MADE EASY
CIVIL ENGINEERING
Strength of Material
BY-Rishi Sir

- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

- GATE
- ESE } PY

- IFS or IAS [last 5 yr

STRENGTH OF MATERIAL

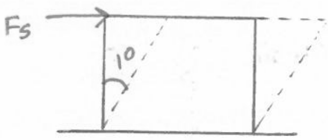
~ Rishi Sir ~

{01/09/25}

1.1) # Engineering Sciences.

- Solid Mechanics
- Fluid Mechanics
- Properties of Material.

Solid Mechanics



$t = 1\,sec \Rightarrow 1^\circ$

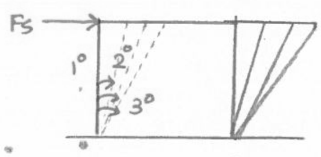
$t = 2\,sec \Rightarrow 1^\circ$

$t = 3\,sec \Rightarrow 1^\circ$

$\vdots$

$t = 10\,sec \Rightarrow 1^\circ$

Fluid Mechanics



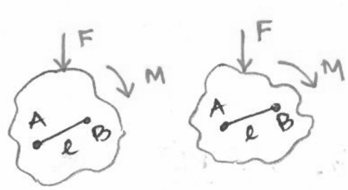
$t = 1\,sec = 1^\circ$

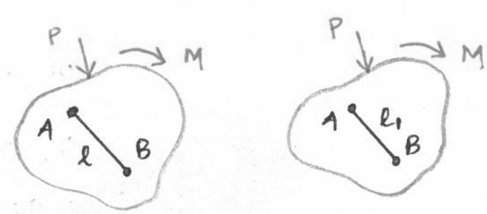
$t = 10\,sec = 2^\circ$

$t = 20\,sec = 3^\circ$

Solid Mechanics:

- Engineering Mechanics. {Study of Rigid Body}
- Strength of Material. / SOM / MOS / MODB {Study of Deformable Bodies}



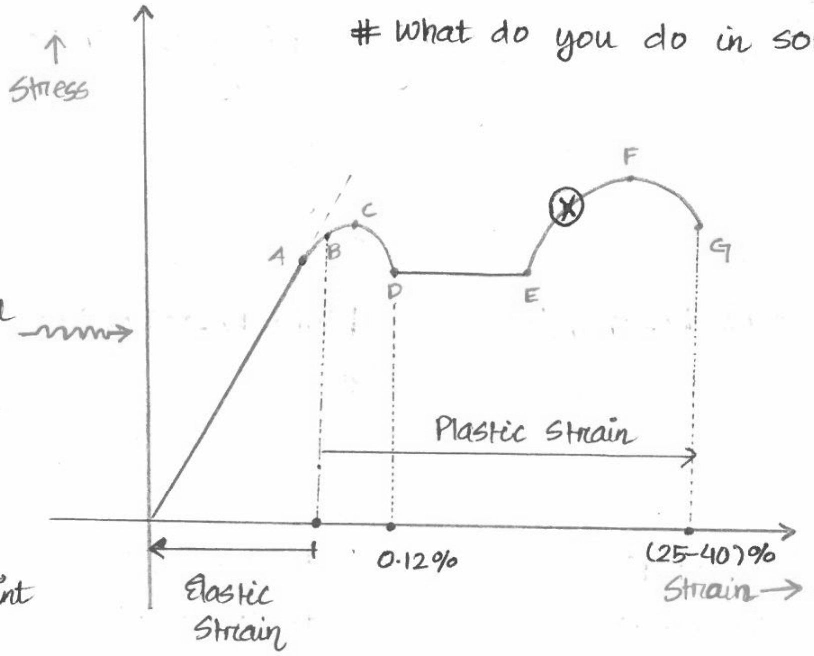


- $\text{Strain} = \dfrac{\text{Change in length}}{\text{Initial Length}} = \dfrac{L_f - L_i}{L_i} = \dfrac{l_1 - l}{l}$

- Deformation.
  - Elastic (✓)
  - Plastic. (×)

What do you do in SOM?

- Mild Steel ⇒ Universal Testing Machine.



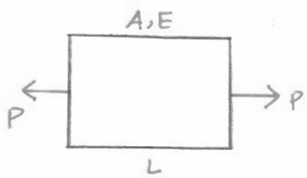
- A = Proportional limit Point

  B = Elastic limit Point

  G = Fracture Point.

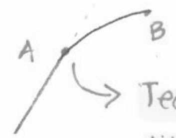
⇒ Mathematically A, B, C, D can be taken for calculation as a single point as strain is very less [Hooke's Law]

- Point ⊗



$\delta = \frac{PL}{AE}$ = SOM (×)

⇒



Techically Hooke's Law is valid till A.

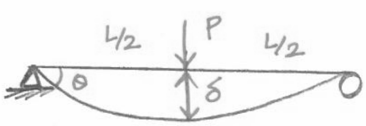
Hoffman's Eq^n is used beyond Elastic Limit $[\sigma_F = K \epsilon^m \epsilon^n]$

- Differential Equation for R.

$$\frac{1}{R} = \frac{d^2y/dx^2}{\left\{1+\left(\frac{dy}{dx}\right)^2\right\}^{3/2}}$$

Curvature for small deformation.

- Plastic Strain >>>> Elastic Strain



θ, δ → very small.

$$\delta = \frac{PL^3}{48EI}$$

$$\left\{\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}\right\}. \Rightarrow M = EI\frac{d^2y}{dx^2}$$

- For rubber

  θ', δ' ⇓ very large.

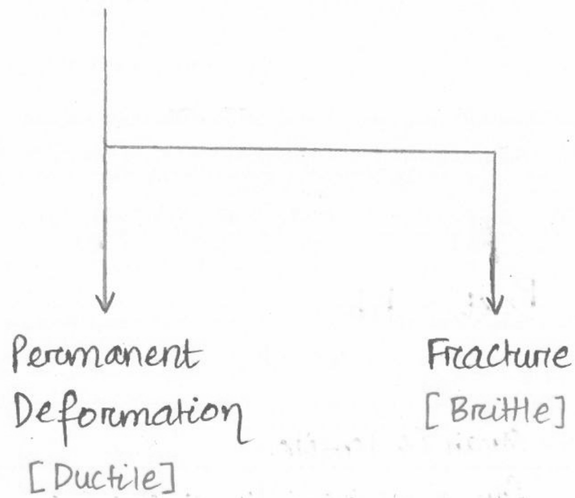
  so, $\delta' \neq \frac{PL^3}{48EI}$

  $\frac{1}{R} \neq d^2y/dx^2$

  ⇓

  FBD.

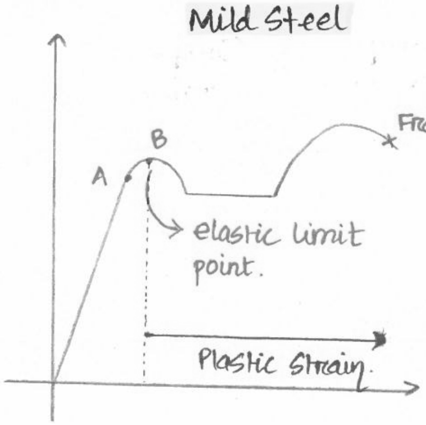
• Failure of Material



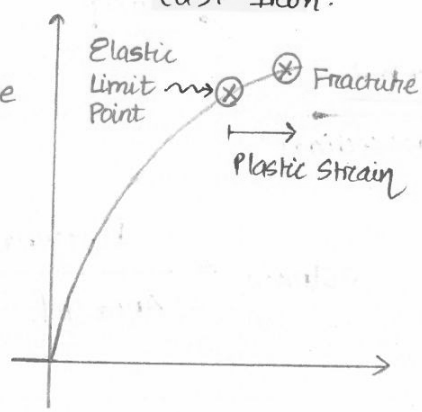
• Longer the x-axis greater is it's Ductile Property.

↳ Greater is its Plastic Deformation.

Mild Steel



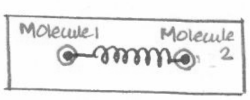
Cast Iron.



⇒ Dist. is very less b/w points hence can be treated as a st. line or curve.

$\Rightarrow \sigma_B = 250\ MPa$

* Difference b/w strength and Stress.

• 

Analogy : consider a spring b/w molecules.

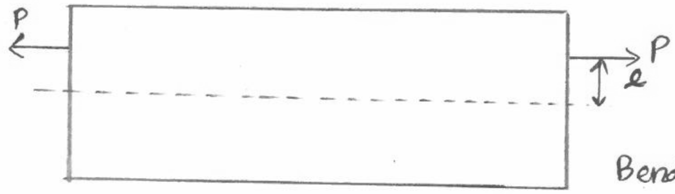
• Internal Resisting force against deformation is called stress.

• Stress at which body deforms permanently is its strength.

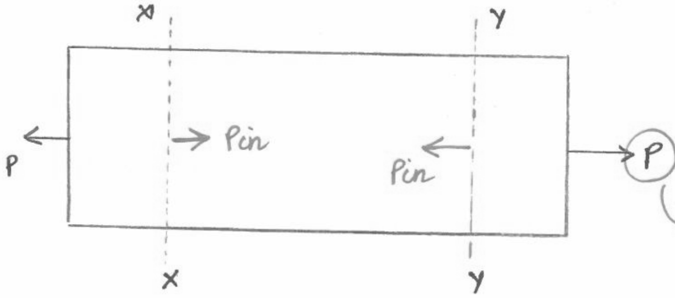
• x-axis → Strain is a fundame unit.

• Stress is a cause of Strain.

• the stress at which body deforms permanently is called strength of Material



Bending.



$P_{ext} = P_{in}$ {bound to happen else body will accelarale}

↳ Tensile.

↳ Strain is tensile.

for σ we have to cut the C/S.

$\sigma \Rightarrow$ tensile

[L+ΔL]

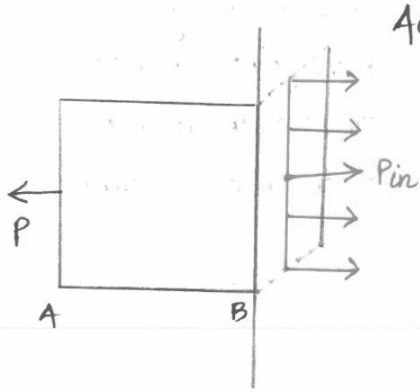
$$\epsilon = \text{Strain} = \frac{\Delta L}{L} = \frac{(L+\Delta L)-L}{L}$$

Hooke's law.

- Tensile Force $\Rightarrow$ Tensile Stress $\Rightarrow$ Tensile Strain {Visualise by cutting
- Comp. Force $\Rightarrow$ Comp. Stress $\Rightarrow$ Comp. Strain

$\sigma \quad \epsilon$

$$\sigma = E\epsilon \Rightarrow \sigma = \frac{P_{internal}}{A_{crosssection}}$$

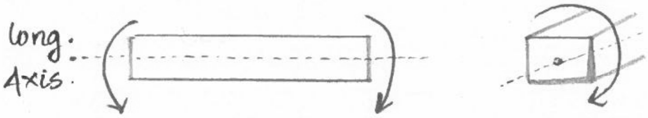


$$\sigma_{stress} = \frac{P_{internal}}{\text{Area of C/S}}$$

- Strain plotted in x-axis $\Rightarrow$ Hence a fundament unit
- Strain is cause of stress
- Strain is fundamental unit & stress is derived from. Strain
- Stress is internal resisting force offered by material against deformation.

Shear Force And Bending Moment Diagram.

- Diff b/w bending and twisting ?



[Right Hand Thumb Rule]

Bending => Transverse Moment.   Twisting ⇒ longitudinal Moment.

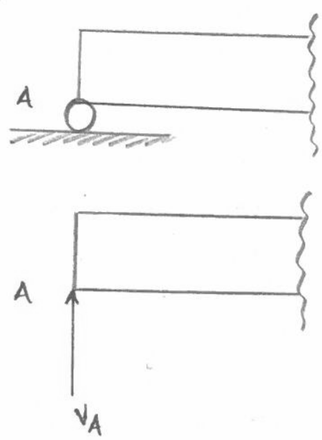
- SFD, BMD.

⇓

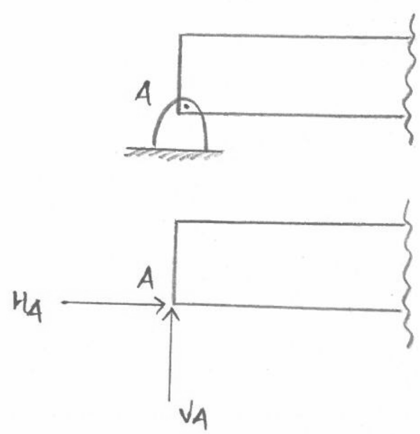
- Analysis of Critical Points / Locations to ensure safety and security of structure against failure.
- If critical points are safe rest points are also safe.

Types of Support

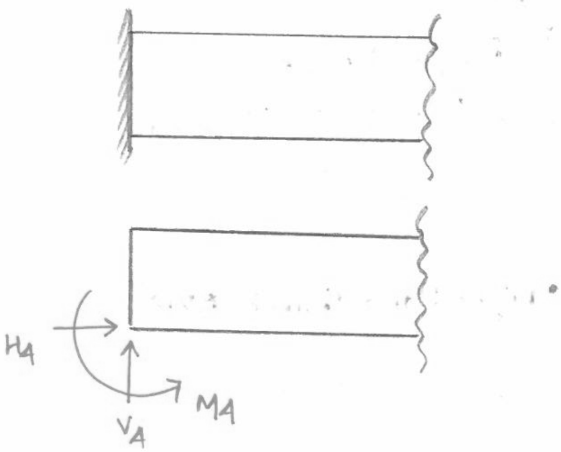
a) Roller Support / Free Support.



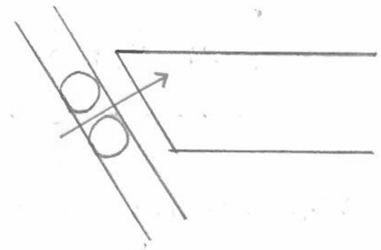
b) Hinge Support / Pinned



c) Fixed Support Reaction.

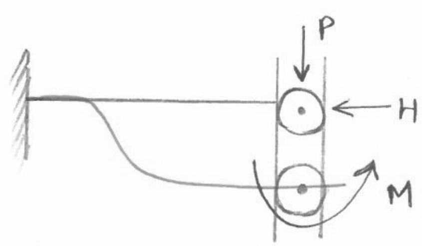


d) Inclined Roller Support

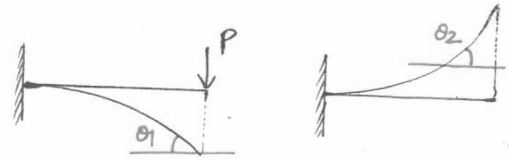


Eg: Bridge.

e) Guided Roller Support



{$\theta = 0°$}



$\theta_1 = \frac{PL^2}{2EI}$ $\qquad$ $\theta_2 = \frac{ML}{2EI}$

Types of Beam.

Simply Supported Beam.

{for short span}
{allows rotation}

Continous Beam

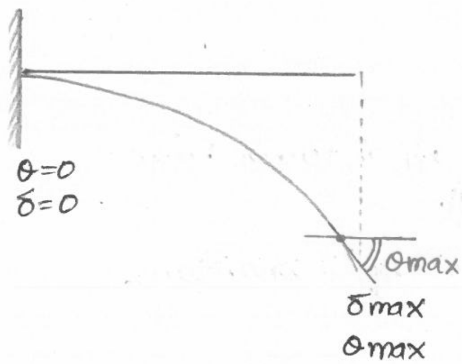
→ after support.

{for long span}

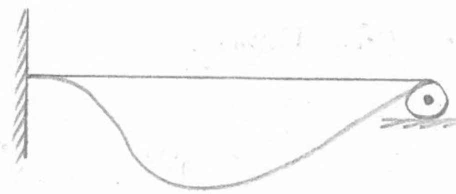
thermal stresses

Beam will slide away.

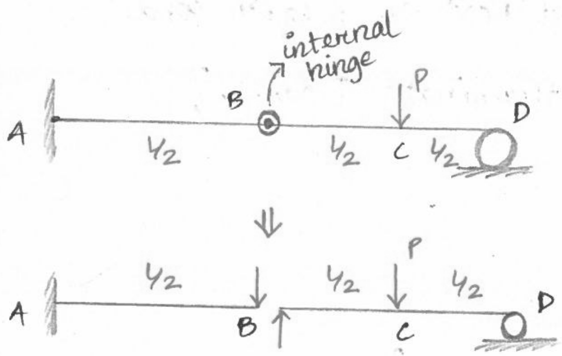
Cantilever Beam.



Propped Cantilever Beam.



Beam with internal Hinge



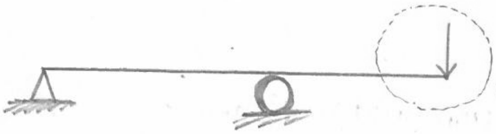
$$(B\cdot M)_{\text{internal hinge}} = 0$$

- Moment of left section is not transferred to right section. and vice versa.

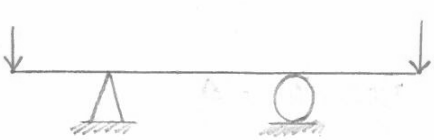
Fixed Beam.

- Most commonly used in structure.

Overhanging Beam.



→ -ve BM is formed.



Analysis of Beam.

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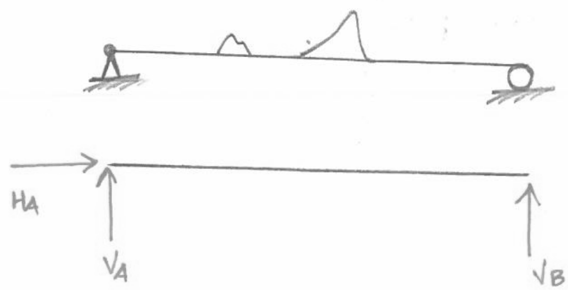
- for 2-Dim Beam.

a) $\Sigma F_x = 0$
b) $\Sigma F_y = 0$
c) $\Sigma M_z = 0$

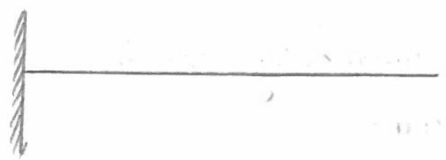
3 eqb^m equation

if beam has an internal hinge
$\Downarrow$
1 additional eqb^m condition.

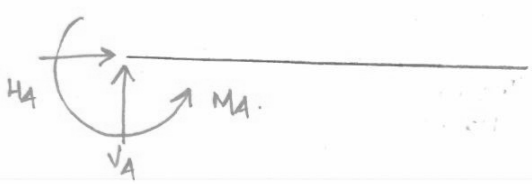
- Eg :

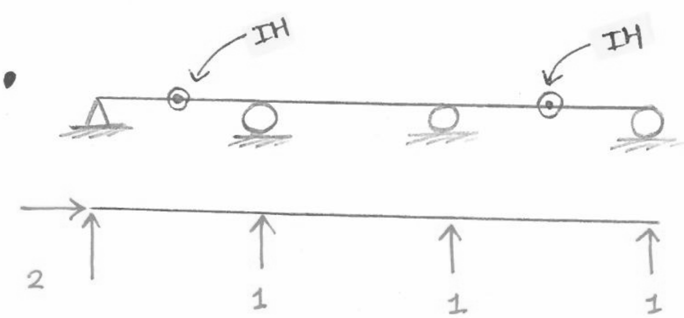


3 Support Rex^n $\Rightarrow$ 3 eqbm cond^n
{Determinate Beam.}

- 

{Determinate Beam.}

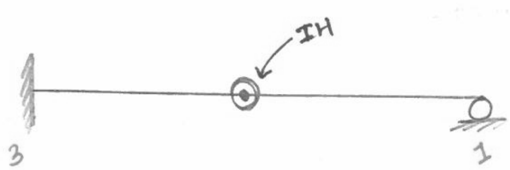


- 

Support Reaction = 2+1+1+1
= 5

Eqbm Equation = 3+2
= 5

{Determinate Beam}

- 

{Determinate Beam}

Support Reaction = 4
Eqbm Eq^n = 3+1 = 4