Date 17/10/2023

~~Unit~~
~~Chapter~~-7

Ch-9 Properties of Matter & Fluid Mechanics

Elasticity:-

Elasticity is that property of material of a body by virtue of which it oppose any change in its shape & size when deforming force are applied on it, and recover its original state as soon as the deforming force are removed.

Deforming force:-

External force try to bring about a change in the length, volume or shape of the body is called deforming force.

Perfectly elastic body:-

A body which perfectly regains its orignal form on removing ~~force~~ external deforming ~~ext~~ force is defined as perfectly elastic body.

Plastic body:-

A body which does not have the property of opposing the deforming force is known as a plastic body.

- All body which remains in the deformed state even after the removing of deforming force is known as plastic body.

Saathi

Date ___/___/___

Restoring force:-

When an external force act at any object then an internal resistance produce in the substance due to the internal molecular force which is called restoring force

Stress:- The restoring force acting per unit area of cross section of the deformed body is called stress.

$$\text{Stress} = \frac{\text{Int. Restoring force}}{\text{Area of cross section}} = \frac{F}{A}$$

SI unit = N/m^2

Dimensional formula = $[ML^{-1}T^{-2}]$

Type of stress

1. Longitudnal Stress
2. Volume Stress
3. Shear Stress
4. Breaking stress

→ Strain :- Strain is the change in the length of the body upon original dimension / length of the body

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

= dimensionless quantity as well as unitless physical quantity

Types of Strain

1. Longitudnal Strain
2. Volume strain
3. Shear strain

Date ___ / ___ / ___

Saathi

Longitudnal strain:- when two cross-sectional areas of the cylinder are subjected to equal and opposite forces the stress experienced by the cylinder is called longitudnal stress.

Volume stress:- when the volume of the body changes due to the deforming force it is termed as volume stress.

Shear stress:- Shear stress is defined as the stress that acts coplanar with the cross-section area of the material.

Breaking stress:- The stress applied to a material is the force per unit area applied to the material. The maximum stress a material can stand before it breaks is called the breaking stress.

\# **Longitudnal strain:-** The ratio of axial deformation to the original length of the body is called longitudnal strain

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

Volume strain:- The ratio of the change in volume of a body to the original volume.

$$= \frac{\Delta V}{V}$$

Shear strain:- It is the change in the shape of the material due to the tangential force applied to any side of the surface of the material.

Page No.

19/10/2023 Date __/__/__

Elasticity

Hooke's law

Stress ∝ strain

Stress = Y strain

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

↓ Young's modulus

$$Y = \frac{F/A}{\Delta l/l} = \frac{N/m^2}{m/m}$$

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

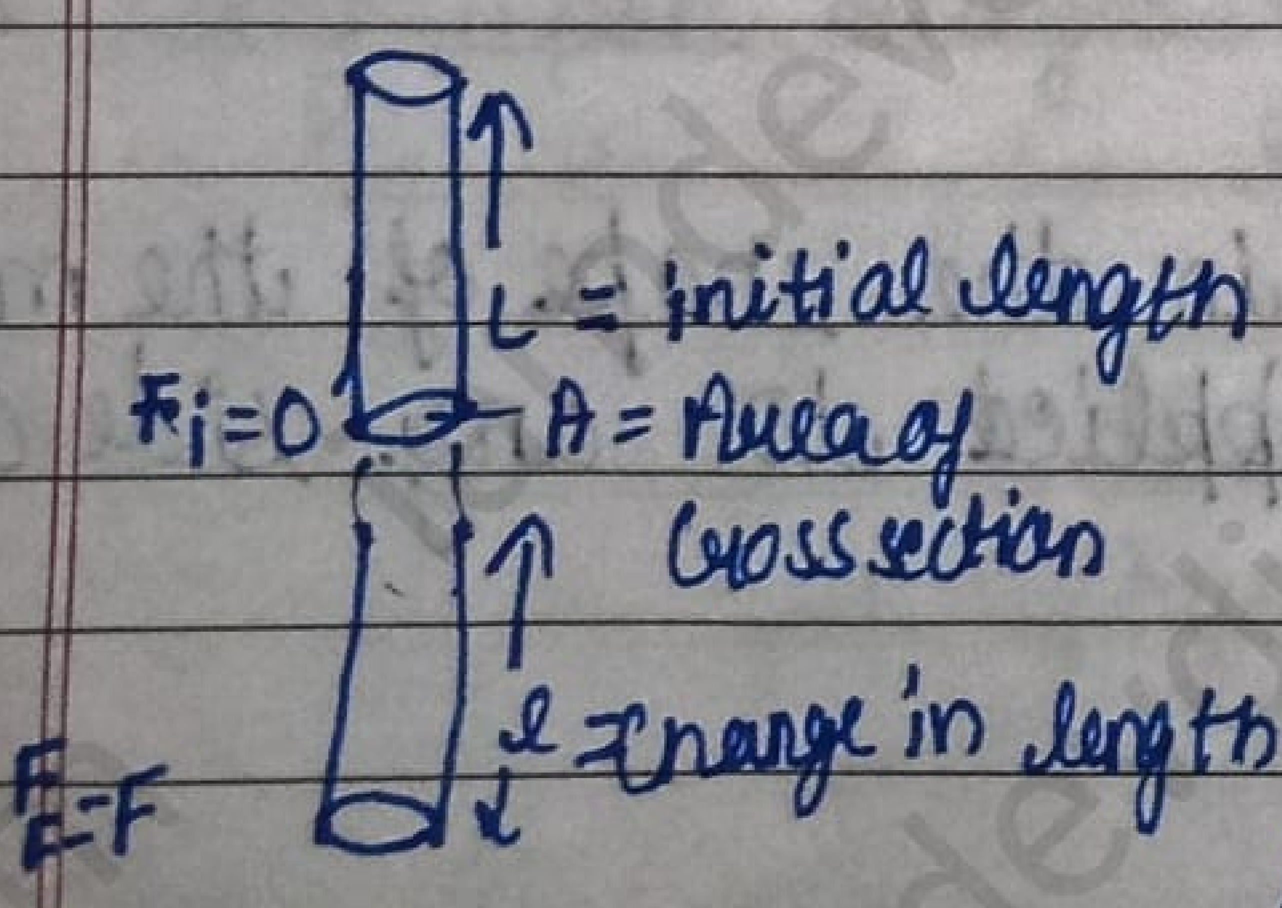
Dimensional formula for $Y = \left[\frac{MLT^{-2}}{L^2}\right]$

$$= [M L^{-1} T^{-2}]$$

Elastic Potential Energy in a stressed wire per unit volume

$$U = \frac{1}{2} \text{ stress} \times \text{strain}$$

OR



$$U = \frac{1}{2} Y \times (\text{strain})^2$$

$F_i = 0$ $\quad F_f = F$

$$\text{Average force} = \frac{F_i + F_f}{2} = \frac{0+F}{2}$$

$$F_{Av} = \frac{F}{2}$$

Date __/__/__

$$W = \frac{F}{2} \times l = \frac{1}{2} F l$$

$$W = \frac{1}{2}\left(\frac{F}{A}\right) l A = \frac{1}{2} \frac{F}{A}\left(\frac{l}{L}\right) A L$$

$$W = \frac{1}{2} \text{ Stress} \times \text{Strain} \times \text{volume}$$

$$U = \frac{W}{\text{volume}} = \frac{1}{2} \text{ Stress} \times \frac{\text{Strain}}{\text{volume}}$$

$$U = \frac{1}{2} \text{ Stress} \times \text{strain}$$

$$U = \frac{1}{2} Y \times \text{Strain} \times \text{Strain}$$

$$U = \frac{1}{2} Y \times (\text{Strain})^2$$

Q- A ~~still~~ steel wire of length 4m and radius 0.24 cm is stressed by 5N force find the increase in its length $Y = 2.3 \times 10^7 \, N/m^2$?

$l = 4m$

$r = 0.24 \text{ cm} \rightarrow 2.4 \times 10^{-2} \text{ cm} = 24 \times 10^{-4} m$

$Y = 2.3 \times 10^7 \, N/m^2$

$F = 5N$

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

$$Y = \frac{F}{\pi R^2} \frac{\Delta l}{L} \Rightarrow \Delta l = \frac{Y \pi R^2 L}{F}$$

Saathi

Date __ / __ / __

$$2.3 \times 10^7 = \frac{5}{3.14 \times (0.24)^2}$$

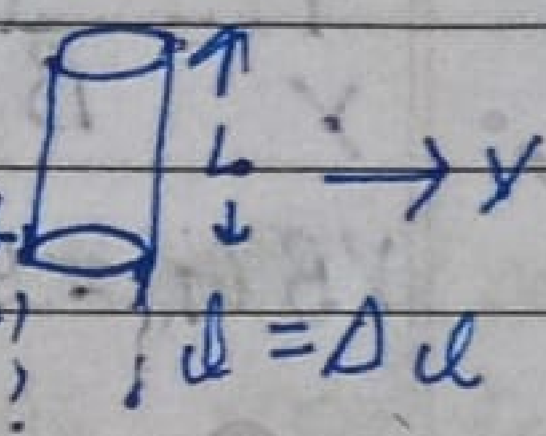
$$2.3 \times 10^7 = \frac{5000000.0}{3.14 \times 0.24 \times 0.24}$$

Types of Modulus Elasticity

1. Young Modulus $\xrightarrow{Y}$ Longitudnal strain
2. Bulk Modulus $\xrightarrow{B}$ Volumetric strain
3. Shear Modulus $\xrightarrow{G}$ Shear strain

⇒ Poisson's Ratio $\xrightarrow{\sigma}$ Lateral strain

1. $Y = \frac{\text{Stress}}{\text{strain}} = \frac{F/A}{l/L} = \frac{FL}{lA} = \frac{FL}{l\pi R^2}$ $\quad \frac{l}{L} = \frac{\Delta L}{L}$



2. $B = \frac{F/A}{-\Delta V/V} = -\frac{FV}{A\Delta V}$

$G = \frac{F/A}{\theta}$

$\frac{\text{Change in Radius}}{\text{initial Radius}} = \frac{-\Delta R}{R}$ = lateral strain

longitudnal strain $= \frac{\Delta L}{L}$

$\sigma = \frac{\text{Lateral strain}}{\text{Longitudnal strain}}$

$\sigma = \frac{-\Delta R/R}{\Delta L/L}$

Date ___

Relation between Y B G and σ

$Y = 3B(1-2\sigma)$

$Y = 2G(1+2\sigma)$

$\sigma = \frac{3B-2G}{2G+6B}$

$\frac{9}{Y} = \frac{3}{B} + \frac{1}{G}$

YBG = 931

Thermal stress :- when a rod is rigidly fixed at its two ends and its temperature is changed then the thermal stress is set up in the rod. Which is given by thermal stress = $\frac{\text{Force}}{\text{Area of cross section}} = \frac{F}{A}$

$$Y \alpha \Delta\theta = \frac{F}{A}$$

$F = Y\alpha\Delta\theta A$ → Area

↳ Temp.

Force, Young Modulus

Application of Elasticity

1. The Metallic part of Machinery are never subjected to a stress beyond the elastic limit otherwise they will get permanently deformed

2. The bridge are designed in such a way they do not bend much or break under the load of a heavy traffic. Force of strongly blowing wind and its own weight.

Date __/__/__

Saathi

Ques - A ~~still~~ steel wire of 4 m in length in stretched 2 mm the cross section of the wire is 2 mm². If the young modulus of steel is $2 \times 10^{11} N/m^2$ then find out the value of Energy-density of the wire and elastic potential energy?

$l = 4 m$

$\Delta l = 2 mm = 2 \times 10^{-3} m$

$A = 2 mm^2 = 2 \times 10^{-6} m$

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

$F =$

(1) Energy density $= \frac{\text{Energy}}{\text{Volume}} = \frac{1}{2} Y \times (\text{Strain})^2$

$= \frac{1}{2} Y \left(\frac{\Delta l}{l}\right)^2$ — (1)

$= \frac{1}{2} 2 \times 10^{11} \times \left[\frac{2 \times 10^{-3}}{4}\right]^2$

$= 10^{11} \times \frac{10^{-6}}{4} = \frac{1}{4} \times 10^5$

$= \frac{10}{4} \times 10^4 = 2.5 \times 10^4$

(2) Total Energy $= U \times$ Volume

$= U \times A l$

Saath

Date __/__/____

Ques - Two parallel and opposite forces each 5000 N are applied to the upper and lower faces of a cubical metal block 25 cm on a side find the angle of Shear and displacement of the upper surface relative to upper surface The shear modulus of the metal is $8 \times 10^{10} N/m^2$ $g = 10 m/s^2$

$G = \frac{F}{A\theta}$ Cubical metal side = 25 cm

$= 25 \times 10^{-2} m$