitude of the external force the stress is measure as external force acting on a unit area of the body.

i.e $\text{stress} = \dfrac{\text{Deforming or Restoring force}}{A}$

$F = \text{Kgm/s}^2$ $\quad \text{Stress} = \dfrac{F}{A}$

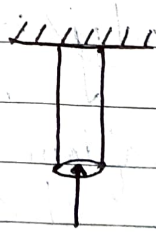
SI Unit of stress $= Nm^{-2}$
Dimension of stress $= [M L^{-1} T^{-2}]$

1)



Normal or Tensile Longitudinal force.

2.



Compressive force.

Diplomawallah.in

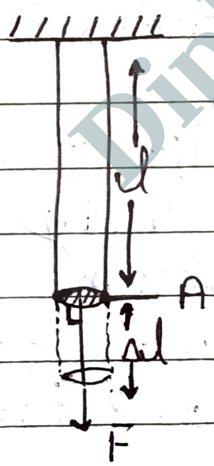
To join our WhatsApp Group contact:- 9508550281

* Types of stress :-

According to direction of applied deforming force on the object there are 3 types of stress :-

(i) Tensile or Normal or longitudnal stress :-

When deforming force applied normally (perpendicular) to the surface area of the body, then restoring or deforming force acting per unit area is called tensile or normal or longitudnal stress.



Tensile stress = $\frac{F}{A}$.

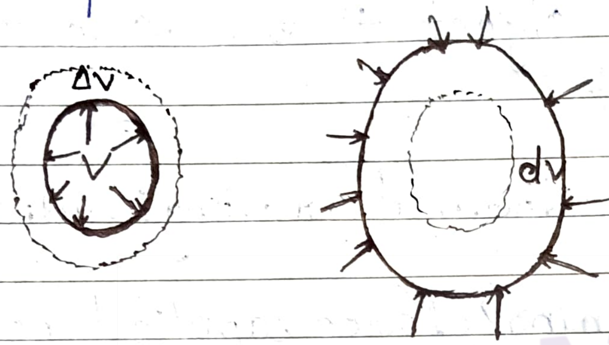
$$\boxed{\text{Tensile stress} = \frac{mg}{\pi r^2}}$$

(ii) Volumetric or compressional stress :-

When we applied deforming force on the object

To join our WhatsApp Group contact:- 9508550281

and it changes volume of the body then deforming or restoring force acting per unit area is called volumetric or compressional stress.



So that Volumetric or Compression stress $= \frac{F}{A}$

3. Tangential or Shearing stress :-

When deforming force applied parallely to the surface area of the body then its shape is changed but volume does not change, then tangential force acting per unit area is called tangential or shearing stress.

To join our WhatsApp Group contact:- 9508550281

Strain

→ The change in shape or size of a body due to deforming force is called strain.
It is measured by the ratio of change in dimension to the original dimension.

i.e $\boxed{\text{strain} = \dfrac{\text{Change in dimension}}{\text{Original dimension}}}$

It has no unit and no dimension.

* Types of strain :-

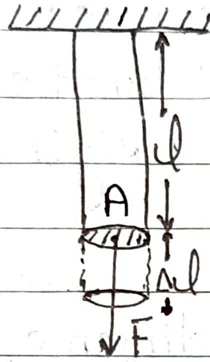
When we applied deforming force on a body according to change in different dimension of the body there are 3 types of strain :-

(i) Tensile or normal or longitudnal strain :-

When we applying a deforming force if there is change in length then tensile strain is develop.

To join our WhatsApp Group contact:- 9508550281

It is measured by the ratio of change in length to the original length.



If l is the original length
Δl is the change in length

$$\boxed{\text{Strain longitudnal} = \frac{\Delta l}{l}}$$

2: Volumetric Or Compressional strain :—

When we applying a deforming force if there is change in volume then Volumetric strain is develop. It is the measured by ratio of change in volume to the original volume.

If V is the original volume.
ΔV is the change in volume.

$$\boxed{\text{Volumetric strain} = \frac{\Delta V}{V}}$$

Diplomawallah.in

To join our WhatsApp Group contact:- 9508550281

3. Tangential strain :-

When we applying a deforming force if there is change in shape of the body then shearing stress is produced. It is measured by the ratio of change in shape by original shape. It is also measured by the angle θ through which a line originally perpendicular to the fixed place is turned due to the applied of the tangential force.

Shearing or tangential strain =

$$\frac{\text{Change in shape}}{\text{Original shape}}$$

$= \tan\theta$ (Here θ is very small.)

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

Diplomawallah.in

To join our WhatsApp Group contact:- 9508550281

17/10/24.

Hook's Law :—

→ Within elastic limit stress is directly proportional to strain :
i.e stress is directly proportional to strain.

i.e

Stress $\propto$ Strain

$$\boxed{\frac{\text{Stress}}{\text{Strain}} = \text{Constant}}$$

This constant is known as modulus of Elasticity. It depends on nature of the material.

Unit of modulus of elasticity

SI Unit $= Nm^{-2}$

CGS Unit $=$ Dyne cm^{-2}

Dimension $= M^{1} L^{-1} T^{-2}$

Pressure, stress and modulus of Elasticity are same unit and dimension.

Diplomawallah.in

To join our WhatsApp Group contact:- 9508550281

There are 3 types of Elasticity :-

(1) Young's modulus of Elasticity (Y)

(2) Bulk modulus of Elasticity (K)

(3) Rigidity modulus of elasticity or modulus of rigidity. (η)

Modulii of Elasticity :-

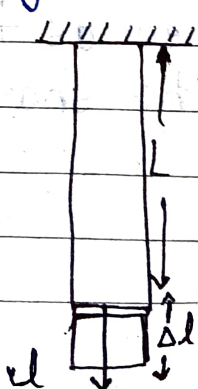
(1) Young's Modulus of elasticity (Y) :-

It is defined as the ratio of tensile or normal our longitudnal stress to the tensile our normal or longitudnal strain.

i.e.

$$Y = \frac{\text{Tensile or longitudnal stress}}{\text{Tensile or longitudnal strain}}$$

$$Y = \frac{F/A}{\Delta l/L}$$



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

$F = mg$

Diplomawallah.in

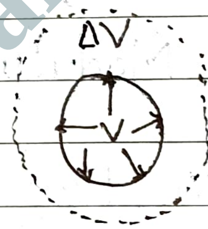
$$\boxed{Y = \frac{F}{A} \cdot \frac{L}{\Delta L}} = \boxed{Y = \frac{mg}{\pi r^2} \cdot \frac{L}{\Delta l}}$$

(2) Bulk modulus of Elasticity (K)

It is defined as the ratio of Volumetric stress to the Volumetric strain.

$$K = \frac{\overset{\text{Normal}}{\cancel{\text{Volumetric}}}\ \text{stress}}{\text{Volumetric strain}}$$

$$K = \frac{F/A}{\Delta V/V}$$



$$\boxed{K = \frac{F}{A} \cdot \frac{V}{\Delta V}}$$

= The SI unit is bulk modulus N/m² or Pa.

(3) Rigidity modulus of elasticity or modulus of rigidity (η)

It is defined as the ratio of of sharing stress to the sharing strain.

Diplomawallah.in

i.e. $\eta = \dfrac{\text{Shearing stress}}{\text{Shearing strain}}$

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

$$= \frac{F/A}{BB'/AB} = \frac{F/A}{\Delta L/L}$$

$$\boxed{\eta = \frac{F}{A} \cdot \frac{L}{\Delta L}}$$

~~Young's~~ The SI unit of shear modulus is N/m^2 or Pa.

Diplomawallah.in

* Relation between Y, K and η :-

$$\frac{Y}{3K} + \frac{Y}{\eta} = 3$$

$$\frac{1}{3K} + \frac{1}{\eta} = \frac{3}{Y}$$

$$\frac{\eta + 3K}{3K\eta} = \frac{3}{Y}$$

$$\boxed{Y = \frac{9K\eta}{\eta + 3K}}$$

Q. Which is more elastic steel or rubber why?

→ Steel is more elastic than rubber.

Let us consider to identical wire of steel and rubber.

$\therefore L_R = L_S = L$

$A_R = A_S = A$

If same deforming force F is applied on both wire than ΔL_R and ΔL_S with the change in length of rubber and steel wire respectively and we know :—

$$\boxed{\Delta L_R > \Delta L_S}$$

Young modulus of elasticity for both wire is :—

$$Y_R = \frac{F}{A} \cdot \frac{L}{\Delta L_R} \quad \text{—— (i)}$$

$$\& \; Y_S = \frac{F}{A} \cdot \frac{L}{\Delta L_S} \quad \text{—— (ii)}$$

Diplomawallah.in

Dividing eq ① by eq ⑪ and we get :—

$$\frac{Y_R}{Y_S} = \frac{\cancel{F/A} \cdot \cancel{L}/\Delta L_R}{\cancel{F/A}\ \cancel{L}/\Delta L_S}$$

$$\frac{Y_R}{Y_S} = \frac{\Delta L_S}{\Delta L_R} \quad \text{——— ③}$$

from eq ⑪

$\because \Delta L_R > \Delta L_S$

$\therefore Y_S > Y_R$

Steel is more elastic than rubber.

Diplomawallah.in

Q. A load of 2 Kg produces extension of 1mm in a wire of 3m in length and 1mm in diameter calculate the young's modulus of the wire?

→ Given,

$m = 2\,Kg$

$L = 3m$

$\Delta L = 1mm$

$d = 1\,mm$

$\Delta L = 1mm = 10^{-3} m$
$d = 1mm = 10^{-3} m$

$\therefore r = \frac{d}{2} = \frac{1}{2} \times 10^{-3} m$

$= 0.5 \times 10^{-3} m$

$Y = \frac{mg}{\Delta r^2} \cdot \frac{L}{\Delta L}$

$= \frac{2 \times 9.8}{3.14 \times 0.5 \times 10^{-3} \times 0.5 \times 10^{-3}} \cdot \frac{3}{10^{-3}}$

$= \frac{2 \times 9.8 \times 3}{3.14 \times 0.5 \times 0.5 \times 10^{-3} \times 10^{-3} \times 10^{-3}}$

$= \frac{19.6 \times 3}{0.785 \times 10^{-9}}$

$= \frac{58.8 \times 10^{9}}{0.785}$

$= 74.90 \times 10^{9}$

$= 7.49 \times 10^{10}$ Ans.

Diplomawallah.in

18/10/24

Q. What force is required to stretch a steel wire to double its length when its area of cross section is $1 cm^2$ and young's modulus of elasticity is $2 \times 10^{11} Nm^{-2}$

→ $Y = 2 \times 10^{11}\ Nm^{-2}$

$A = 1cm^2 = 10^{-4}\ m^2$

Let length = L

When force is applied length of the wire is doubled (2L)

∴ change in length $\Delta L = 2L - 1$

$= L$

$F = ?$

$$Y = \frac{F}{A} \cdot \frac{L}{\Delta L}$$

$$Y = \frac{Y \cdot A\ \Delta L}{L}$$

$$= \frac{2 \times 10^{11} \times 10^{-4} \times \cancel{L}}{\cancel{L}}$$

$= 2 \times 10^{7}$ N Ans-

Diplomawallah.in

Q. Two wires made of the same material have there length in the ratio 3:4 and there diameter in the ratio 2:3 if both of them are stretched by the same load what is the ratio of there extension?

→ Given,

$$\frac{L_1}{L_2} = \frac{3}{4}$$

$$\frac{d_1}{d_2} = \frac{2}{3}$$

$F_1 = F_2 = F$

$Y_1 = Y_2 = Y$

$$\therefore \frac{r_1}{r_2} = \frac{d_1/\cancel{2}}{d_2/\cancel{2}} = \frac{d_1}{d_2}$$

$$= \frac{2}{3}$$

$$\frac{\Delta L_1}{\Delta L_2} = ?$$

both wires are made of same material therefore, $Y_1 = Y_2$

$$\frac{F}{A_1} \cdot \frac{L_1}{\Delta L_1} = \frac{F}{A_2} \cdot \frac{L_2}{\Delta L_2}$$

$$\frac{\Delta L_1}{\Delta L_2} = \frac{L_1}{L_2} \cdot \frac{A_2}{A_1} = \frac{L_1}{L_2} \cdot \frac{\cancel{\pi} r_2^2}{\cancel{\pi} r_1^2}$$

$$\frac{\Delta L_1}{\Delta L_2} = \frac{L_1}{L_2} \cdot \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{3}{4}\right)\left(\frac{3}{2}\right)^2$$

$$= \frac{3 \times 9}{4 \times 4} = \frac{27}{16}$$

$\Delta L_1 : \Delta L_2 = 27 : 16$ Ans

Diplomawallah.in

Q. Two wires of the same length and material are stretched by the same force if the radii of the wires are in the ratio 1:2 what is the ratio of elongation produce?

→ Given.

$$L_1 = L_2 = L$$

$$A_1 = A_2 = A$$

$$\frac{\cancel{F}}{\cancel{A_1}} \cdot \frac{L}{\Delta L_1} = \frac{\cancel{F}}{\cancel{A_2}} \cdot \frac{L_2}{\Delta L_2}$$

$$\frac{\Delta L_1}{\Delta L_2} = \frac{A_2}{A_1} = \left(\frac{\pi r_2^2}{\pi r_1^2}\right) = \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{2}{1}\right)^2$$

$$= 4 : 1$$

Q. if the η and K of the material are 0.42×10^{11} Nm^{-2} and 0.21×10^{-11} Nm^{-2} respectively calculate youngs modulus of elasticity?

→ $\eta = 0.42 \times 10^{-11}$ Nm^{-2}

$K = 0.21 \times 10^{11}$ Nm^{-2}

$$Y = \frac{9K\eta}{\eta + 3K}$$

Diplomawallah.in

$$Y = \frac{9 \times 0.21 \times 10^{11} \times 0.42 \times 10^{11}}{0.42 \times 10^{11} + 3 \times 0.21 \times 10^{11}}$$

$$= \frac{9 \times 0.21 \times 0.42 \times 10^{22}}{1.05 \times 10^{11}}$$

$$= 0.756 \times 10^{11}$$
$$= 7.56 \times 10^{10} \ N/m^2 \text{ Ans-}$$

Q. A steel rail is 20 m long and has an area of cross section 40 cm^2 between summer and winter its length changes by 1 cm if it is Lead in winter what force parallel to its length is necessary to keep it from increasing the length in summer ? ($Y = 19 \times 10^{10} \ Nm^{-2}$

→ Given,

$L = 20 cm$
$A = 40 cm^2$
$= 40 \times 10^{-4} \ m^2$
$Y = 19 \times 10^{10} \ N/m^2$
$\Delta L = 1 cm$
$= 10^{-2} \ m^2$

$$Y R = \frac{F}{A} \cdot \frac{L}{\Delta L}$$

Diplomawallah.in

$$F = \frac{Y R \cdot n \cdot \Delta L}{L}$$

$$= \frac{19 \times 10^{10} \times \overset{2}{\cancel{40}} \times 10^{-4} \times 10^{-2}}{\cancel{20}}$$

$= 3.8 \times 10^{4}$

$= 3.8 \times 10^{5}\ N$

Q. A wire of length 1 m is stretched by the force of 10 N the area of cross section of the wire is $2 \times 10^{-6}\ m^2$ and Y is $2 \times 10^{11}\ Nm^{-2}$ find

(i) The stress

(ii) The strain

(iii) The increase in length of the wire.

→ Given,

Length = 1 m

Force = 10 N

$Y = 2 \times 10^{11}\ N/m^2$

(i) Stress = $\frac{\text{Force}}{\text{Area}}$

$$= \frac{\overset{5}{\cancel{10}}\ N}{\cancel{2} \times 10^{-6}} = 5 \times 10^{6}\ N/m^2$$

Diplomawallah.in

(ii) $Y = \frac{\text{Stress}}{\text{Strain}}$

$$\therefore \text{Strain} = \frac{\text{Stress}}{Y}$$

$$= \frac{5 \times 10^6 \ N/m^2}{2 \times 10^{11}}$$

$$= 2.5 \times 10^{6-11} \ N/m^2$$

$$= 2.5 \times 10^{-5} \ N/m^2 \text{ Ans}$$

(iii) $\text{Strain} = \frac{\Delta L}{L}$

$$\Delta L = L \times \text{Strain}$$

$$= 1 \times 2.5 \times 10^{-5}$$

$$= 2.5 \times 10^{-5} \ m \text{ Ans}$$

Q. If the pressure on a sphere is increase by 90 atomsphere then its volume decreases by 0.05 %. what is the bulk modulus of Elasticity of the material of the sphere?

→ $B = \frac{F}{A} \cdot \frac{V}{\Delta V} = \frac{PV}{\Delta V}$

$P = 90 \text{ atm}$

Diplomawallah.in

$= 90 \times 1.013 \times 10^5 \ N/m^{-2}$

$$B = 10^5 \times 90 \times 1.031 \times \frac{\cancel{10000}^{\,2000}}{\cancel{0.05}}$$

$= 91.17 \times 2000 \times 10^5$

$= 182.34 \times 1000$

$= 1.823 \times 10^5 \times 10^5$

$= 1.825 \times 10^{10} \ N/m^2$ Ans

Diplomawallah.in

* Elastic limit :-

"The maximum stress from which an elastic body will recover its original state after the removal of the deforming force, is called elastic limit."

Every solid has a certain value of elastic limit through which it may be deformed and can returns to its original condition.

* Compresibility :-

The compresibility of a material is a measure of how easily the material is compressed. In other words, compresibility is just the resiprocal of ~~tangential stress (or shear stress)~~ bulk modulus i.e

$$\text{Compresibility}, \; K = \frac{1}{K}$$

$$\text{S.I Unit} = N^{-1}m^{2} \text{ or } Pa^{-1}$$

Ex :- Young's modulus for steel is $20 \times 10^{10} \, N/m^2$ whereas shear modulus for steel is $8 \times 10^{10} \, N/m^2$.

Diplomawallah.in

* Poisson's Ratio :-

The ratio of ~~related~~ lateral strain to the longitudinal strain is called Poisson's ratio. (σ)

Let L, D = Original length and diameter respectively of the wire.

$\Delta L, \Delta D$ = Slight increase in length and a corresponding slight decrease in the diameter of the wire.

$$\text{Longitudnal strain} = \frac{\Delta L}{L}$$

$$\text{Lateral strain} = \frac{-\Delta D}{D}$$

The negative sign shows that if length increase, the diameter decreases.

$$\therefore \text{Poisson's Ratio } \sigma = \frac{\text{Lateral strain}}{\text{Longitudnal strain}}$$

$$= \frac{-\Delta D/D}{\Delta L/L}$$

$$\sigma = -\frac{\Delta D}{D} \times \frac{L}{\Delta L}$$

Diplomawallah.in

Poisson's ratio is never more than 0.5, its value is usually between 0.2 and 0.4

* Factor of safety :—

The ratio of maximum load is , ultimate stress that the structure can bear to the actual load is i.e. working stress on the structure is known as factor of safety.

i.e ; $\text{Factor of safety} = \dfrac{\text{Ultimate stress}}{\text{Working stress}}$

- maximum or ultimate stress

The maximum axial load that can be applied to the material without causing fracture is called ultimate load.

i.e :– $\text{Factor of safety} = \dfrac{\text{Ultimate stress}}{\text{Working stress}}$

Ultimate stress :– $\dfrac{\text{Ultimate load}}{\text{Original cross-sectional area}}$

* Working stress :—

The maximum permitted stress on the system

Diplomawallah.in

which carry a material is known as working stress".

In design, the working stress should be limited to value not exceeding the proportional limit. This is measured by the ratio of ultimate stress or to the factor of safety.

i.e. working stress = $\frac{\text{Ultimate stress}}{\text{Factor of safety}}$

Factor of safety is the measure of structural capacity of a system beyond the expected or actual loads. It describes how much the system is than it usually needs to be for a calculated load.

for Ex:- massage on lift may be written as " For 300 Kgs only" but its actual capacity may be 500kg

Factor of safety depends on wear and tear of the material, maximum load subjected to object, characteristics of load such as fixed or variable etc:-

Diplomawallah.in

Factor of safety i.e ratio of ultimate stress, to the working stress must be greater than 1.

* Factor affecting Elasticity :-

The elasticity of a material is affected by the following factors :-

① Effect of harming and rolling :- Hammering and rolling leads to the breaking up of the crystal grains into smaller parts. Thus, the elasticity of the material is increased.

Diplomawallah.in

② Effect of Annealing :- Annealing means heating and then cooling gradually. The process of annealing results into the formation of larger crystal grains. Hence, the elasticity of the material decreases.

③ Effect of Temperature :- The elasticity of materials decreases with the increases in temp. and increases with the decrease in temperature.

4. Al effects of pressure of impurities in the material the elasticity of a material can be increased or decreased by adding impurities in it depending on the nature of the impurities.

* Application of Elasticity :-

1. The elastic property of steel & concrete area taken into account is designing beams and pillors in consturuction work.

2. It is used to determine the strength of a material.

3. It is used to study the tensils strength of different metals in engineering.

4. While designing the steel or concrete structure, it is designed to bear more load than actually expected.

Diplomawallah.in