JEE MAIN | IIT JEE

Elasticity

Properties of Solids

REVISION in 20 Min

-Mohit Goenka, IIT Kharagpur

Topics to cover in Properties of Solids | Elasticity

1. Elastic body vs Plastic body
2. Stress & Strain in elastic material *(example)*
3. Relation between Stress & Strain *(Hooke's Law)*
4. Modulus of Elasticity *(standard example)*
5. Analogy with springs
6. Potential Energy
7. Elongation due to Self weight
8. Poisson Ratio
9. Relation among Modulus of elasticity

EDUNITI

Chapter	Formulae_Concept VIDEO LINK
Unit & Dimensions	https://youtu.be/wdd-wlZF4Hk
Errors and Vectors	
Vernier Caliper	https://youtu.be/pVoN045dV8I
Screw Gauge	https://youtu.be/gYd2PtmZ0mw
Kinematics_Motion in 1d	
Kinematics_Motion in 2d	
Laws of Motion	
Work Energy Power	https://youtu.be/kjrXoE-kDI8
Centre of Mass	
Centre of Mass of Standard Bodies	https://youtu.be/oCeACfryB-U
Collision	
Rotational Motion_Moment of Inertia	https://youtu.be/9ckZdOhy3z0
Gravitation	https://youtu.be/rAj2huLVaEk
Properties of Solids	
Fluids Statics (Part 1)	https://youtu.be/RFKx9B9yo3M
Fluid Dynamics (Part 2)	https://youtu.be/Y717vQpUEJQ
Fluid Properties (Part 3)	https://youtu.be/V8xUWWK2oT0
Simple Harmonic Motion	https://youtu.be/RIb7ofNG09I
Thermal Properties	
KTG	https://youtu.be/XO1tvFhIa0I
Thermodynamics	https://youtu.be/iz_kf1jRDRw
Wave Motion -Organ Pipes and Resonance Tube	https://youtu.be/fB7pfJ77za8
Wave Motion - Doppler's Effect	https://youtu.be/9-BxOaamnwg
Electrostatics	https://youtu.be/3stXbGRMcrk
Capacitors	https://youtu.be/EXEiickNUkY
Current Electricity	https://youtu.be/gm8FUfjrX18
Moving Charges and Magnetic Effect of Current	https://youtu.be/ULD2Ok1CGJk
Earth's Magnetism	https://youtu.be/a4CT5uVwAK4
Magnetic Properties	https://youtu.be/63cwdYXNlYE
EMI	https://youtu.be/puVavm_GFRM
Alternating Current	https://youtu.be/74dTY-pzM_o
Ray Optics	https://youtu.be/BhnyTWzIlBA
Wave Optics Part 1_Interference	https://youtu.be/LG5nlE8XTeI
Wave Optics Part 2_Diffraction_Polarization	https://youtu.be/ymMyyJGGqnY
Optical Instruments	https://youtu.be/OQssbDH0A4I
Electromagnetic Waves	https://youtu.be/bcVXgEkyQZY
Semiconductors_Basics + Zener Diode	https://youtu.be/_A2JomQ7-50
Semiconductors_Transistors	https://youtu.be/psDwl84Nzb0
Semiconductors_Logic Gates	https://youtu.be/pZdQAzLbFTo
Communication Systems	https://youtu.be/8NgMqK9X79Y
Modern Physics_Part 1_Atomic Physics	https://youtu.be/9VKUnE3mpHk
Modern Physics_Part 2_Photoelectric Effect	https://youtu.be/24oTQp84jrk
Modern Physics_Part 3_Dual Nature of Light	https://youtu.be/0zoR_saMAQY
Modern Physics_Part 4_Radioactivity	https://youtu.be/AdX3YBhQyog
Modern Physics_Part 5_Nuclear Physics	https://youtu.be/VDWqVahGixc
Modern Physics_Part 6_X Rays	https://youtu.be/dSHXdzX7NX0

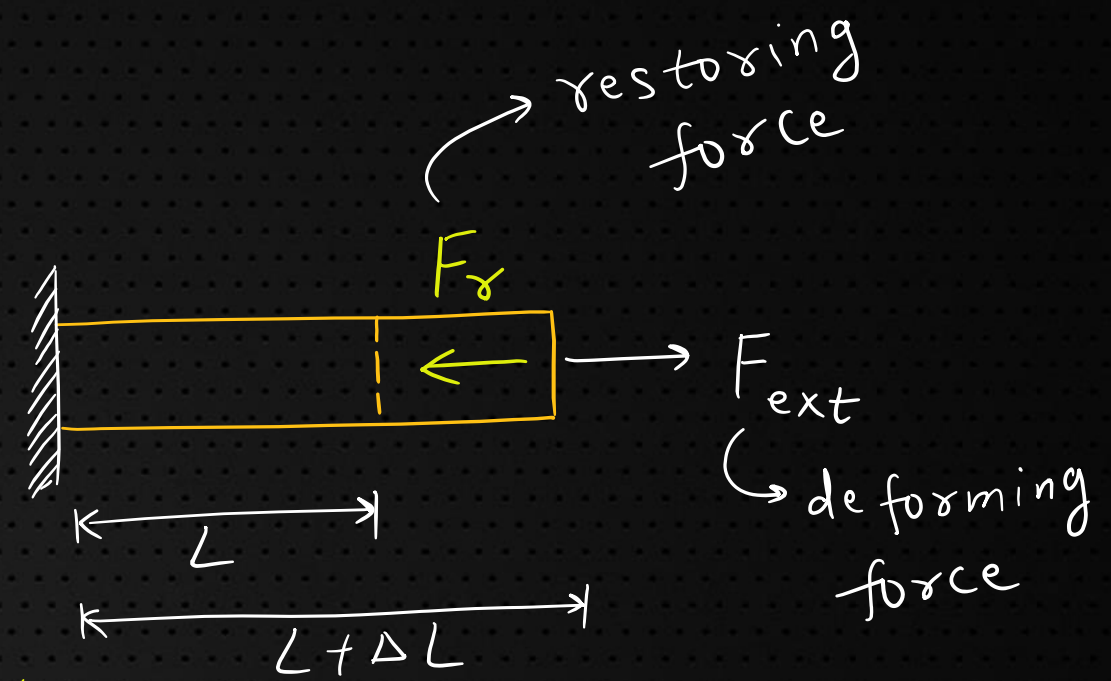
1. Elastic vs Plastic body

↳ body that regains orginal shape after removal of deforming force

Ex: steel

↳ body doesn't regain shape

Ex: dough, clay



↳ At equilibrium condition

$$F_{ext} = F_r$$

2. Stress & strain (elastic material)

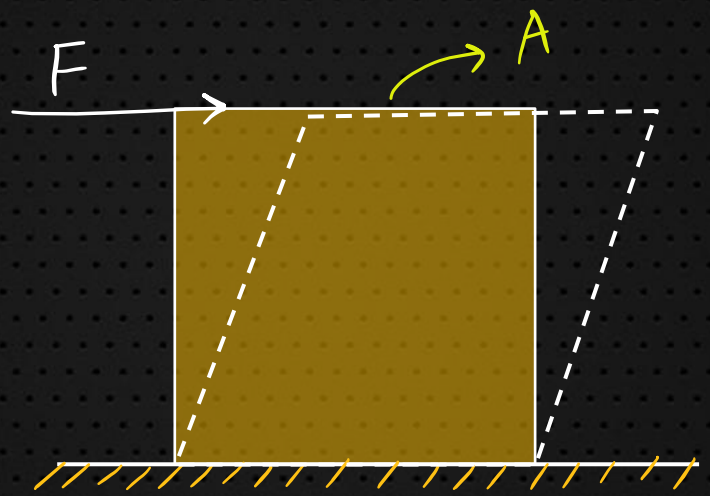
↳ due to restoring force

Stress

Normal stress

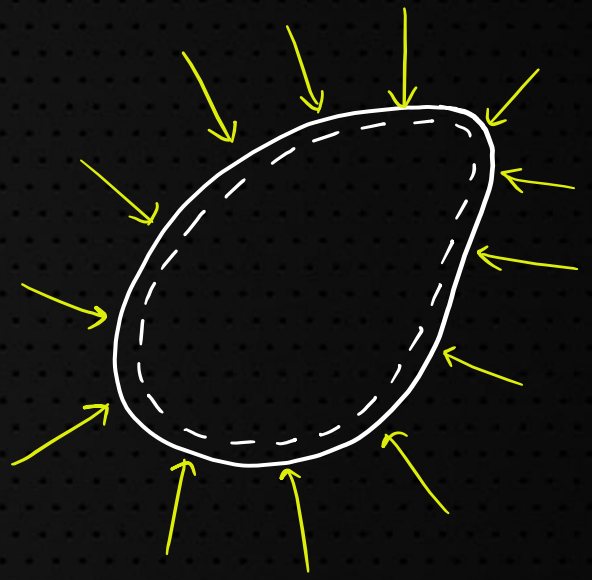
$$\text{Stress} = \frac{F}{A}$$

Shear stress



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

Hydraulic stress

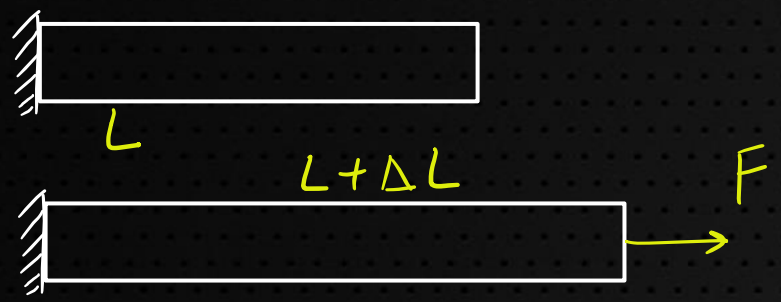


Here it is ΔP or P_{excess}

... continued

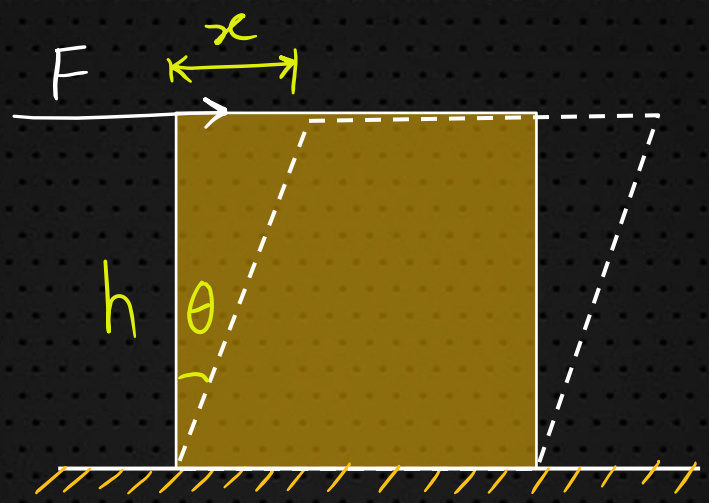
strain

Normal strain



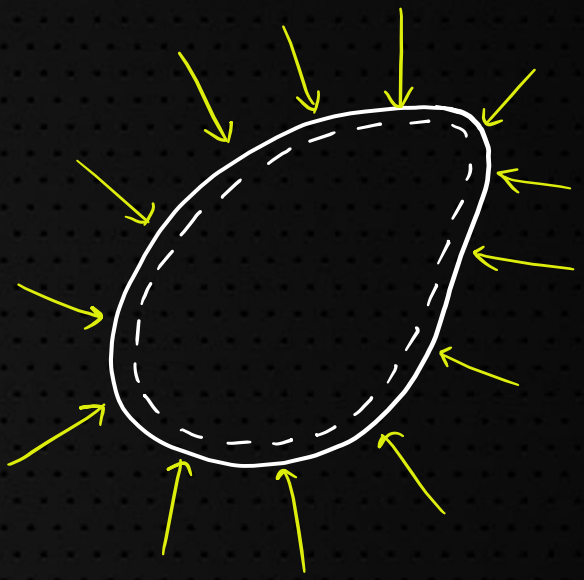
$$\text{Strain} = \frac{\Delta L}{L}$$

Shear strain



$$\text{Strain} = \theta = \frac{x}{h}$$

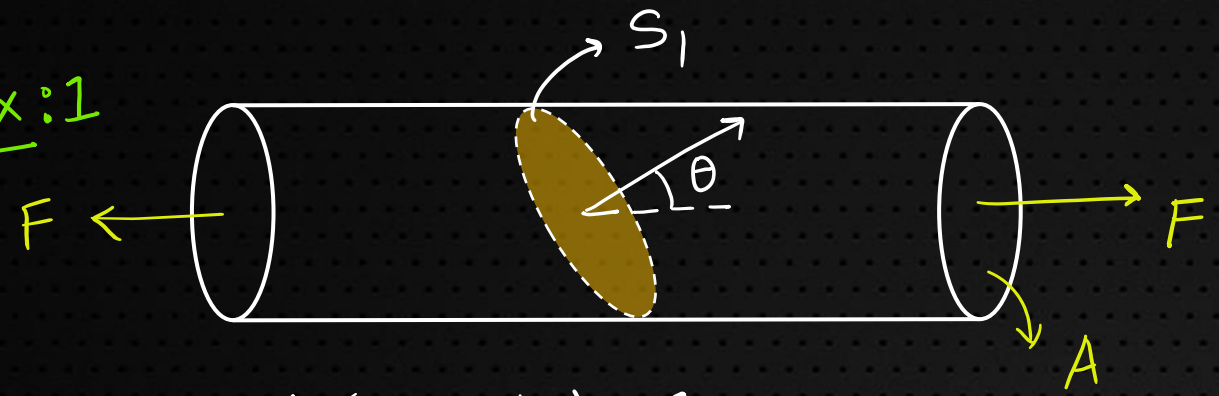
Volume strain



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

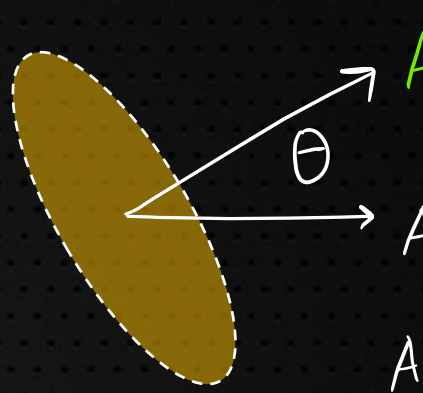
... Continued

Ex:1



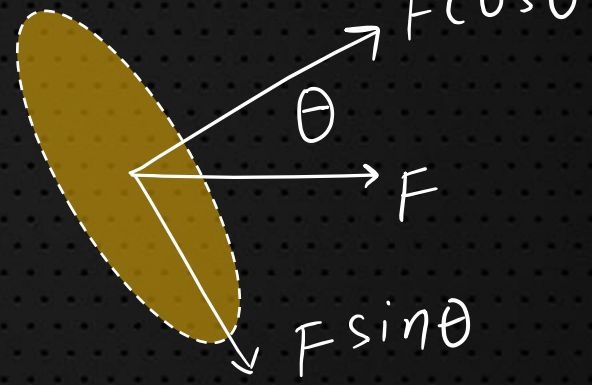
find Normal (tensile) & shear stress on S_1.

Soln:



$A'\cos\theta = A$

$\Rightarrow A' = \frac{A}{\cos\theta}$



(i) Tensile stress

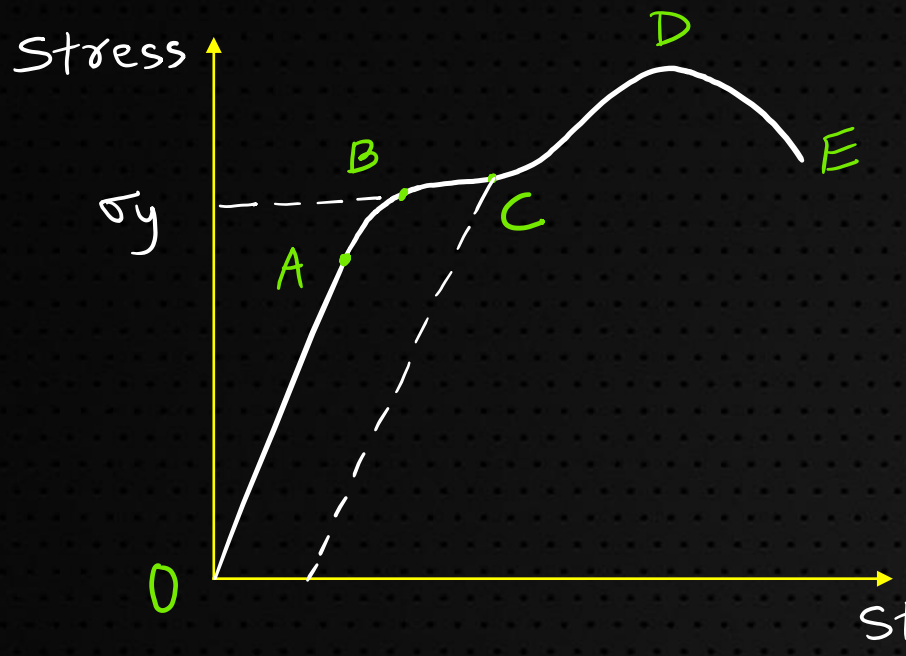
$= \frac{F\cos\theta}{A/\cos\theta}$

$= \frac{F\cos^2\theta}{A}$

(ii) shear stress

$= \frac{F\sin\theta}{A/\cos\theta} = \frac{F\sin 2\theta}{2A}$

3. Relation between Stress & strain (Hooke's Law)



elastic zone

(i) $O \rightarrow A$: Stress $\propto$ strain (Hooke's Law)

$\Rightarrow$ stress = k x strain

↳ Modulus of elasticity

(ii) $A \rightarrow B$: non-Linear but still elastic

B point is elastic Limit

σ_y is yield strength

Plastic zone

(iii) $B \rightarrow D$: strain ↑ rapidly and if deforming force removed, strain $\neq 0$

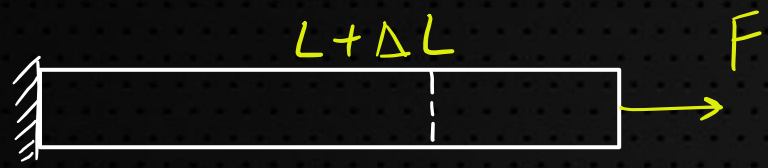
D Pt. Ultimate tensile strength

E $\rightarrow$ fracture pt.

NOTE: (a) Brittle if D & E are close and Ductile if D & E are far.

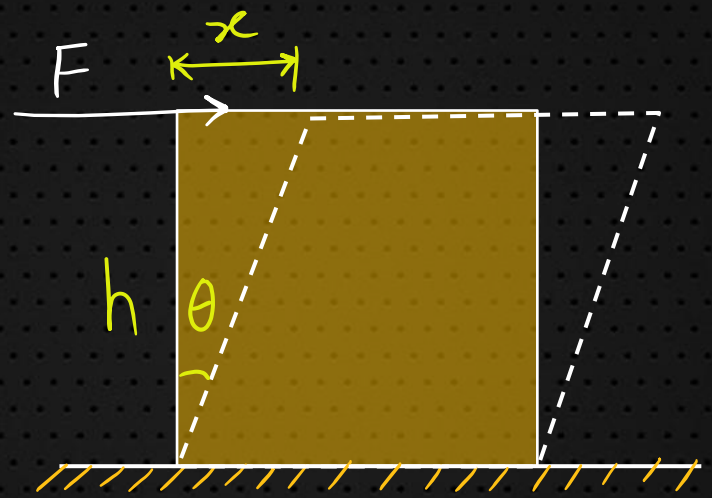
4. Modulus of Elasticity

Young's Modulus



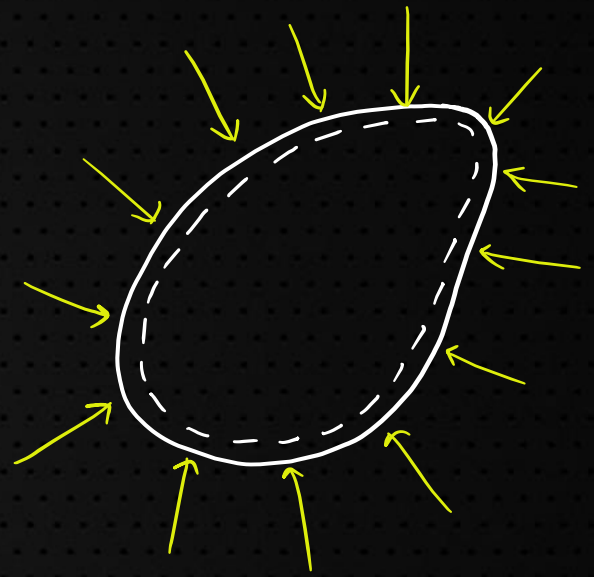
$$Y = \frac{F/A}{\Delta L/L}$$

Shear Modulus or Modulus of rigidity



$$G = \frac{F/A}{x/h}$$

Bulk Modulus

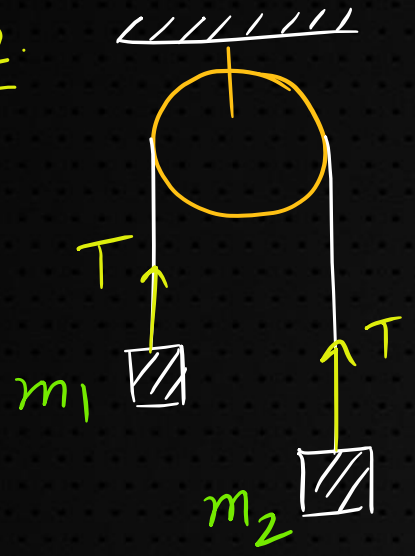


$$B = \frac{\Delta P}{-\Delta V/V} \quad \text{or} \quad -V\frac{dP}{dV}$$

Compressibility, $K = \frac{1}{B}$

... continued

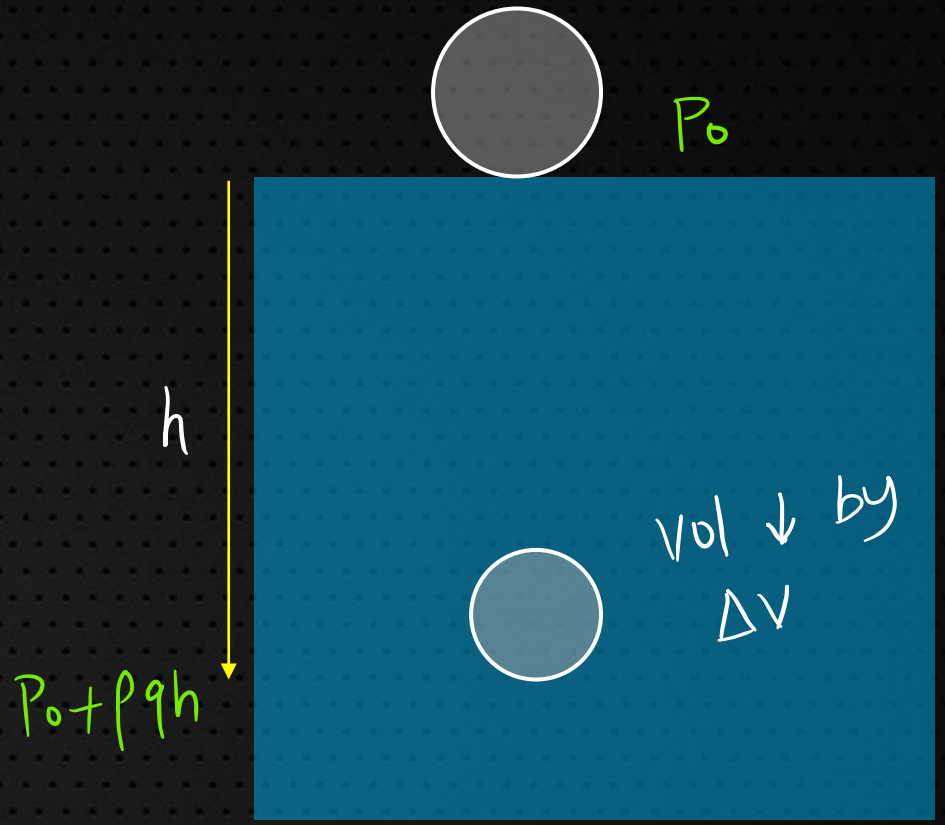
Ex 2.



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

$$T = \frac{2 m_1 m_2 g}{m_1 + m_2}$$

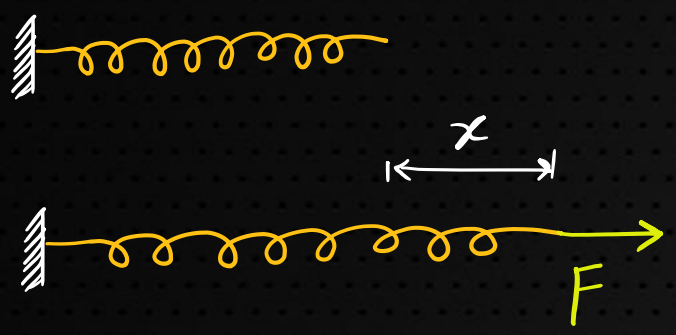
Ex 3.



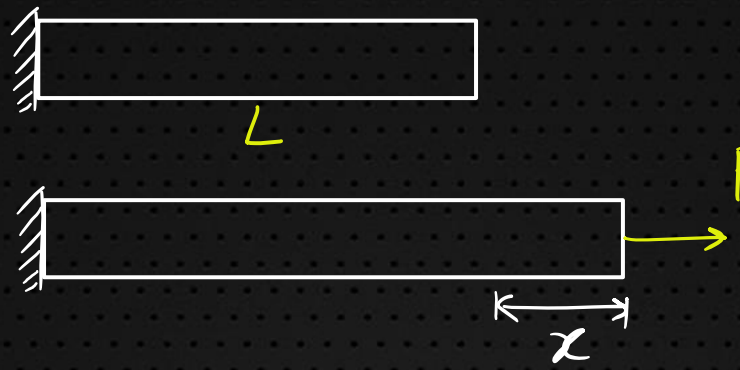
$$\Delta P = B \times \frac{\Delta V}{V} \quad \Rightarrow \Delta V = \frac{V}{B} \cdot \Delta P$$

$$\Rightarrow \Delta V = \frac{V}{B} \cdot \rho g h$$

5. Analogy with springs



$\equiv$



$$F = kx$$

$$\frac{F}{A} = Y \cdot \frac{x}{L} \Rightarrow F = \boxed{\frac{YA}{L}}\, x$$

equivalent force constant

$$k = \frac{YA}{L}$$

Ex 4.

$$k_1 = \frac{Y_1 A_1}{L_1}, \quad k_2 = \frac{Y_2 A_2}{L_2} \qquad \therefore \; k_{eq} = \frac{k_1 k_2}{k_1 + k_2}$$

$$\Rightarrow F = k_{eq} \cdot x$$

6. Potential Energy

(a) Energy density, $u = \frac{1}{2} \times \text{stress} \times \text{strain}$

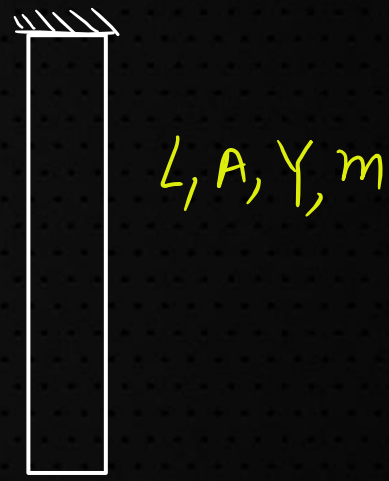
J/m^3

$\Rightarrow$ Energy, $U = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{Volume}$

Note: $U = \frac{1}{2} kx^2 = \frac{1}{2} \frac{YA}{L} \cdot x^2$

7. Elongation due to Self weight

$x = \frac{MgL}{2YA}$



8. Poisson ratio, σ

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

9. Relation among Y, G & B

(a) $$B = \frac{Y}{3(1-2\sigma)}$$

(b) $$G = \frac{Y}{2(1+\sigma)}$$

from (a) & (b) → (c) $$B = \frac{YG}{9G-3Y}$$

{ this Question asked in JEE 2021, Feb

EDUNITI

To Practice Questions - Solids & Fluids

2021 March	2021 July	2021 August	2020	Top PYQs
https://youtu.be/r06cZLwmtGE	https://youtu.be/lkwiZzOCTgE	https://youtu.be/q6z76sKhzn4	https://youtu.be/Mq1zjAfSLik	https://youtu.be/VAtNBDytnjc

EDUNITI

Revision Series Playlist Link https://bit.ly/3eBbib9

JEE Main PYQs Link https://bit.ly/2S54jzh *Chapter wise 2021, 2020, 2018*

GoldMine Link https://bit.ly/2VhOGFF