* STRENGTH OF MATERAILS [OR] SOLID MECHANICS

Solid mechanics is a Science which deals with behaviour of Solids under various loads [Static, dynamic], It deals with the Condition that stress is lesser than Strength [Safe working Condition]

→ properties of materials:-

1. STRENGTH:- Ability of a material to resist load [Tension, Compression & Shear], gradual load, Sudden load, Impact load, point load, udl, U.V.L] without under going deformation.

2. STIFFNESS:- load resisting Capacity of a material per unit deflection

$$\boxed{K = \frac{W}{y}}$$

→ Stiffness is a measure of young's modulus [E].

3. ELASTICITY:- Ability to regain dimensions when applied load is removed

4. PLASTICITY:- Ability to retain dimensions when applied load is removed

5. DUCTILITY:- Ability of a material to resist tensile load by undergoing permanent deformation without failure. material with large deformation at failure is ductile

$$\boxed{\text{Ductility factor} = \frac{\text{Strain at fracture or failure}}{\text{Strain at yield}}}$$

Best ductile materials are gold, Silver, Tungsten, platinum, & bronze.

$$D.F = \frac{\varepsilon_{\text{failure or ultimate}}}{\varepsilon_{\text{yield}}} \Rightarrow \text{for mild steel } \boxed{D.F = 250}$$

Ductile materials are deformed into wires.

6. MALLEABILITY:- property of material by which it Can be beaten & rolled into Sheets & plates is Called malleability.

Ability of material to resist Compressive load by undergoing permanent [plastic] deformation without failure.

→ All ductile materials are malleable

AE: plastic response of material to Compressive force is malleability.

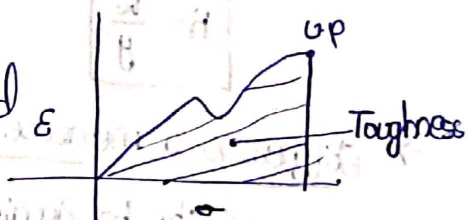
7. HARDNESS: Ability of a material to resist Scratches, Indentations, abrasion etc. This materials are difficult to machine [cutter] but Can be utilised for Cutting other materials.

Ex: MCS, H.C.S, H.S.S [High Speed steel], Cubic boron nitride, diamond

8. TOUGHNESS: 1. STRENGTH + DUCTILITY

Toughness modulus ← 2. Static test: Toughness is area under stress- strain Curve upto ultimate point

3. Dynamic test: Toughness is Energy absorbed & by material upto ultimate point



4. Resisting impact load without failure is Known as Impact Strength (or) Toughness

- Total energy absorbed by a body within elastic limit is Called "Resilience"
- Ability of material to absorb energy when it is deformed elastically & release energy upon unloading is "resilience".
- Max energy stored by a body at elastic limit is "proof resilience".
- Max energy stored by a body at elastic limit is Known as "modulus of"
- proof resilience ratio with unit Volume is Known as "modulus of"

10. BRITTLENESS: Ability to fail under impact loads.

Ex: glass, Cast iron etc.

11. CREEP: It depends on four parameters

1. Constant stress 2. strain 3. time 4. temperature

→ Change in length of material with time under Constant load is "Creep".

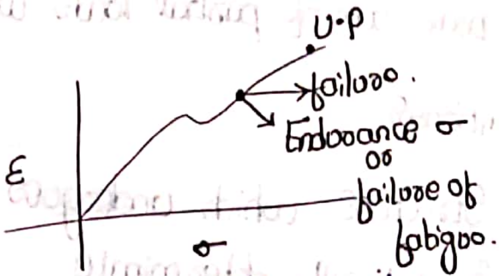
→ Continuous deformation with time under Sustained loading is "Creep".

→ slow and progressive deformation under Constant stress at high temperatures is Called Creep.

12. FATIGUE:- After no. of Cycle of reversal loads failure of material is "Fatigue failure".

→ A member which is Subjected to reversible tensile or Comp. σ may fail at a stress lower than σ ultimate of material. This property is fatigue of material.

• whenever a member is failured within ultimate stress at a point is due to "Endurance σ" or "fatigue failure".



⇒ ASSUMPTIONS IN STRENGTH OF MATERIALS:-

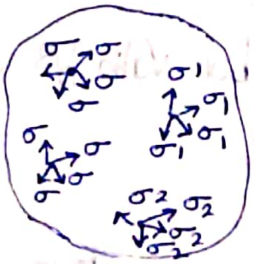
1. material is Continuous [no voids, gaps, defects]

2. material is homogeneous* & Isotropic***

→ Homogeneous = Same origin

A material having Identical properties through out it's volume in any one direction is Said to be "homogeneous".
Ex:- wood, Iron, Copper, Ag.
Ex:- for non homogeneous - Alloys.

→ ISOTROPIC = Same directionality



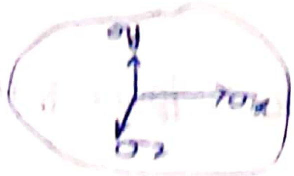
⇒ material which exhibit Same elastic properties in all directions at one point is Called isotropic.

→ Elastic Constants are identical in all directions at one point.

Ex: Iron, Copper, Silver, glass, steel, brass, etc.

• Wood is "anisotropic" (or) "non isotropic" being [layered, elongated grains (or) fibrous materials are anisotropic].

→ ORTHOTROPIC: properties in ⊥er direction at a point are not Same



have $\sigma_x / \sigma_y / \sigma_z$

3. Weight of material is neglected

④ *** ***

SUPER POSITION PRINCIPLE IS VALID:-

Algebraic Sum of partial loads will be equal to Net load

Conditions:-

1. Structure which undergoes ——— S.P is Valid.

(i) Statically determinate (ii) Indeterminate

(iii) Structure obeys Hookes law (iv) Elastic deformation

2. SP is valid when materials are ———

(i) elastic (ii) linear elastic (iii) metals (iv) homogeneous.

3. Structure Subjected to ——— S.P is Valid

(i) Small deformation (ii) large deformation

4. Sp is Valid for material Subjected to Small slopes & deflections [negligible]

5. Sp is Valid when deflections are linear functions of applied forces.

6. Sp is not Valid for Impact loads but Valid for gradual load.

⑤ st. Venant's principle is Valid :-

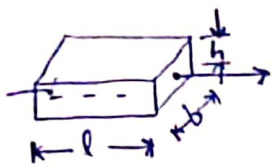
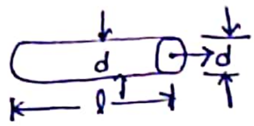
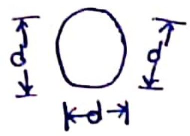
Sudden change in any dimension Causes stress Concentration & Can be prevented by using fillets or "chamfers". [PL to Converted to U.D.L]

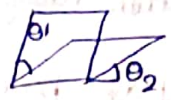
* The elastic limit & youngs modulus decreases with increase in temp
* yield point is not effected by temp.
* Decreasing order of ductility
wrought iron > mild steel > Cast iron > pig iron.
* for a beam carrying udl the strain energy will be maximum in case of Cantilever beam
* $\alpha_{brass} > \alpha_{steel}$ & $\alpha_{Cu} > \alpha_{steel}$
* $\alpha_{Al} > \alpha_{brass} > \alpha_{copper} > \alpha_{mild\ steel}$

=> STRAIN:

Strain

- $\left[\frac{\Delta \text{dimen}}{\text{dime}}\right]$ Normal
  - e_{linear}
  - $e_{lateral}$
  - e_{vol}
- shear strain [change in right angle]

	e_{linear}	$e_{lateral}$	e_{vol}
	$\frac{\Delta L}{L}$	$\frac{\Delta b}{b}, \frac{\Delta h}{h}$	$\frac{\Delta l}{L}+\frac{\Delta b}{b}+\frac{\Delta h}{h}$
	$\frac{\Delta L}{L}$	$\frac{\Delta d}{d}, \frac{\Delta d}{d}$	$\frac{\Delta L}{L}+2\frac{\Delta d}{d}$
	$\frac{\Delta d}{d}$	$\frac{\Delta d}{d}, \frac{\Delta d}{d}$	$3e$



$\phi = \theta_1+\theta_2$

Units - Radians

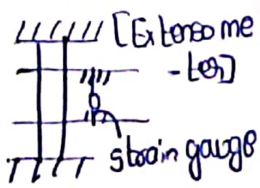
units: dimensionless

1. unit of vol. strain = No units
2. parameter which relates Simple stress & strain is Young's modulus
3. Intensity of unit stress Causing unit strain is "E"

=> STRESS - STRAIN CURVE:

1. Tension test
2. Universal testing machine [strain oriented machine]

**
* Gauge length: It is the distance over in which change in length is measured. it is equals $\boxed{5.64\sqrt{A_0}}$ where A_0 is the original CS area

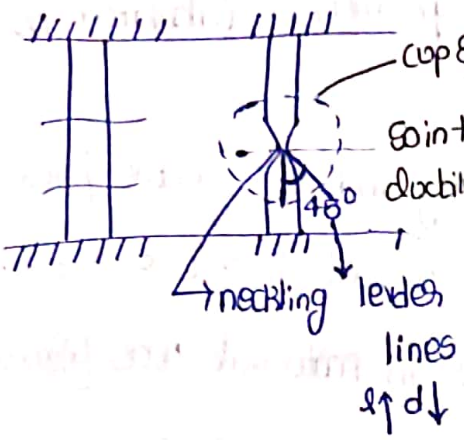


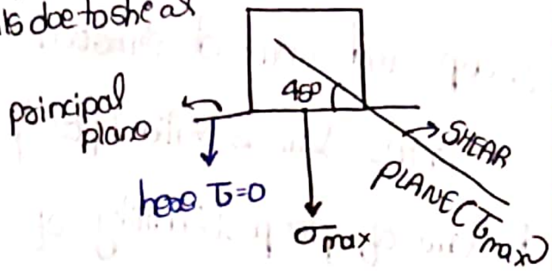
Note:

depend	Independent
L_{gauge}	L_{total}
$A_{original}$	Shape of CS

Scanned with CamScanner

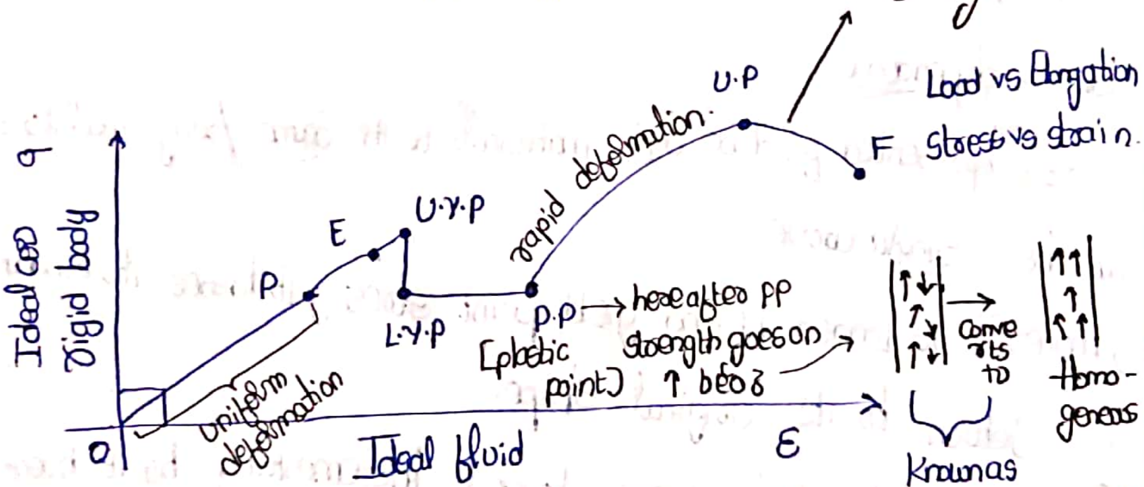
3. Specimen:- It should be ductile material bcoz → Strong in tension
→ moderate in Comp
→ Weak in shear





⇒ % of Elongation $= \left[\frac{L_F - L_0}{L_0}\right] \times 100$

⇒ % of Reduction of area $= \left[\frac{A_0 - A_F}{A_0}\right] \times 100$

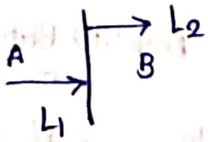


- permanent deformation starts from yield point
- Temporary " Ends at Elastic limit.

O – P → linear elastic

P.E → non- linear elastic

E – U.Y.P → Coincident ——— ex:



U.Y.P — L.Y.P → Yielding

L.Y.P — P.P → plastic zone

PP —U.P → strain hardening ***

U.P — Failure → strain Softening [Necking].

* The actual stress at fracture is more than Nominal σ at fracture

NOTES

1) Working stress for mild steel specimen is calculated using F.O.S on yield point stress.

2) Cup and cone deformation usually indicates <u>ductile failure</u>.

3) Hooke's law is valid upto proportionality limit [$\sigma \propto \varepsilon$]

4) law of proportionality of σ & ε in material was formulated by <u>Hook robert</u>

5) *** Ratio of strain at fracture to that of yield for mild steel is <u>250</u>

6) For most metals σ-ε relation under elastic limit follows <u>Linear dependence</u>

7) σ-ε curve represented for two diff materials with same Young's modulus will be <u>Single curve</u>

8) material is loaded beyond yield point stress, it losses its tendency to return to its original shape.

9) A thin mild steel wire is loaded incrementally till it breaks, Extension notated with increase in load will be increasing uniformly first then increases rapidly.

10) NOTCHED BAR TEST

done to know <u>Impact strength</u>

Ductile $\xrightarrow{\text{Notch}}$ Brittle

Notch ↓ STRESS CONCENTRATION.

IZOD TEST

11) <u>Toughness modulus</u> of material is area of stress - strain curve upto failure.

17/05/19

12) $FoS)_{material} = \frac{\sigma_{ultimate}}{\sigma_{working}}$

13) Sequences-

proportionality Limit → E.L → Y.L → Failure.

14) A mild steel specimen is tested under tension a Continous graph load & Extension is obtained. A load at which there is Considerable extension without increase in load is lower yield point

$FoS)_{Ductile} = \frac{\text{lower yield stress}}{\text{Working stress or permissible } \sigma}$

15) Tension Coefficient = $\frac{\text{Force}}{\text{length}}$

16) Tenacity = Tensile strength.

17) Ratio of maximum load to original C.S area of the test piece is ultimate stress.

18) Residual Stress is deformation stress.

19) when the change in length takes place, is the strain is linear [load is in direction of length]

20) $\sigma_{working} < \sigma_{yield(deformation)}$ [Safe Condition]

21) permanent set is irrecoverable deformation in body.

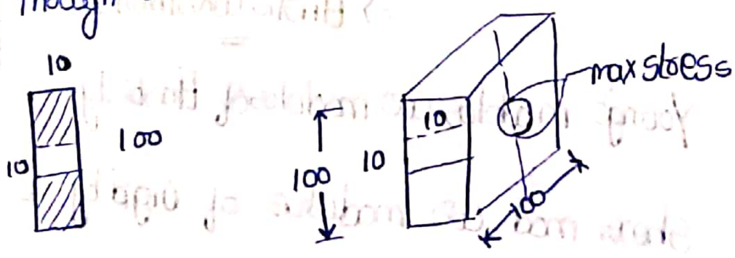
22) A 100mm wide, 10 mm thick, is having hole 10mm, F = 9KN then Max σ on a Section passing through Centre of hole will be ——

sol $A_1 - A_2$

$\Rightarrow 100 \times 10 - 10 \times 10$

$A = 900$

$\therefore \sigma = \frac{900}{9} = 10MPa$



23) If Carbon Content increases then ductility decreases. i.e.

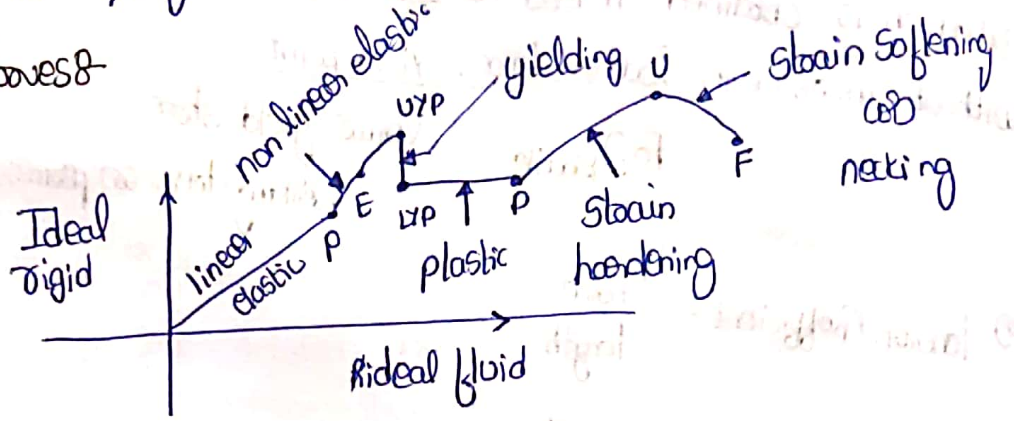
24) High Yield strength increases material less ductile.

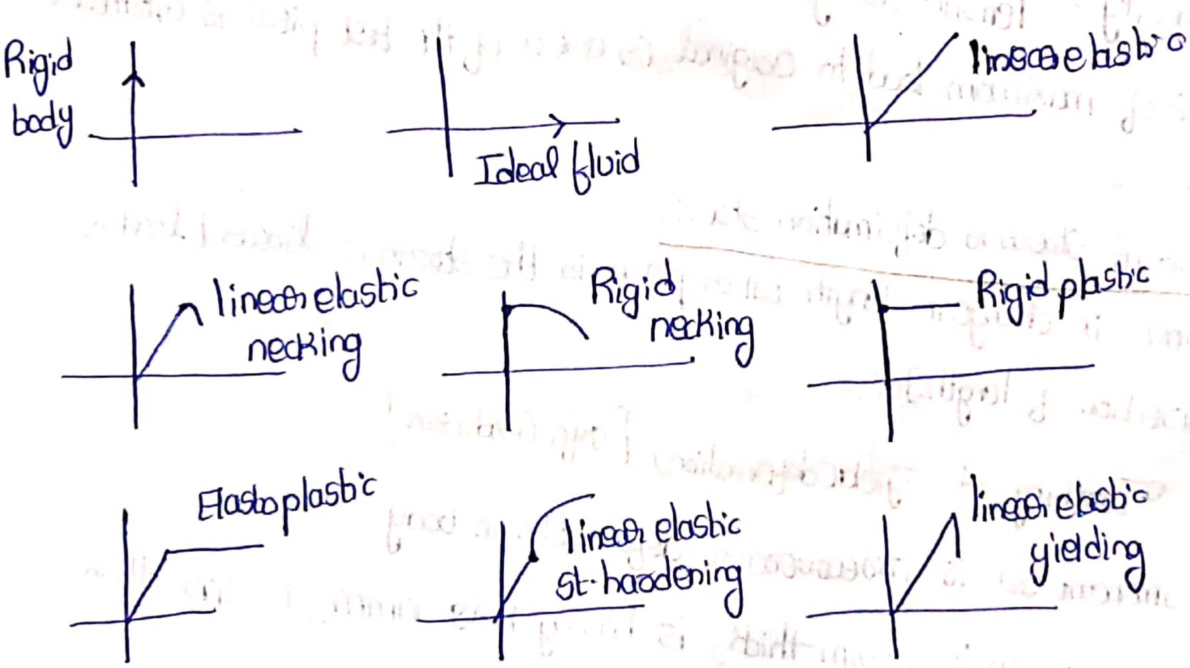
yield point ↑ permanent deformation ↑ Ductility ↓

26) strain hardening of material is increase in stress with strain beyond the yield stress

27) when mild steel is stretched upto strain hardening state & load is released recovery path of stress strain curve will have slope equal to Young's modulus.

=> Types of Curves:-





=> ELASTIC CONSTANTS

1. Young's modulus (or) modulus of Elasticity = $\frac{\text{Linear } \sigma}{\text{linear } \varepsilon} = E$

2. Shear mod (or) modulus of rigidity = $\frac{\text{Shear } \sigma}{\text{Shear } \varepsilon}$ = G, N or G

3. Bulk mod (or) dilation Constant = $\frac{\text{Direct } \sigma}{\text{Volumetric strain}}$ = K.

Direct stress is also known as vol stress

	$\underline{\underline{E}}$
Diamond	1200 GPa
steel	200
Cu	120
Brass [G-I]	100 → Bronze 80
Aluminium	70 [seventy].
Timber [Rubber]	10

Q) Max Elasticity is in $\underline{[b]}$

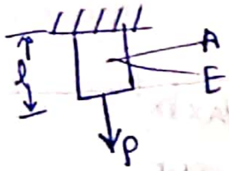
a) rubber b) diamond c) steel d) Cu

⇒ NOTE :-

1) For isotropic materials → $\boxed{E > K > G}$ [i.e only for brittle i.e $\mu < 0.25$]

⇒ RIGIDITY :- [G]

① Axial rigidity :- [AE] i.e $\Delta l \downarrow$ If $AE \uparrow$ i.e $\Delta l \propto \frac{1}{AE}$.



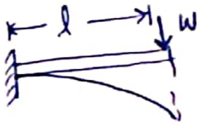
$E = \frac{\sigma}{\varepsilon}$

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

$$\boxed{\Delta l = \frac{Pl}{AE}}$$

Units - N

② Flexural rigidity :- [EI].



Here $EI \uparrow$ $y \downarrow$

Units :- [N-mm²].

$y = \frac{Wl^3}{3EI}$

③ Torsional rigidity :- [GJ]

Here $GJ \uparrow$ $\theta \downarrow$

$\frac{T}{\theta} = \frac{GJ}{l}$

units :- N-mm²

⇒ POISSON'S RATIO :- [μ or $\frac{1}{m}$]

Ratio of lateral strain to linear strain with sign changed

$$\mu = \frac{\varepsilon_{lateral}}{\varepsilon_{linear}}$$

1. μ = -ve for genetic materials.

2. $\mu = 0$ for Cork.

3. μ = +ve for all engg materials

4. $\mu = 0.5$ for Elastic incompressible material [$\delta v = 0$ i.e rubber, fluids, wax, mercury etc]

$\downarrow$ indicates Constant volume.

5. μ for isotropic material $= 0.25$

6. μ for hard & brittle material < 0.25

7. μ for Soft materials > 0.25

8. μ for steel $= 0.27$ to 0.3.

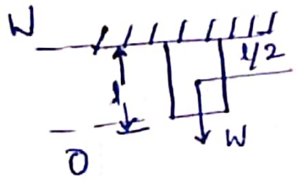
9. μ for Cast iron = but $\mu < 0.25$ here $0.27 \cong 0.25$.

(a) 0.27 (b) 0.31 (c) 0.33 (d) 0.36

10. μ of Aluminium $= 0.33$

11. μ of Concrete $= 0.15$

→ Self weight deformation:-



WKT $\Delta l = \frac{PL}{AE} = \frac{W}{2}\frac{L}{AE}$

$= \frac{\gamma V l}{2AE} = \frac{\gamma A \times l \times l}{2AE}$

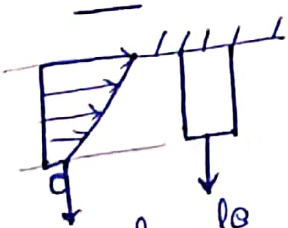
$\boxed{\Delta l = \frac{Pl}{2AE}}$ or $\boxed{\Delta l = \frac{\gamma L^2}{2E}}$

* Independent on area
* dependent on l^2

→ Note:- $\Delta l_{Cone} = \frac{1}{3} \Delta l_{cylinder}$

$\Delta l_{Cone} = \frac{1}{3} \times \frac{\gamma L^2}{2E} = \frac{\gamma L^2}{6E}$ //.

⇒ SELF WEIGHT σ [IN PRISMATIC BAR]



$\sigma = \frac{W}{A} = \frac{\gamma A l}{A}$

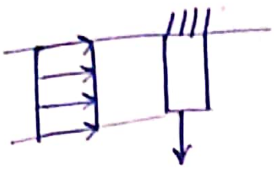
$\boxed{\sigma = \gamma l^1}$

* Independent on area
* dependent on L^1

NOTE:-

Indepen"	dependen"	
A	l^2	→ Self weight Δl
A	l^1	→ Self weight σ

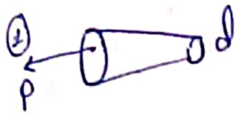
⇒ WEIGHT LESS PRISMATIC BAR:-

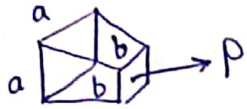


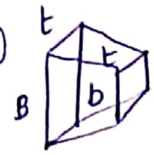
P=W

$$\sigma = \frac{P}{A} = \frac{W}{A}.$$

⇒ Tapering bars:-

①  ⇒ $\Delta l = \frac{4Pl}{(\pi D d)E}$

②  ⇒ $\Delta l = \frac{Pl}{ab\,E}$

③  ⇒ $\Delta l = \frac{PL}{(B-b)tE} \log_e\left[\frac{B}{b}\right]$.

⇒ Important points:-

1) Independent no. of elastic Constants for

① Isotropic → 2 [**] [E, G / μ] or [K, μ] or [G, μ]

② Orthotropic → 9

③ Anisotropic → 21

2) For non-dilatent [INCOMPRESSIBLE] $\mu_{max} = 0.5$

3) $\mu = 0.25$, $\frac{E}{G} = ?$

Sol: $\frac{E}{G} = 2[1+\mu]$ → $\frac{E}{G} = 2[1.25]$ ⇒ $\frac{E}{G} = 2.50$

⇒ $\frac{E}{G} = 2.5$ //.

⇒ RELATIONSHIP:-

① ⇒ $E = 2G[1+\mu]$

② $E = 3K[1-2\mu]$

③ $E = \frac{9KG}{3K+G}$

④ $\mu = \frac{3K-2G}{6K+2G}$

4) If $K=G$ then $\mu =$ ——

sol $\mu = \dfrac{3K-2C}{6K+2C} = \dfrac{1}{8}$ ||.

5) Relation b/w 3 Elastic Constants $E = \dfrac{9KG}{3K+G}$

Q) $E=2G$ then $K =$ ——

sol $2G = \dfrac{3KG}{3K+G} \Rightarrow 3K+G = \dfrac{3K}{2} \Rightarrow G = \dfrac{3K-6K}{2} \Rightarrow \}$ wrong

WKT $E=2G[1+\cancel{\mu}^{\,0}]$ so $E=2G$ then $\mu=0$

Here WKT $E=3K[1-2\mu] \Rightarrow \boxed{K=\dfrac{E}{3}}$

5) $G=80$, $K=140$, $\mu=?$

sol $\mu = \dfrac{3K-2C}{6K+2C} = \dfrac{420-160}{840+160} = \dfrac{260}{1000} = 0.26$ ||. $\begin{array}{r}420\\ -160\\ \hline 260\end{array}$

⇒ THERMAL STRESSES:-

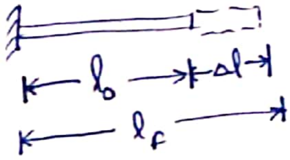
1. Thermal or temp stresses are secondary stresses

2. Coefficient of thermal expansion:-

$$\varepsilon = \alpha\,(t^{\circ}C)$$

$$\varepsilon = \alpha\,(\Delta T)$$

$$\alpha = \frac{\varepsilon}{\Delta T} = \frac{\Delta(\text{Dimension})}{(\text{original dimension}) \times (\Delta T)}$$

→ 

$$\boxed{\frac{l_f - l_0}{l_0(\Delta T)} = \alpha}$$

$$l_f - l_0 = l_0\,\alpha(\Delta T)$$

$$l_F = l_0 + l_0\,\alpha(\Delta T)$$

$$\boxed{l_F = l_0[1+\alpha(\Delta T)]}$$

$$l_F = l_0[1+\varepsilon]$$

3. THERMAL STRESSES :-

$$\varepsilon = \alpha(\Delta T)$$

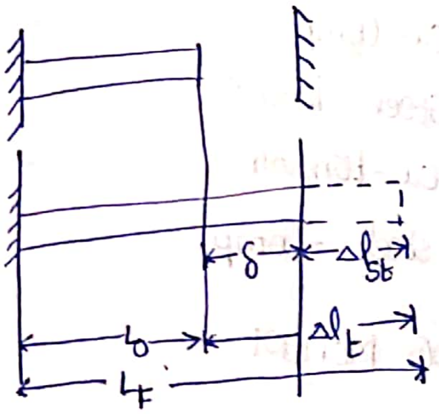
$$\frac{\sigma}{E} = \alpha(\Delta T)$$

$$\boxed{\sigma = E\alpha(\Delta T)}$$

4.* A beam is heated & Expands freely [No stress]

5.  Temp ↑ → Comp σ, Temp ↓ → Ten σ } Thermal σ's

⇒ Thermal σ's with yield Supports :-



$$\Delta l_{st} = \Delta l_t - \Delta$$

$$\Delta l_{st} = L_0\alpha(\Delta T) - \Delta$$

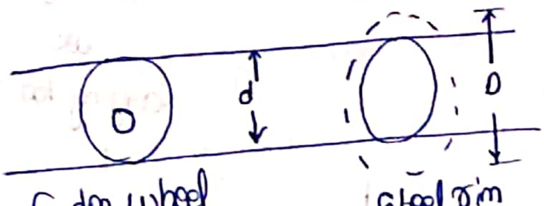
$$\frac{\Delta l_{st}}{L} = \frac{L\alpha(\Delta T)}{L} - \frac{\Delta}{l_0}$$

$$\boxed{\varepsilon = \alpha(\Delta T) - \frac{\Delta}{l_0}}$$

$$\frac{\sigma}{E} = \alpha(\Delta T - \frac{\Delta}{l})$$

$$\boxed{\sigma = E\left[\alpha(\Delta T) - \frac{\Delta}{l_0}\right]}$$

⇒ HOOP STRESS (OR) CIRCUMFERENTIAL STRESS :-



Steel rim allowed to cool from D to d over wheel then

* Wooden wheel → Comp
* Steel rim → Tension.

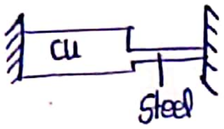
$$\varepsilon = \frac{\pi D - \pi d}{\pi d} \Rightarrow \alpha(\Delta T) = \frac{D-d}{d}$$

$$\boxed{\Delta T = \frac{1}{\alpha}\left[\frac{D-d}{d}\right]}$$

$$\Rightarrow \frac{\sigma}{E} = \frac{D-d}{d}$$

$$\boxed{\sigma = E\left[\frac{D-d}{d}\right]}$$

$\Rightarrow$ COMPOSITE MEMBERS :- $[\alpha_{cu} > \alpha_{steel}]$ & $\alpha_{Brass} > \alpha_{steel}$

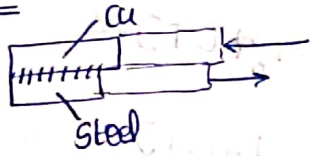
① 

SERIES

$t\uparrow \Rightarrow$ Both are in Comp

$t\downarrow \Rightarrow$ Both are in tension

② PARALLEL :-

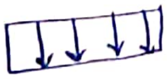


$t\uparrow$ — Cu – Comp, Steel – Tension

$t\downarrow$ — Cu – tension, steel – Comp

* SHEAR FORCE & BENDING MOMENT

Loads
- point
  - ↓ Concentrated load
- distributed
  - U.D.L
    - or Rectangular load

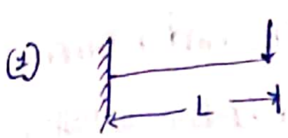


  - Non uniformly or Varying load
    - uniformly varying loads or Triangular loads

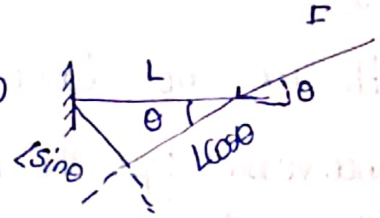
w

    - Non-Uniform or fluctuating loads

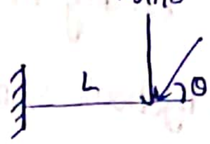
Moment = Force × arm of moment

(1)


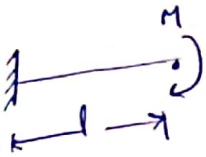
$M)_0 = F \times L$

(2)


$M_0) FLSin\theta$

(3)


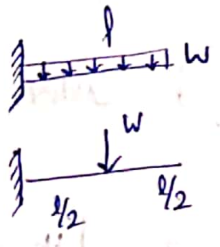
$M_0) FSin\theta \cdot L$

(4)


moment of at a point is Concentrated point

$M_0) = M_{//}$.

→ U.D.L TO P.L :-



S.F = Area of the loading diagram

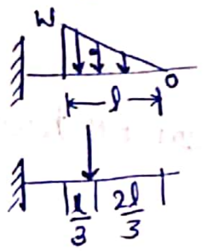
point of application = Centroid of area

$w \times l$ = Area) centroid = $l/2$

So, Area = wl

Centroid = $l/2$.

→ U.V.L To P.L :-



Area = $\frac{1}{2} \times b \times h = \frac{1}{2} \times w \times l$

Centroid from base $= \frac{L}{3}$. [ie from w].

→ Shear force & Sign Convention :-

Algebraic Sum of all the forces from right to left [vice Versa] upto the Section is Called shear force at that Section.

→ Bending moment & Sign Convention:

Algebraic Sum of all the moments Caused by forces and moments from right to left [Vice versa] upto the Considered Section is Called Bending moment at that Section.

↓ ← Hogging [-ve]   ↑ ← Sagging [+ve]

⇒ features of SFD & BMD:

1) If there is a point load at a point acting on a beam, at a Section SF changes Suddenly & BM has no change.

2) If there is no load b/w two points S.F remains Constant [Horizontal line] and bending moment changes linearly [straight inclined line]

3) If there is u.d.l b/w two points S.F changes linearly & BM changes parabolically.

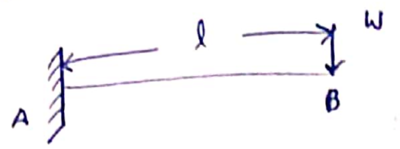
4) If there is u.v.l b/w two points S.F changes parabolically and B.M changes Cubical parabolla.

5) If there is Concentrated moment at a Section then SF has no change but BM changes Suddenly.

	S.F.D	B.M.D
↓	Suddenly	no change
no load	—	/ or \
U.D.L ←	/ or \	P
	no change	Sudden change
	P	Cubical parabola.

① CANTILEVER :-

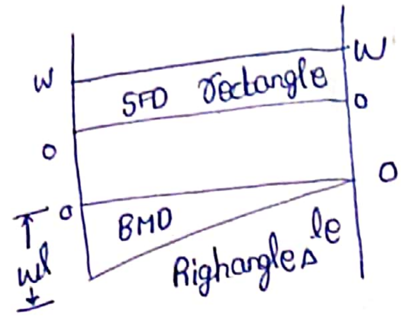
(i) Cantilever beam is Subjected to point load.



$SF)_B = +W$

$SF)_A = 0$

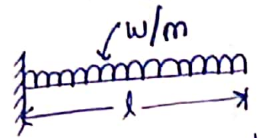
$SF)_{\text{Just before A}} = W$



$BM)_B = 0$

$BM)_A = w \times l$

(ii) Cantilever Subjected to U.D.L.

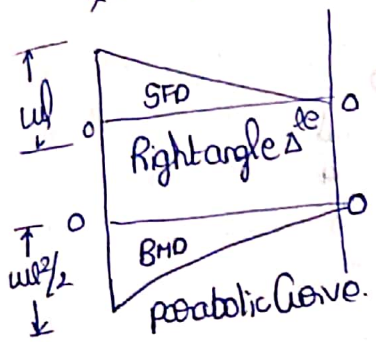


$SF)_B = 0$

$SF)_x = w \times x$

$SF)_A = 0$

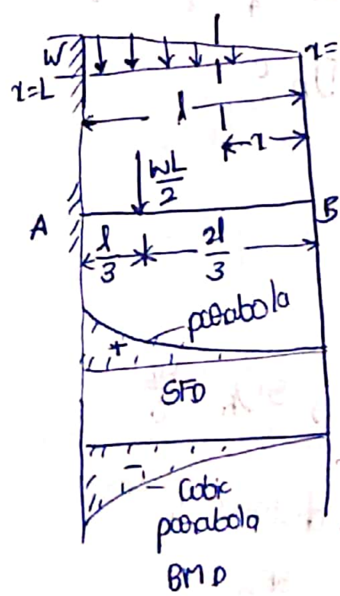
$SF)_{\text{Just before A}} = w \times l$



$BM)_B = 0$

$BM)_A = \frac{wl^2}{2}$

(iii) Cantilever Subjected to U.V.L



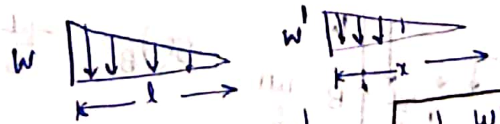
$SF)_B = 0$

$SF)_A = \frac{WL}{2}$

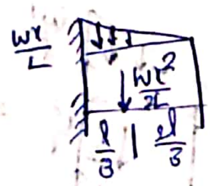
$BM)_B = 0$

$BM)_A = \frac{-WL^2}{6}$

Now Considering x distance from free end



$\frac{W}{l} = \frac{W'}{x} \Rightarrow \boxed{W' = \frac{Wx}{L}}$

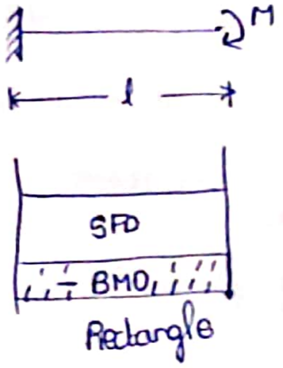


Area of loaded diagram

$= \frac{1}{2} \times x \times \frac{Wx}{L} = \frac{Wx^2}{2L}$

$\boxed{SF = \frac{Wx^2}{2L}}$ $\boxed{BM = -\frac{Wx^3}{6L}}$

(iv) Cantilever Subjected to moment :-



$SF)_B = 0$

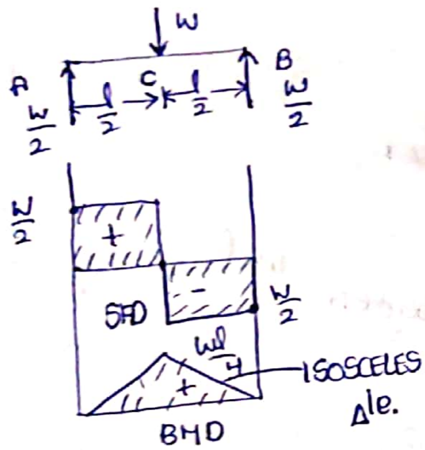
$SF)_A = 0$

$BM)_B = -M$

$BM)_A = -M$.

② SS BEAM :-

1. SS beam Subjected to point load at Center



$SF)_B = -\frac{W}{2}$

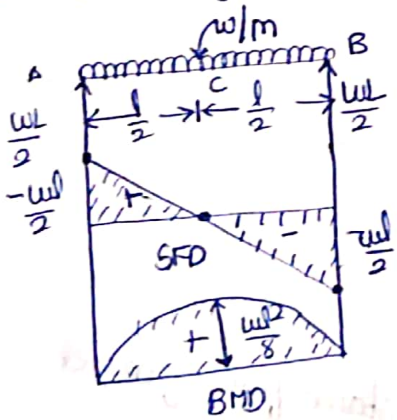
$SF)_C = -\frac{W}{2} + W = \frac{W}{2}$

$SF)_A = \frac{W}{2}$

$BM)_B = BM)_A = 0$

$BM_C) = \frac{W}{2} \times \frac{l}{2} = \frac{Wl}{4}$

2. SS beam Subjected to udL

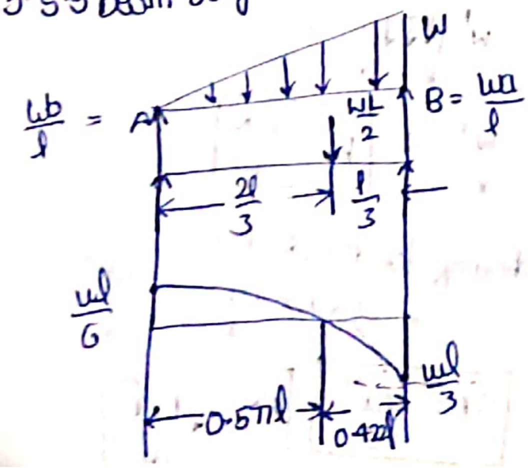


$SF)_B = -\frac{WL}{2}$, $BM)_B = 0$

$SF)_C = 0$ $BM)_C = \frac{WL^2}{4} - \frac{WL^2}{8} = \frac{WL^2}{8}$

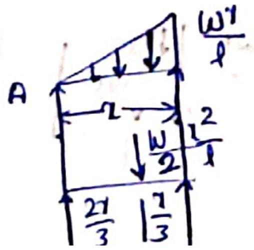
$SF)_A = \frac{WL}{2}$ $BM)_A = 0$.

3. SS beam Subjected to UVL



$SF)_B = -\frac{WL}{3}$, $SF)_A = \frac{WL}{6}$

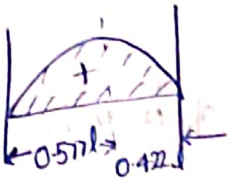
Considering Certain distance 'x', SF = 0



then $SF)_{xx}$

$= \frac{Wl}{6} - \frac{Wx^2}{2L} = 0$

$\boxed{x = \frac{L}{\sqrt{3}}}$ from A



$$\text{Now } BM)_{xx} = \frac{wl}{6}(x) - \frac{wx^2}{2L}\left(\frac{x}{3}\right)$$

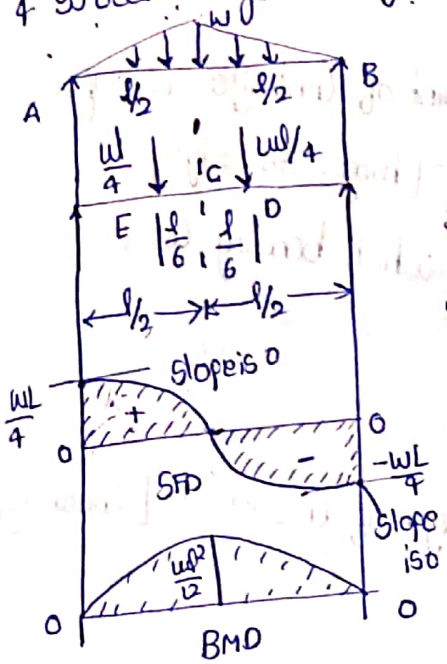
$$= \frac{wl}{6}\left[\frac{L}{\sqrt{3}}\right] - \left[\frac{wx^3}{6L}\right]$$

$$= \frac{WL}{6}\left(\frac{L}{\sqrt{3}}\right) - \frac{w}{6L}\left(\frac{L^3}{\sqrt{3}\times\sqrt{3}\times\sqrt{3}}\right)$$

$$= \frac{WL^2}{6\sqrt{3}}\left[1 - \frac{1}{3}\right]$$

$$\boxed{BM)_{max} = \frac{WL^2}{9\sqrt{3}} = 0.064WL^2 \text{ from A}}$$

4. SS beam Subjected Symmetric U.V.L



Here Total load $= \frac{wl}{4}\times 2 = \frac{wl}{2}$

$R_A = R_B = \frac{wl}{4}$

$SF)_B = -\frac{wl}{4}$, $SF)_D = -\frac{wl}{4} + \frac{wl}{4} = 0$

$SF)_E$ = Not necessary $SF)_A = \frac{WL}{4}$

$BM)_B = 0 = BM)_A$

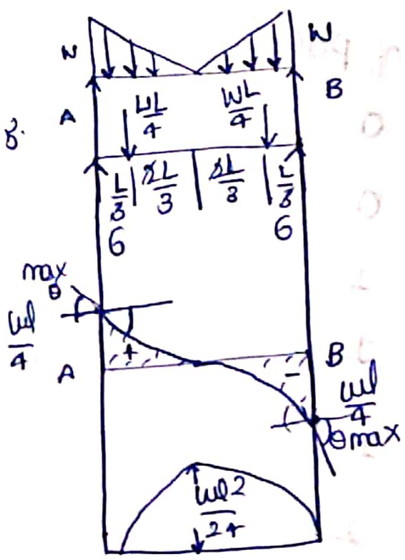
$$BM)_C = \frac{wl}{4}\times\frac{l}{2} - \frac{wl}{4}\times\frac{l}{6} = \frac{wl^2}{8} - \frac{wl^2}{24}$$

$$= \frac{3wl^2 - wl^2}{24} = \frac{wl^2}{12}$$

$$\begin{array}{r|l} 4 & 8, 24 \\ 2 & 2, 6 \\ & 1, 3 \end{array}$$

$$\boxed{BM)_{max} = \frac{wl^2}{12}}$$

5.



$SF)_B = -\frac{wl}{4}$, $SF)_A = \frac{wl}{4}$

$$\text{Max BM at Centre} = \frac{wl}{4}\left[\frac{L}{2}\right] - \frac{wl}{4}\left(\frac{L}{3}\right)$$

$$BM)_C = \frac{wl^2}{4}\left[\frac{1}{2} - \frac{1}{3}\right]$$

$$\boxed{BM_C) = \frac{wl^2}{24}}$$

NOTES-

① Rate of change of shear force with respect to length of beam is equals to intensity of load

$$\boxed{\frac{dF}{dx} = -w}$$

② Rate of change of bending moment with respect to length of beam is equals to shear force

$$\boxed{\frac{dM}{dx} = F}$$

=> point of Contraflexure -

1. In a bending beam a point is known as "point of Contraflexure". It is a location where bending moment is "zero [changes its sign]

2. In a bending moment diagram it is a point which bending curve intersect zero line"

=> Point of inflection -

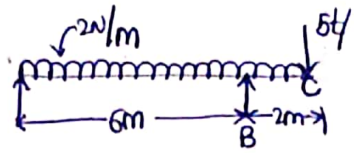
It is the point on the curve at which sign of curvature [Concavity] changes. [Deflection curve changes sign]

=> Types of beam & No. of point of Contraflexure -

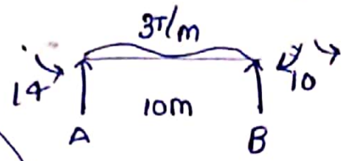
		No of P.O.C
1. Cantilever beam	—	0
2. S.S. beam	—	0
3. Single overhanging beam	—	1
4. propped Cantilever beam	—	1
5. double overhanging beam	—	2
6. Fixed beam	—	2
7. Continuous beam	—	Based on no. of Supports

A.EE

Q) pgno-418 $BM)_B = -5\times2 - 2\times\frac{2}{2} = -14\,tm$ [Hogging].



Q) pgno-418 $SF)_A = 0.5 - 3\times10 =$



$R_B\times10 - 10 + 3\times\frac{10}{2} = 0$

$-10R_B - 10 + 15 = 0 \Rightarrow R_B = 0.5$

$-10R_B = -5 \quad R_B = 0.5$

$10R_B = 25$

$2.5 - 30$

wrong

$\Rightarrow$ moments about B=0 $\Rightarrow R_A\times\cancel{6}^{10} - 14 - 3\times\frac{10}{2} = 0 \Rightarrow R_A = \frac{44}{\cancel{6}10} = 4.4$ } wrong

$R_A\times10 - 14 - [3\times10]5 + 10$

$R_A = 17.4$ //.

AEE

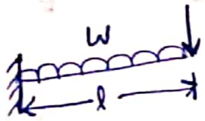
8Q) pgno-418 $\dfrac{\frac{wl^2}{2}}{\frac{wl^2}{8}} \Rightarrow \dfrac{\frac{1}{2}}{\frac{1}{8}} \Rightarrow \frac{8}{2} \Rightarrow 4:1$ //

AEE

9Q) pgno-418 (1)

AEE

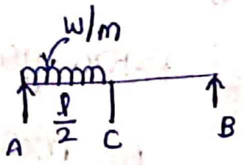
14Q) pg-418



$\Rightarrow -wl - \frac{wl^2}{2} \Rightarrow -wl\left[1+\frac{l}{2}\right] \Rightarrow -wl\left[\frac{2+l}{2}\right]$ } wrong

$\Rightarrow -wl - \frac{wl}{2} \Rightarrow -wl\left[1+\frac{1}{2}\right] \Rightarrow \underline{-1.5wl}$

19Q) pgno-428 $-R_B\times l + \frac{wl^2}{2} = 0$ } wrong $\quad R_B\times l = \frac{w\left(\frac{l}{4}\right)}{2}$



$R_B l = \frac{wl^2}{2} \Rightarrow R_B = \frac{wl}{2}$ } wrong

$\Rightarrow R_B = \frac{wl}{8}, \; R_A = \frac{wl}{2} - \frac{wl}{8} = \frac{4wl - wl}{8} = \frac{3wl}{8}$

$SF)_B = \frac{wl}{8} \qquad SF)_A = \frac{wl}{2}$

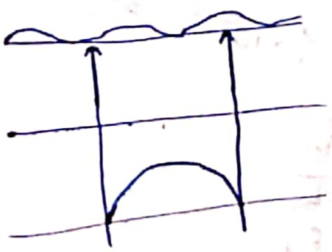
Max $Bm)$ shear sign change $\Rightarrow -\frac{3wl}{8} + \frac{wl\,x}{2} = 0 \Rightarrow x = \frac{3l}{8}$ ✓

$= x = \frac{3}{4}l \qquad 4) 30(7^{0}$

wrong{ $\frac{wx}{2} = \frac{3wl}{\cancel{8}4}$

AEE

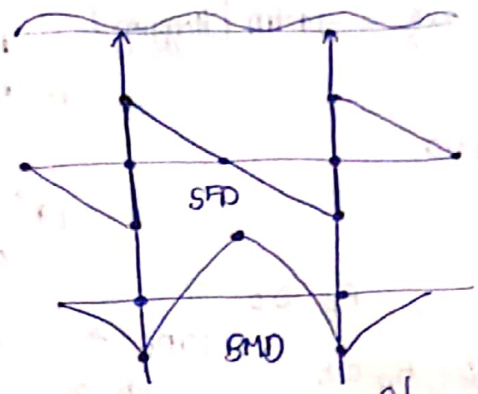
71Q)



} wrong.

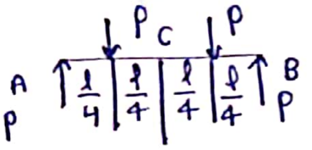
Scanned with CamScanner

7) Q



AEE 78Q) $25x = 60$ then $x = 2.4m$ from Support

AEE 98Q)



$BM)_C = \frac{Pl}{2} - \frac{Pl}{4} = \frac{2pl - pl}{4} = \frac{Pl}{4}$ //.

⇒ IMPORTANT POINTS :-

① $\varepsilon_z = \frac{\sigma_z}{E} - \mu\frac{\sigma_y}{E} - \mu\frac{\sigma_z}{E}$ | or $\Delta V = \delta V = \varepsilon_x(1-2\mu) \times$ volume

If It is 2 dimension ⇒ $\varepsilon_x = \frac{\sigma_x}{E} - \mu\frac{\sigma_y}{E}$ | * for Cube

$\varepsilon_y = \frac{\sigma_y}{E} - \mu\frac{\sigma_x}{E}$ | $\delta V = \Delta V = \frac{3P}{E}(1-2\mu) \times vol$

② $\frac{K}{E} = \frac{1}{3}$ & 1

31Q) AEE :- $E > K > G$ generally

But here $K < E$ i.e $\mu < 0.25$ for brittle materials.

So option (b) 0.15 is ✓

42)Q AEE :- $E_v = \varepsilon_x + \varepsilon_y + \varepsilon_z = \frac{\sigma}{E} - \mu\frac{\sigma}{E} - \mu\frac{\sigma}{E}$

$E_v = \frac{\sigma}{E}(1-2\mu) \times 3 \times$ volume

$\varepsilon_v = \varepsilon(1-2\mu) \times 3 \times vol$, option-① ✓

50. $K = \left[\frac{dp}{\Delta V}\right]$ ⇒ $\Delta V = \frac{dp}{K} = \frac{100}{0.667 \times 10^5} = \frac{100}{\frac{2}{3} \times 10^5} = \frac{3}{2} \times 10^{-3} = 1.5 \times 10^{-3}$

③ For Composite members :-

$\sigma = \frac{P}{A}$

$P = \sigma A$

$\boxed{P = \sigma_1 A_1 + \sigma_2 A_2}$

$\frac{\Delta l_1}{L} = \frac{\Delta l_2}{L}$

$\varepsilon_1 = \varepsilon_2$

$\frac{\sigma_1}{E_1} = \frac{\sigma_2}{E_2}$ ⇒ $\frac{\sigma_1}{\sigma_2} = \frac{E_1}{E_2}$ → modular ratio

$\therefore \frac{\sigma_1}{\sigma_2} = \frac{E_1}{E_2} = \left\{ \frac{E_{strong}}{E_{weak}} \right\}$ modular ratio

98) AEE pg-168 $\varepsilon_x = \frac{\sigma_x}{E} - \mu\frac{\sigma_y}{E} - \mu\frac{\sigma_z}{E}$

$= \frac{\sigma}{E} - 0.25\frac{\sigma}{E} - 0.25\frac{\sigma}{E}$

$\varepsilon_x = \frac{\sigma}{E}[0.5]$

then $Vol\ \varepsilon = \varepsilon_x + \varepsilon_y + \varepsilon_z = 1.5\frac{\sigma}{E}$ the option 2 is ✓

100) AEE pg168

Total 4	Indendent " 2 "
E, C, K, μ	E, μ K, μ C, μ

⇒ STRAIN ROSETTES

Arrangement of Strain gauges to find linear strain

Rectangular DELTA STAR.

20/05/19

Answers of AEE

pg no-168 18) $\sigma = \frac{F_s}{A} = \frac{F_s}{\pi d t} \Rightarrow F_s = \sigma\pi d t = 30\times\pi\times 20\times 20 = 37{,}699\,kg.$

16) $\sigma = \frac{F}{A} \Rightarrow 140\times10^6 = \frac{500\times10^3}{\frac{\pi}{4}\left(D - \frac{4D}{5}\right)^2} = \frac{500\times10^3}{\frac{\pi}{4}\left(\frac{D}{5}\right)^2}$ } wrong

Ruf

$\Rightarrow \frac{2}{10}D = \frac{1}{5}D$

$D - \frac{1}{5}D$

$\frac{4D}{5}$

$\Rightarrow 140\times10^6 = \frac{500\times10^3}{\frac{\pi}{4}\cdot\frac{D^2}{25}} \Rightarrow D^2 = \frac{500\times10^3\times25\times4}{140\times10^6}$ $\frac{1}{10}D$ } wrong

$\Rightarrow D^2 = \frac{5}{14}$ } wrong

$\Rightarrow 140\times10^6 = \frac{500\times10^3}{\frac{\pi}{4}(D^2 - 0.8D^2)} \Rightarrow D = 112mm$ //.

21) $\frac{\sigma_s}{\sigma_b} = \frac{200}{100} = 2$ //.

19) $E = 2\times10^6\,kg/cm^2 = 2\times10^6\times10/10^2\ N/mm^2$

$= 2\times10^5\,N/mm^2$

$E = \frac{\sigma}{\varepsilon} \Rightarrow 2\times10^5 = \frac{\frac{P}{\frac{\pi}{4}\times144}}{\frac{45}{1000000}} \Rightarrow \frac{2}{10} = \frac{P\times4}{\pi\times144\times45}$

(OR) $\frac{5}{81}$

$P = \frac{45\times44}{20}$ ... $\Leftarrow \frac{45}{1000} = \frac{P\times1000\times4}{144\times2\times10^5}$ $\Rightarrow P = 99\times\pi$

pg-19 & 17) WKT, $\mu = \frac{\varepsilon_{lat}}{\varepsilon_{linear}} \Rightarrow \mu = \frac{\Delta D/A}{\frac{4P}{\pi D^2 E}} \Rightarrow \Delta D = \frac{4\mu P D}{\pi D^2 E}$

$\Delta D = \frac{4P\mu}{\pi E D}$ //.

Q15 → pg-20) $\frac{\Delta l)_{SW}}{\Delta l)_{load}} = \frac{\frac{1}{2}wl/AE}{wl/AE} = \frac{1}{2} \Rightarrow 1:2$

Q31 → pg-20) $\Delta l = \frac{\gamma L^2}{2E} \Rightarrow \frac{3.2}{1000} = \frac{50 \times 4^2}{2 \times E} \Rightarrow E = \frac{50 \times 4^2 \times 1000 \times 10}{32 \times 2}$

$E \Rightarrow \frac{\cancel{50}^{25} \times \cancel{10000}^{5000} \times \cancel{16}^{1}}{\cancel{32 \times 2}_{2}}$

Q35-pg→20) $\Delta l = \frac{PL}{AE}$, $\Delta l \propto \frac{1}{AE}$

$\frac{\Delta l_2}{\Delta l_1} = \frac{(AE)_1}{(AE)_2} \Rightarrow \frac{AE_1}{\left[\frac{AE}{2}\right]} = 2 \Rightarrow \boxed{\Delta L_2 = 2y}$

Q39-pg20) $\gamma = 100 kN/m^3$, $\sigma = 100 N/mm^2$

$\sigma = \gamma \times L \Rightarrow 100 = \frac{100 \times 10^3}{10^9} \times L \Rightarrow L = \frac{10^{11}}{10^5} mm = 10^6 mm = 10^3 m$.

Q46) Compound bars can be analyzed based on equillibrium & Compatability Conditions

∴ Compatability Conditions (or) Eqn generally deals with displacement, ε, slope etc.

Q.(Com)→X Generally used condition is same deformation or same "ε"

Q65-pg22) % reduction $\propto \frac{1}{\text{% Elongation [ductility]}}$ //

A	B
% R - 60%	% R - 40%
E = less	E = more
ductile less	ductile more

∴ B is more ductile than A.

Q-69) Strain energy theory:- [Not in syllabus]

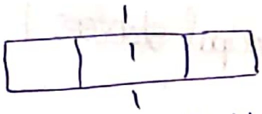
$$\boxed{\sigma_y^2 = \sigma_1^2 + \sigma_2^2 + \sigma_3^2 - 2\mu[\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1]}$$

Here for Cube $\sigma_y^2 = 3\sigma^2[1-2\mu]$

$$\boxed{\sigma = \frac{\sigma_y}{\sqrt{3[1-2\mu]}}}$$

Q-72) Material with μ is increase then material becomes soft then volumetric change of also increases

Q-82) $50+P = 30+90$ then $50+P=70$ then $P=20$



Should be / should be

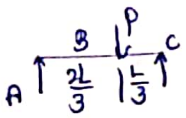
Q-99 → pg 25) $\Delta l = \frac{Pl}{AE}$ ⇒ then $\boxed{\Delta l = \frac{PL}{A_1E_1 + A_2E_2}}$

Here $\Delta l = \frac{PL}{AE + 2AE} = \frac{1}{3}\frac{PL}{AE}$

Q-50) Generally based on the real values of the materials

$$\boxed{\tau_{max} = \frac{\text{Normal stresses}}{2}}$$

Q-6) Q



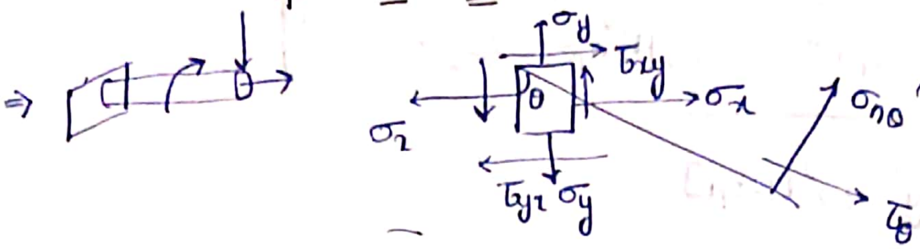
⇒ $BC = \frac{P\,2L/3}{L} = P\frac{2}{3}$ & $AB = \frac{P\cancel{L}}{3L} = \frac{P}{3}$

then $\frac{AB}{BC} = \frac{P\frac{2}{3}}{\frac{P}{3}} = \frac{2}{1}$ ⇒ 2:1 //.

* THERMALS :-

1Q) $E = \alpha t$, $\frac{\sigma}{E} = \alpha t$ ⇒ $\sigma = E\alpha T = 2\times10^6 \times 1.5\times10^{-6}\times 20 = 60\,kg/cm^2$ (Tension) Comp.

* COMPLEX STRESSES

⇒ 

Every plane has normal σ & shear stress

then $\sigma_{n\theta} = \dfrac{\sigma_x+\sigma_y}{2} + \dfrac{\sigma_x-\sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$

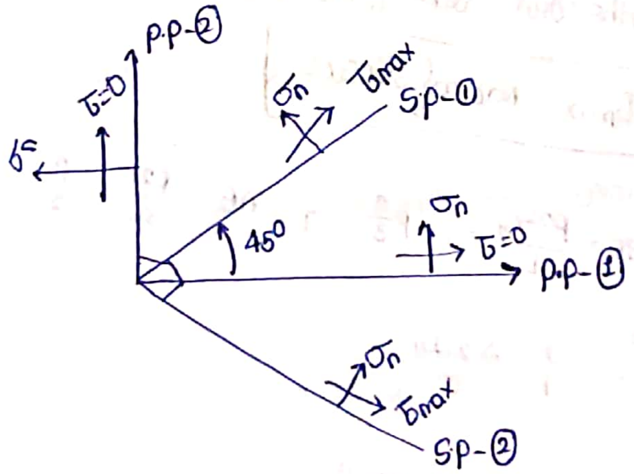
$$\tau_\theta = \frac{\sigma_x-\sigma_y}{2}\sin 2\theta - \tau_{xy}\cos 2\theta$$

⇒ Principal stresses [τ = 0] plane is principal plane &

$$0 = \frac{\sigma_x-\sigma_y}{2}\sin 2\theta - \tau_{xy}\cos 2\theta$$

$$\frac{\sigma_x-\sigma_y}{2}\sin 2\theta = \tau_{xy}\cos 2\theta$$

$$\boxed{\theta_p = \frac{1}{2}\tan^{-1}\left[\frac{2\tau_{xy}}{\sigma_x-\sigma_y}\right]}$$



⇒ Max ~~principle~~ principal stress theory [Rankine's theory] [brittle material] &

$$\sigma_{max} \le \sigma_{yp} \text{ [Safe]}$$

$$\left.\begin{matrix}\sigma_1 & \sigma_{max}\\ \sigma_2 & \sigma_{min}\end{matrix}\right\} = \frac{\sigma_x+\sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\boxed{A \pm \sqrt{B}}$$

⇒ Max principal shear stresses theory [Ductile material] [Guests / Trescas / Coulombs]

$$\tau_{max} \leq \tau_{yp} \text{ [safe]}$$

$$\tau_{max} = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{A+\sqrt{B} - (A-\sqrt{B})}{2} = \sqrt{B}$$

$$\boxed{\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}}$$

NOTE:- σ_n = normal average stress

$$\boxed{\sigma_n = \frac{\sigma_x + \sigma_y}{2}} \quad \& \quad \boxed{\tau_{max} = \frac{\sigma_x - \sigma_y}{2}}$$

$$\left.\begin{matrix}\sigma_{max} \\ \sigma_{min}\end{matrix}\right\} = \sigma_n \pm \tau_{max}$$

5 theory's of failures

⇒ Rankines [p. stress] $\sigma_{max} = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$ } Brittle materials

⇒ Guests [τ_{max}] = $\sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

⇒ St. Venants [principle & theory] = $\sigma_{max} = \sigma_1 - \mu\sigma_2$ [for 2-d body]

⇒ Strain energy [Haigh's theory] = $\sigma_{max} = \sigma_1^2 + \sigma_2^2 - 2\mu\sigma_1\sigma_2$ [for 2-d body]

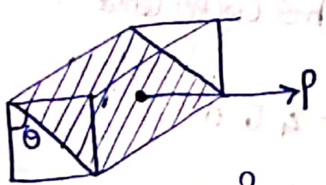
Just no

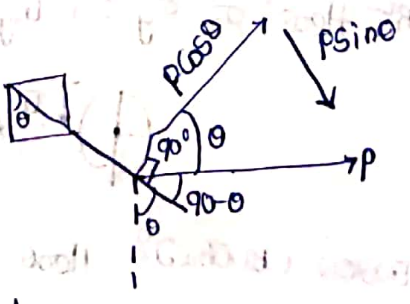
⇒ VDH → Henckys' Distortion energy = $\sigma_{max} = \sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2$ [for 2d body]

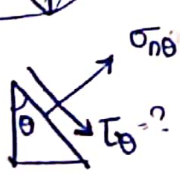
└→ Vonmises

} Ductile materials

⇒ UNIDIRECTIONAL TENSILE LOAD (P):



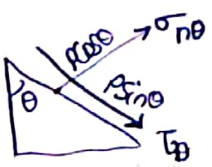




A 

⇒ $A_\theta = \frac{A}{\cos\theta}$

Now



$$\Rightarrow \sigma_{n\theta} = \frac{P_n}{A_n} = \frac{P\cos\theta}{\frac{A}{\cos\theta}} \qquad \boxed{\sigma_{n\theta} = \sigma\cos^2\theta}$$

$$\Rightarrow \tau_\theta = \frac{P_t}{A_t} = \frac{P\sin\theta}{\frac{A}{\cos\theta}}, \qquad \boxed{\tau_\theta = \frac{\sigma}{2}\sin 2\theta}$$

(OR)

for $\sigma_{n\theta} = \frac{\sigma_x+\sigma_y}{2} + \frac{\sigma_x-\sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$

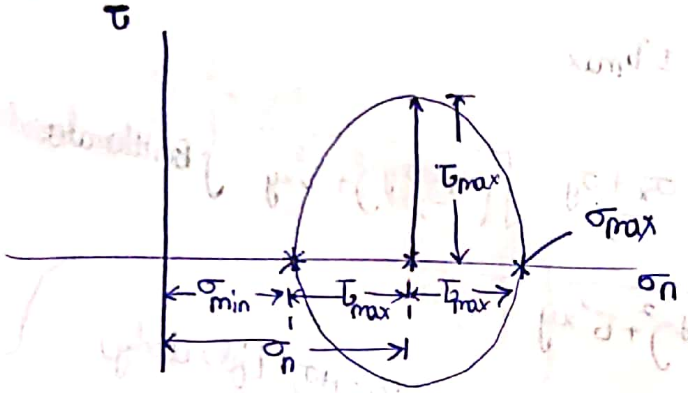
We know that $\sigma_y = \tau_{xy} = 0$

then $\sigma_{n\theta} = \frac{\sigma}{2} + \frac{\sigma}{2}\cos 2\theta = \frac{\sigma}{2}[1+\cos 2\theta] = \boxed{\sigma\cos^2\theta}$

$\tau_\theta = \frac{\sigma_x-\sigma_y}{2}\sin 2\theta - \tau_{xy}\cos^2\theta$

$$\boxed{\tau_\theta = \frac{\sigma}{2}\sin 2\theta}$$

⇒ MOHR'S CIRCLE:-

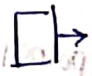


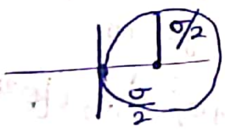
Here Radius $= \tau_{max}$

$\sigma_{max} = \sigma_n + \tau_{max}$

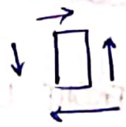
$\sigma_{min} = \sigma_n - \tau_{max}$

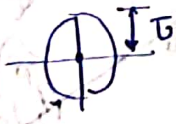
Centre $[\sigma_n, 0]$

① PURE TENSION:- Here $\sigma_x = \sigma$, $\sigma_y = \tau_{max} = 0$ i.e  $\sigma_x = \sigma$



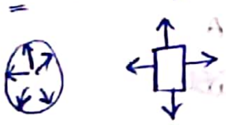
* Here mohr's Circle touches the origin

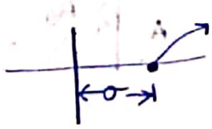
② PURE SHEAR:- Here $\sigma_x = \sigma_y = 0$ & $\tau_{xy} = \tau$ i.e 



* Here mohr's Circle Centre is origin

③ SURFACE TENSION (BUBBLE):- Here $\sigma_x = \sigma_y = \sigma$ & $\tau = 0$

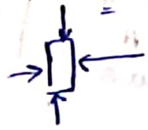
i.e 



→ point Circle

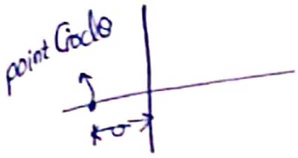
* positive (σ_n) axis & point Circle

④ HYDROSTATIC PRESSURE SUBMERGED BODY:-

 i.e $\sigma_x = \sigma_y = -\sigma$ & $\tau_{xy} = 0$

Scanned with CamScanner

* negative σ_n axis & point Circle.



⇒ Here $\sigma_x = \varepsilon_x$, $\sigma_y = \varepsilon_y$ & $\tau_{xy} = \frac{\phi_{xy}}{2}$

Then,

(1) $$\boxed{\left.\begin{matrix}\varepsilon_{max}\\ \varepsilon_{min}\end{matrix}\right\} = \frac{\varepsilon_x+\varepsilon_y}{2} \pm \sqrt{\left(\frac{\varepsilon_x-\varepsilon_y}{2}\right)^2+\left(\frac{\phi_{xy}}{2}\right)^2}}$$

(2) $$\frac{\phi_{max}}{2} = \sqrt{\left(\frac{\varepsilon_x-\varepsilon_y}{2}\right)^2+\left(\frac{\phi_{xy}}{2}\right)^2}$$

$$\boxed{\phi_{max} = \sqrt{(\varepsilon_x-\varepsilon_y)^2+(\phi_{xy})^2}}$$

(3) $$\boxed{\varepsilon_n = \frac{\varepsilon_x+\varepsilon_y}{2}}$$

⇒ 3D - SPATIAL STRESS SYSTEMS

$$\begin{bmatrix} \sigma_x & \tau_{xy} & \tau_{yz} \\ \tau_{yx} & \sigma_y & \tau_{zx} \\ \tau_{zy} & \tau_{xz} & \sigma_z \end{bmatrix}$$

stress & strain are tensors (magnitude) & more than 1 direction

DETERMINENT OF MATRIX.

Here, $\tau_{xy} = \tau_{yx}$, $\tau_{zy} = \tau_{yz}$, & $\tau_{zx} = \tau_{xz}$

⇒ 2D $\begin{bmatrix} \sigma_x & \tau_{xy} \\ \sigma_{yx} & \sigma_y \end{bmatrix}$ ⇒ magnitude = $[\sigma_x\sigma_y - \tau_{xy}^2]$ //.

⇒ *

SYSTEM	TOTAL σ & ε Components	Independent σ, ε Components
1D	1	1
2D	4	3
3D	9	6

No. of strain gauges required to know change in length.

Scanned with CamScanner

* TORSION IN SHAFTS

→ Torsion is twisting about the axis

→ Couple in the C.S of beam Causes torsion

→ B.M takes place along the Centroidal axis

→ Couple in the plane of beam Causes bending

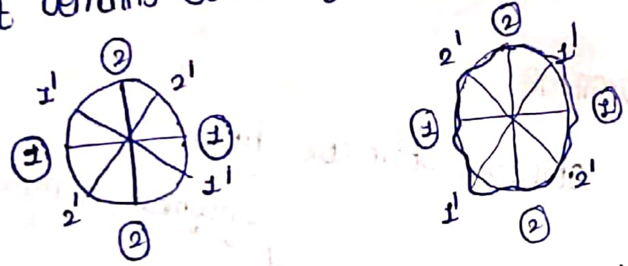
→ pure torsion is (i) axial force = 0 i.e $\varepsilon x = 0$

(ii) Bending i.e $\varepsilon y = 0$

(iii) $\tau_{xy} = \tau$

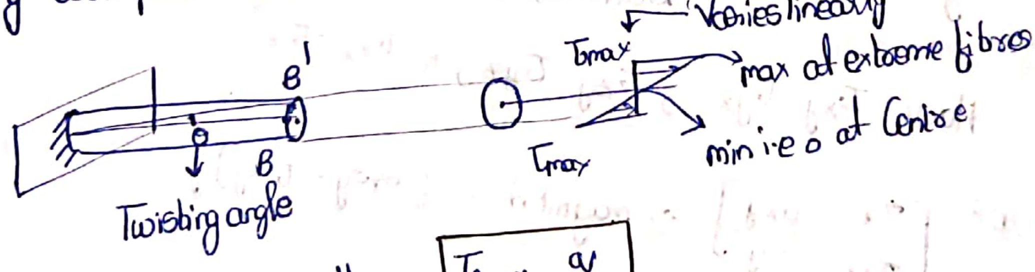
*** ASSUMPTIONS**

1. Torque is uniform along the shaft
2. C.S of shaft remains Same before and after application of load.



3. Remaining assumptions are same as S.O.M assumptions.

⇒



then $\boxed{\dfrac{\tau_{max}}{R} = \dfrac{\tau}{r}}$

⇒ Torsional Eqn:

$$\boxed{\frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{l}}$$

Torsional rigidity

$$\frac{T}{\theta} = \frac{GJ}{l}$$

$GJ \uparrow$ — $\theta \downarrow$ slope ↓

Flexural rigidity

$$\frac{EI}{R} = M$$

$EI \uparrow$, ↑ stiffness ↓ deflection ↓ slopes

⇒ DESIGNS

21/05/19

(i) SHAFTS

power $= \frac{2\pi NT}{60}$ where T is the Torque in N-m
p is the power in watts

then $p = \frac{2\pi NT}{4500}$ where $T \to$ kg-m
$p \to$ H·P

Here $\frac{P_h \text{ [power of hollow]}}{P_s \text{ [" " solid]}} = \frac{\text{Torque}_h}{\text{Torque}_s} = \frac{Z_p)_h}{Z_p)_s} = \frac{\text{strength})_h}{\text{strength})_s}$ #

& $\boxed{\frac{W_h}{W_S} = \frac{A_h}{A_S}}$ * 1 h.p = 746 watts

→ Inertia: It is the resistance to the linear acceleration
$F = ma$ Inertia

→ Moment of inertia: It is the resistance to angular acceleration i.e $T = I\alpha$
M.I

M.I M.I
$[m^4]$

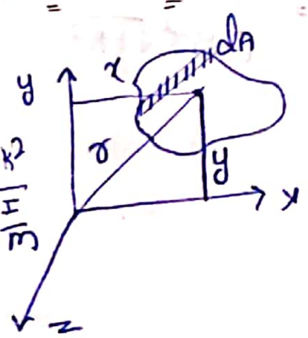
Area | mass $[kgm^2]$
↓ | ↓

⇒ SECOND MOMENT OF AREA:

Then $I_{xx} = \Sigma y^2 \cdot dA$ | $\Sigma y^2 dm$
$I_{yy} = \Sigma x^2 dA$ | $\Sigma x^2 dm$
$I_{zz} = \Sigma r^2 dA$ | $\Sigma r^2 dm$

→ radius of gyration

$I = AK^2$ | $I = mk^2$
$K = \sqrt{\frac{I}{A}}$ | $K = \sqrt{\frac{I}{m}}$



→ || axis theorem ⇒ $I_{AB} = I_G + Ah^2$

⊥ axis theorem ⇒ $J = I_{zz} = I_{xx} + I_{yy}$

Here Design → Solid shaft $\frac{T}{J} = \frac{\tau}{R}$ ⇒ $T = \tau \times \frac{J}{R} = \tau Z_p$ i.e $T = \tau Z_p$

WKT $Z_p = \frac{\pi d^3}{16}$ then the $T = \tau \cdot \frac{\pi d^3}{16}$.

Now $\boxed{\tau = \frac{16T}{\pi d^3}}$

Here for Hollow shaft → $T = \tau \times \frac{\pi}{16D}[D^4 - d^4] = \tau \times \frac{\pi D^4}{16D}\left[1 - \left(\frac{d}{D}\right)^4\right]$

⇒ $T = \tau \times \frac{\pi D^3}{16}[1 - K^4]$ $\left[\because K = \frac{d}{D}\right]$

Now $\boxed{\tau = \frac{16T}{\pi D^3 [1-K^4]}}$

→ Comparisionof shafts

① $N_h = N_s$ | & $\frac{\text{strength})_h}{\text{strength})_s} = \frac{Z_p)_h}{Z_p)_s}$

$A_h = A_s$

$d_h = d_s$

Then $\frac{\pi}{4}(D^2-d^2) = \frac{\pi}{4} d_s^2$

$d_s = (D^2-d^2)^{1/2}$

$d_s^3 = [D^2-d^2]^{3/2} = [D^2-d^2][D^2-d^2]^{1/2}$

Then $\frac{Z_p)_h}{Z_p)_s} = \frac{\frac{\pi}{16D}(D^4-d^4)}{\frac{\pi}{16}(d_s)^3}$

$= \frac{D^4-d^4}{D[d_s^3]} = \frac{D^4-d^4}{D[D^2-d^2][D^2-d^2]^{1/2}}$

$= \frac{D^4[1-K^4]}{D \cdot D^2[1-K^2]\sqrt{D^2[1-K^2]}} = \frac{(1)^2-(K^2)^2}{(1-K)^2\sqrt{1-K^2}}$

$$\boxed{\frac{Z_p)_h}{Z_p)_s} = \frac{1+K^2}{\sqrt{1-K^2}}}$$

② here strength$)_h$ = strength$)_s$

then $\frac{W_h}{W_s} = \frac{A_h}{A_s} = ?$

then $Z_p)_h = Z_p)_s$

$\frac{\pi}{16D}(D^4-d^4) = \frac{\pi}{16} d_s^3$

$d_s = \left[\frac{D^4-d^4}{D}\right]^{1/3}$

then $\frac{A_h}{A_s} = \frac{\frac{\pi}{4}(D^2-d^2)}{\frac{\pi}{4} d_s^2} = \frac{D^2[1-K^2]}{\frac{D^4}{D}[1-K^4]^{2/3}} = \frac{1-K^2}{(1-K^4)^{2/3}}$

then $\boxed{\dfrac{A_h}{A_s} = \dfrac{W_h}{W_s} = \dfrac{1-K^2}{(1-K^4)^{2/3}}}$

→ Condition

*** AEE

① When $W_h = W_s$ & $A_h = A_s$ then $\dfrac{\text{stren})_h}{\text{stren})_s} = \dfrac{1+K^2}{\sqrt{1-K^2}}$

***

② $d_s = D$ $\boxed{\dfrac{\text{strength})_h}{\text{strength})_s} = 1-K^4}$

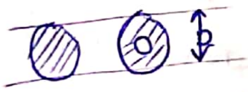
③ $\text{strength})_h = \text{strength})_s$ then $\dfrac{W)_h}{W)_s} = \dfrac{A)_h}{A_s} = \dfrac{1-K^2}{(1-K^4)^{2/3}}$.

*① If $W_h = W_s$ then $T_{\text{Hollowshaft}} > T_{\text{solid shaft}}$

becoz  then for hollow dia increases wrt T& diameter.

$W = W$

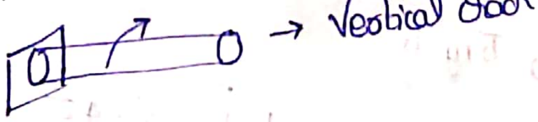
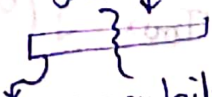
*② If $d_s = D$ then $\text{strength})_{\text{hollow}} \leq \text{strength})_{\text{solid}}$

becoz  diameter not material ↓ strength also ↓

*③) If $d_s = D$, here $d = 0.5D$ then

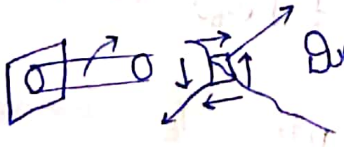
$\dfrac{\text{strength})_h}{\text{strength})_s} = 1-K^4 = 1-\dfrac{1}{16} = \dfrac{15}{16}$.

⇒ FAILURE CRITERIAS

1. For ductile  → Vertical crack 

Small crack

becoz of easy failure

2. For brittle  Due to tension 45° crack

⇒ DESIGNS

① pure bendings $\dfrac{M}{I} = \dfrac{\sigma_b}{y}$

$M = \sigma_b \cdot \dfrac{I}{y} = \sigma_b \times \dfrac{\frac{\pi}{64} \times D^4}{\frac{D}{2}} = \dfrac{\pi d^3}{32} \cdot \sigma_b$

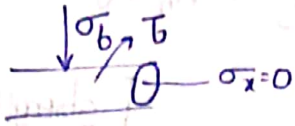
$\boxed{\sigma_b = \dfrac{32M}{\pi D^3[1-K^4]}}$ for hollow

$\boxed{\sigma_b = \dfrac{32M}{\pi D^3}}$ for solid

② Torsion:

$\boxed{\tau = \frac{16T}{\pi D^3}}$ and for solid $\boxed{\tau = \frac{16T}{\pi D^3[1-K^4]}}$ for hollow

→ Combined stress:



① Brittle (Rankine)

$$\text{WKT } \sigma_{max} = \frac{\sigma_x+\sigma_y}{2} + \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \frac{\sigma_b}{2} + \sqrt{\left[\frac{\sigma_b}{2}\right]^2 + \tau^2}$$

$$= \frac{1}{2}\left[\sigma_b + \sqrt{\sigma_b^2 + 4\tau^2}\right]$$

$$= \frac{1}{2}\left[\frac{32M}{\pi d^3} + \sqrt{\left[\frac{32M}{\pi d^3}\right]^2 + 4\left[\frac{16T}{\pi d^3}\right]^2}\right]$$ torsional equivalent.

(OR)

$$\sigma_{bmax} = \frac{32}{\pi d^3}\left[\frac{1}{2}\left(M + \sqrt{M^2+T^2}\right)\right]$$ mechanical bending equivalent

$\boxed{\sigma_{bmax} = \frac{32M_e}{\pi d^3}}$ where $M_e \rightarrow$ ~~mechanical~~ equivalent

$M_e = \frac{1}{2}\left(M + \sqrt{M^2+T^2}\right)$

② Guest (Ductile)

$$\tau_{max} = \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

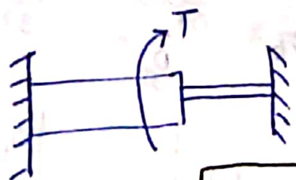
Here $\sigma_x = 0$, $\sigma_y = \sigma_b$, $\tau_{xy} = \tau$

then $\tau_{max} = \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2} = \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\tau^2}$.

$\boxed{\tau_{max} = \frac{16T_e}{d^3\pi}}$ where T_e is Torsional equivalent

$T_e = \sqrt{M^2+T^2}$

⇒ SHAFTS IN SERIES:

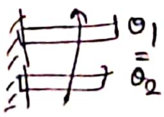


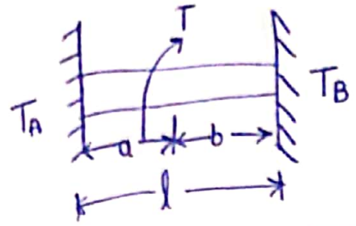
$\boxed{\theta \propto \frac{1}{d^4}}$

then $\boxed{\frac{\theta_2}{\theta_1} = \left(\frac{d_1}{d_2}\right)^4}$

⇒ Shafts in $\parallel^{el}$

$\boxed{\theta_1 = \theta_2}$

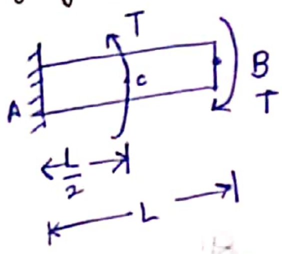


⇒ 

Here $\boxed{T = T_A + T_B}$

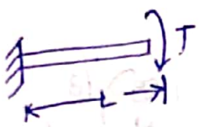
$$T_B = \frac{Ta}{l}, \quad \& \quad T_A = \frac{Tb}{l}.$$

⇒ Angular twist:



WKT Angular twist

$$\boxed{\theta = \frac{TL}{GJ}}$$

Here Considering 

$$\theta_B - \cancel{\theta_A}^{\,0} = \frac{TL}{GJ}$$

$$\theta_C - \cancel{\theta_A}^{\,0} = \frac{TL}{2GJ}$$

then $\boxed{\theta_B - \theta_C = \frac{TL}{2GJ}}$ **

WKT Stiffness $= k = W/\theta$

Torsional stiffness $= T/\theta$

Torsional rigidity $= GJ$

then $\frac{T}{\theta} = \frac{GJ}{\cancel{l} \to 1}$

$$\boxed{\frac{T}{\theta} = GJ}$$

Torsional stiffness   Torsional rigidity

Q) A shaft transmits 80HP at 60 rpm. If max torque is 30% greater than mean torque then max torque in kg/m is —

Sol $80 = \frac{2 \times \pi \times 60 \times T}{4500}$ ⇒ $T = \frac{\overset{20}{\cancel{80}} \times \overset{150}{\cancel{4500}}}{\cancel{2} \times \pi \times \cancel{60}_{3}}$, $= \frac{20 \times 150}{\pi} = \frac{3000}{\pi}$

$T_{max} = \frac{30}{100} \times \frac{3000}{\pi} = \frac{900}{\pi}$ } wrong $T_{max} = 1.3 \times \frac{3000}{\pi} = \frac{3900}{\pi}$ Nm.

23Q AEE8 $\left.\begin{matrix}\sigma_{max} \\ \sigma_{min}\end{matrix}\right\} = \frac{\sigma_b}{2} \pm \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2}$

*

Now $\sigma_b = \frac{32M}{\pi d^3} = \frac{32 \times 2500\pi}{\pi \times (10^2)^3} = 80\,MPa$

Given $\tau = 30\,MPa$.

$\left.\begin{matrix}\sigma_{max} \\ \sigma_{min}\end{matrix}\right\} = \frac{80}{2} \pm \sqrt{\left(\frac{80}{2}\right)^2 + 30^2}$

$= 40 \pm 50 \Rightarrow 90\,MPa \; \& \; -10\,MPa$ //.

AEE

Q-27) Given $T_h = T_s$

$(\tau Z_p)_h = (\tau Z_p)_s$

$D_o^3 \frac{\pi}{16}(1-K^4) = \frac{\pi}{16} D^3$

$D_o^3\left(1 - \frac{16}{81}\right) = D^3$

$\left(\frac{D}{D_o}\right)^3 = \frac{81-16}{81} = \frac{65}{81} \Rightarrow \frac{D}{D_o} = \left(\frac{65}{81}\right)^{1/3}$ //.

$\begin{array}{r} 81 \\ -16 \\ \hline 65 \end{array}$

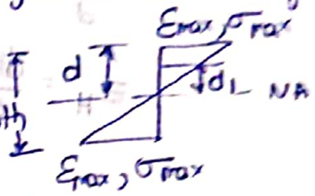
Q-31) $\left(\frac{T_S - T_H}{100\, T_S}\right) \times 100$

- $U = \frac{P^2 l}{2AE}$ for this chapter $\boxed{U = \frac{T^2 l}{2GJ}}$ generally $\boxed{U = \frac{1}{2} P \Delta l}$.

* THEORY OF SIMPLE BENDING

→ ASSUMPTIONS :- [Euler-Bernoulli].

1. It was developed by euler
2. Transverse section of beam which is plane before bending will remain plane after bending
3. It is valid for static load with no residual stress
4. plane section hypothesis in simple bending states, assumes bending strain is proportional to distance from neutral axis



5. strain varies linearly along depth
6. Radius of Curvature is far greater than deflection of beam.
7. It is valid for steel members
8. It is valid when cross section do not warp [bent / twist]

⇒ BM Eqn :-

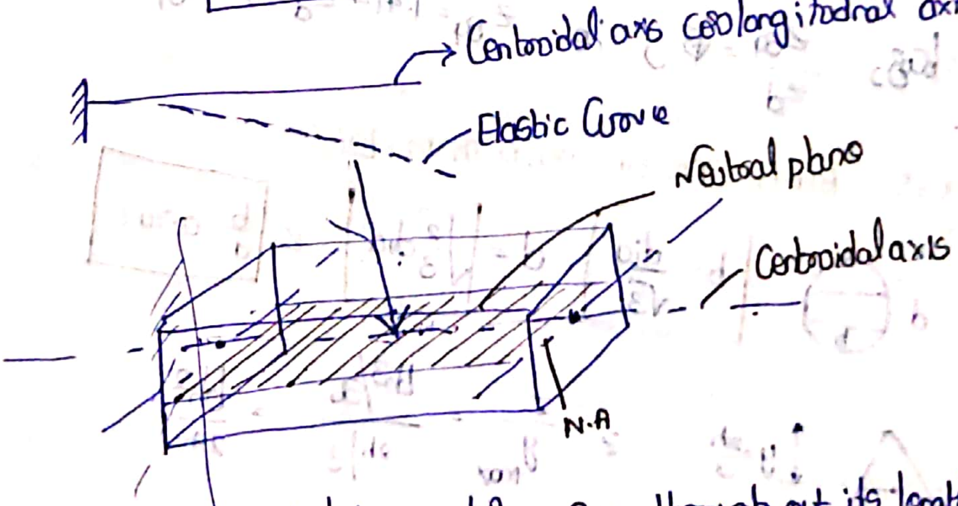
$$\frac{M}{I} = \frac{\sigma_b}{y} = \frac{E}{R}$$

Bending σ is also known as skin σ

pure bending →

pure bending SF=0

→ BM is non zero Constant



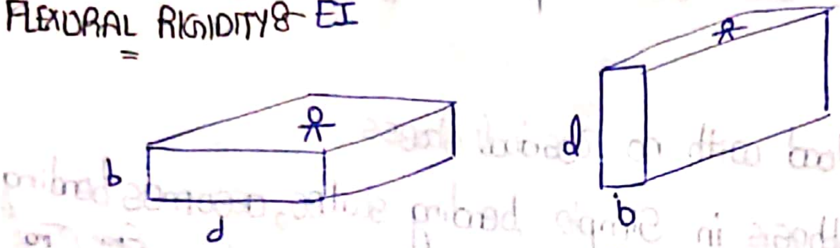
Beam of uniform CS subjected to uniform B.M through out its length then deflection shape of beam is Circular arc

⇒ Section modulus:- [First moment of area]

$z = \frac{I}{y}$ where y is the distance from N.A to outermost layer

Significance:- ↑ z then ↑ strength in bending. (or) $z = \frac{I}{y_{max}}$

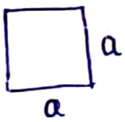
⇒ FLEXURAL RIGIDITY:- EI



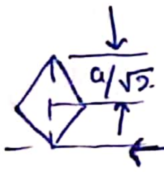
$Z_H = \frac{db^2}{6}$ $\quad Z_V = \frac{bd^2}{6}$

Here $\boxed{Z_V > Z_H}$ so strength$)_V$ > strength$)_H$

⇒ Z for diff Sections:-

(1) 

$z = \frac{I}{y} = \frac{\frac{a a^3}{12}}{\frac{a}{2}} = \frac{a^3}{6}$

(2) 

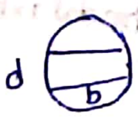
$z = \frac{I}{y} = \frac{\frac{a a^3}{12}}{\frac{a}{\sqrt{2}}} = \frac{a^3}{6\sqrt{2}}$

Square diagonal ⊥ to the base figure:

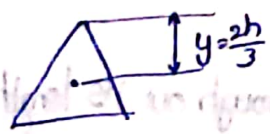
* Square is more strength than Square diagonal ⊥ to the base figure

bcoz, $\frac{Z_{sq}}{Z_d} = \sqrt{2}$, i.e. $Z_{sq} = 1.414 Z_d$ ⇒ Z_{sq} = 41.4% strong than Z_d

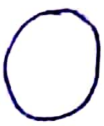
⇒ STRONGEST BEAM CAN BE CUTTED FROM LOG:-



$\boxed{b = \frac{dia}{\sqrt{3}}}$ $\quad d = \boxed{\sqrt{\frac{2}{3}} dia}$ & $\boxed{\frac{b}{d} = 0.707}$

(3) 

$z = \frac{I}{y_{max}} = \frac{bh^3/36}{2h/3} = \frac{bh^2}{24}$

(4) 

$z = \frac{I}{y_{max}} = \frac{\pi d^3}{32}$

*** ⇒ BEAM OF UNIFORM STRENGTH :- Maximum bending stress is same at every section along its longitudinal axis.

(OR)

Bending stress is constant throughout the length of beam.

$$M = \overset{\text{const}}{\sigma} Z$$

$$\boxed{M \propto Z}$$

exel question

for rectangle $M \propto bd^2$ than $M \propto b$ & $M \propto d^2$ then $\boxed{d \propto \sqrt{m}}$ *

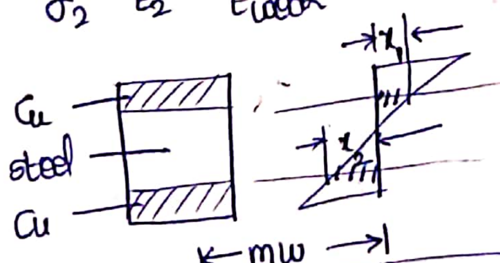
NOTE :- The real, practicle beams are not uniform strength

2. uniform strength is achieved by pure bending only.

⇒ Equivalent area method :-

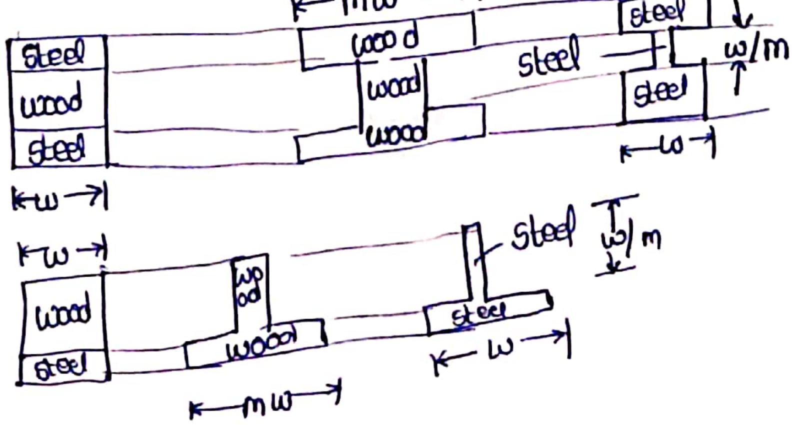
(1) Comp members :-

$$\frac{\sigma_1}{\sigma_2} = \frac{E_1}{E_2} = \frac{E_{strong}}{E_{weak}} = \text{modular ration.}$$



Here x_2 must be equal to x_1 at Junctions.

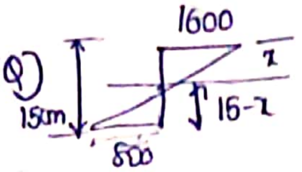
$x_1 = x_2$



* Non homogeneous → Homogeneous

Dimensions alter wrt l, b, & h.

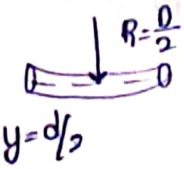
5AEEQ)



$\frac{1600}{x} = \frac{800}{15-x}$

then $\boxed{x = 10cm}$

7AEEQ)



$\frac{\sigma}{y} = \frac{E}{R}$ then $\frac{\sigma}{\frac{d}{2}} = \frac{E}{\frac{D}{2}}$ & $\boxed{\sigma = \frac{Ed}{D}}$

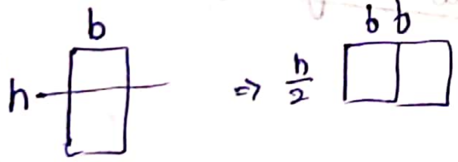
8AEEQ) bxd of n times & bxnd

then ratio is $\frac{Z_1}{Z_2} = \frac{\frac{nbd^2}{6}}{\frac{bn^2d^2}{6}} = \frac{1}{n}$ //.

12AEEQ) $\frac{M}{I} = \frac{F}{y} = \frac{E}{R}$ then $\frac{1}{R} \propto \frac{1}{I}$

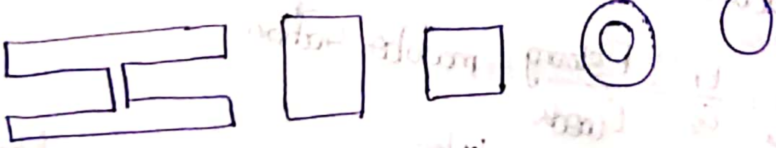
$\frac{C_1}{C_2} = \frac{I_2}{I_1} = n^2 = 9$ //.

26AEEQ)



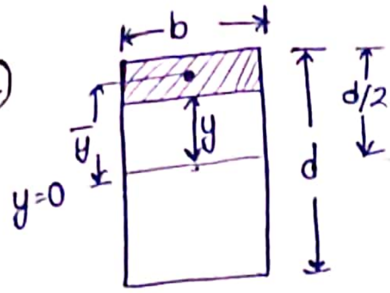
$\frac{S_2}{S_1} = \frac{Z_2}{Z_1} = \frac{2b\frac{h^2}{4} \times \frac{1}{6}}{\frac{bh^2}{6}} = \frac{1}{2}$

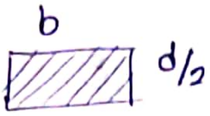
44Q) from Neutral it must have maximum area



⇒ FLEXORAL SHEAR STRESS VARIATIONS

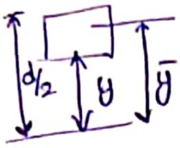
①





WKT, $\tau = \frac{FA\bar{y}}{Ib}$

Here $A = b\left[\frac{d}{2} - y\right]$

If there is  then $\bar{y} = \frac{1}{2}\left(\frac{d}{2} + y\right)$

Then eqn becomes $\tau = F \times b\left[\frac{d}{2} - y\right]\left[\frac{d}{2} + y\right] \times \frac{1}{2}$

$$\boxed{\tau = \frac{6F}{bd^3}\left[\frac{d^2}{4} - y^2\right]}$$

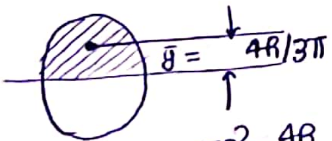
i.e $\boxed{\tau \propto y^2} \rightarrow$ parabola

If $y = 0$ then $\tau = \frac{6F}{bd^3}\left[\frac{d^2}{4}\right]$ ⇒ $\tau_{max} = \frac{3}{2}\frac{F}{bd} \rightarrow \tau_{avg}$

$$\boxed{\tau_{max} \text{ at } y = 0 \text{ is } \frac{3}{2}\tau_{Avg}}$$

If $y = d/2$ then $\tau = 0$ then τ diagram would be  $\tau_{max} = \frac{3}{2}\tau_{avg}$.

② CIRCLES



& WKT $A = \frac{\pi R^2}{2}$ & $\tau_{max} = \frac{FA\bar{y}}{Ib}$

$$\tau = \frac{F \times \frac{\pi R^2}{2} \times \frac{4R}{3\pi}}{\frac{\pi R^4}{4} \times 2R} = \frac{4}{3}\frac{F}{\pi R^2}$$

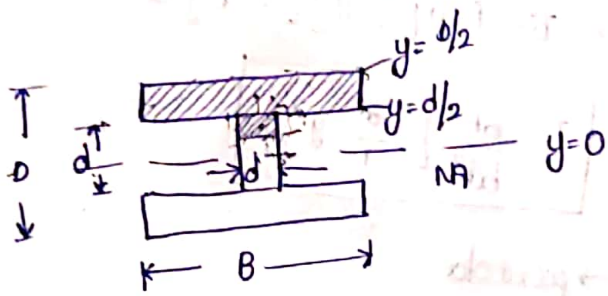
$$\boxed{\tau_{max} = \frac{4}{3}\tau_{avg}}$$

$\tau \propto \frac{1}{R^2}$ — parabolic

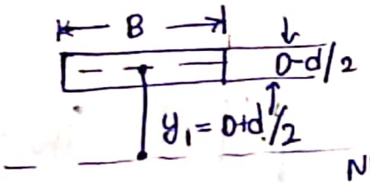
&  $\tau_{max} = \frac{4}{3}\tau_{avg}$

SECTION	τ_{max}/τ_{avg}	τ_{NA}/τ_{avg}
□	$\frac{3}{2}$	$\frac{3}{2}$
○	$4/3$	$4/3$
△	$\frac{3}{2}$	$\frac{4}{3}$
◇	$\frac{9}{8}$	1

(8) I-SECTIONS

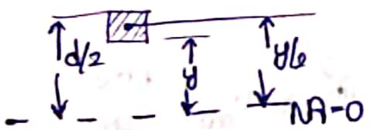


$$\tau = \frac{F}{Ib}[A\bar{y}]$$



$$A = \frac{B}{2}[D^2 - d^2], \quad y' = \frac{d}{2} + \frac{D-d}{4} = \frac{1}{4}(D+d)$$

$\frac{2d+D-d}{4}$

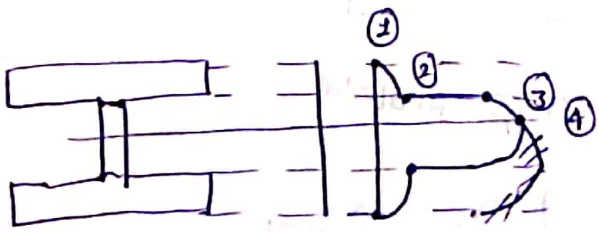


$$A_2 = \left(\frac{d}{2} - y\right)b, \quad y_2 = \frac{1}{2}\left[\frac{d}{2} + y\right]$$

$$\Rightarrow \tau = \frac{F}{Ib}[A\bar{y}] = \frac{F}{Ib}[A_1\bar{y}_1 + A_2\bar{y}_2]$$

$$\boxed{\tau = \frac{F}{Ib}\left[\frac{B}{8}\left(\frac{D^2-d^2}{1}\right) + \frac{b}{2}\left(\frac{d^2}{4} - y^2\right)\right]}$$

$$\tau_{max} = \frac{F}{8Ib}\left[B(D^2 - d^2) + bd^2\right]$$



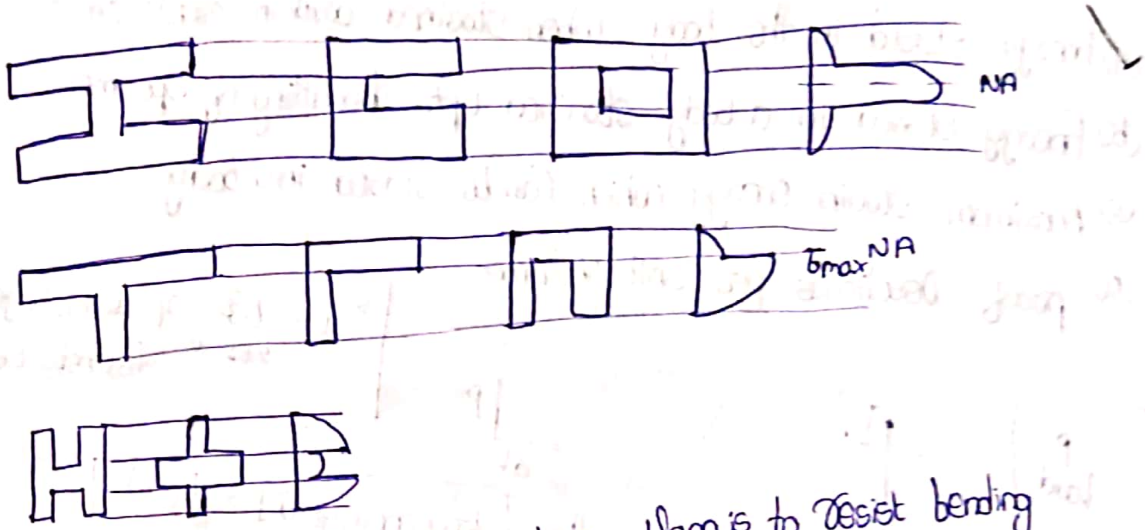
① → At top of flange $y = \frac{D}{2}$ then $\boxed{\tau = 0}$

② → At End of flange ie $B = b$ then $\boxed{\tau = \frac{F}{8I}(D^2 - d^2)}$

③ → At start of web ie $\tau = \boxed{\frac{F}{8Ib}[B(D^2 - d^2)]}$

④ $\tau_{max} = \frac{F}{8Ib}[B(D^2 - d^2) + bd^2]$

⇒ $Z = \frac{FA\bar{y}}{Ib}$ then $\boxed{Z \propto \frac{1}{b}}$



* ① In flanged beam web is to resist shear, flange is to resist bending

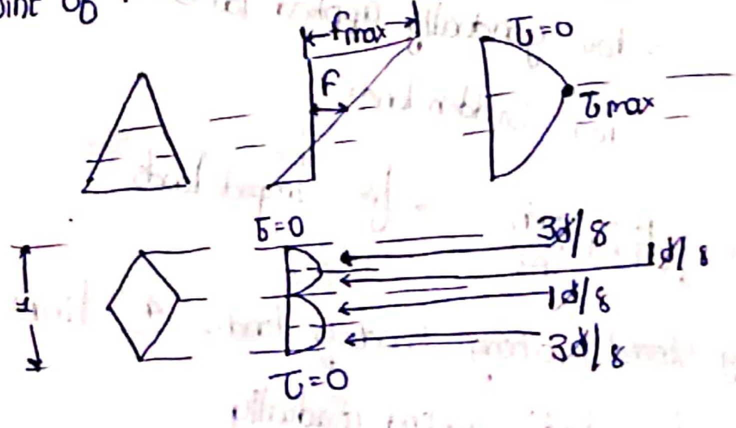
② For vertical load without torsion both I & Box Section are Equally Stronger [with same depth & CS area]

③ If slight torsion is acting then Box Section is better.

4 Bending is prime Criteria for design and shear is Secondary.

5 At the point of maximum bending stress, shear stress must be zero

6 At the point of maximum shear stress bending need not to be zero

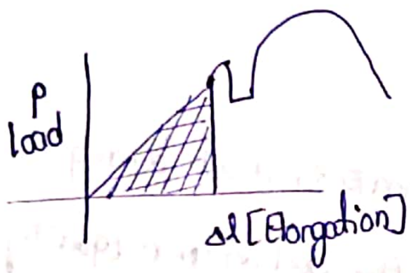


⇒ STRAIN ENERGY :-

1. Energy stored in a body within elastic limit is known as "strain energy".
2. Total strain energy stored in a body is termed as "resilience"
3. Maximum strain energy which can be stored in a body is "proof resilience"
4. Strain energy is the
   (a) ✓ Energy stored in the body when strained within elastic limit
   (b) Energy stored in a body strained upto breaking of specimen
   (c) Maximum strain energy which can be stored in a body
   (d) proof resilience per unit volume.

& $U = \frac{M^2 L}{2EI}$ } If beam is subjected to constant B M

5.



then $\boxed{\text{strain energy}[U] = \frac{1}{2} P \Delta l}$

$= \frac{1}{2} \times P \times \frac{Pl}{AE} \times \frac{A}{A}$

& strain energy $= \int_0^L \frac{M^2}{2EI} dx$

$U = \frac{P^2 Al}{2A^2 E} = \frac{P^2}{A^2} \frac{AL}{2E}$

& $u = \frac{1}{2} \times \sigma \times \epsilon \times vol$

$\boxed{U = \frac{p^2}{2E} \times V}$ & $\boxed{u = \frac{P^2 L}{2AE}}$

& $\boxed{u = \frac{1}{2} \times \sigma \times \epsilon \times vol}$

* for shafts $\boxed{U = \frac{T^2 L}{2GJ}}$

6. $\sigma = \frac{P}{A}$ → for gradually applied loads

$\sigma = \frac{2P}{A}$ → for sudden loads

$\sigma = \frac{P}{A} + \sqrt{\left(\frac{P}{A}\right)^2 + \frac{2EPh}{AL}}$ → for Impact loads

7. Strain energy stored in a body suddenly load is <u>4</u> times strain energy when same load is applied gradually

8. Strain energy stored in body when load is applied gradually is $\frac{\sigma^2}{2E}$

stress in sudden load is $2P/A$

⇒ SPRINGS

Spring is an elastic member whose function is to store energy when load is applied by temporary deformation and comes back to original position when it is removed.

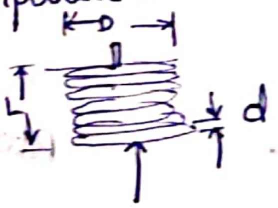
⇒ Applications

1. To control vibration & forces
2. To control motion in link mechanism.
3. To apply forces
4. To measure forces.

Ex- Cam followers, springs in weight balances, dynamometers, springs in clocks, watches, suspension systems etc

→ Types of springs- (i) Helical spring (ii) Conical spring (iii) Torsional spiral spring. (iv) Leaf spring

① Solid length- when the compression spring is compressed until all the coils comes in contact with each other



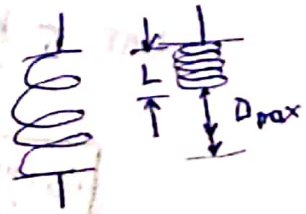
$$L = n \times d$$

n = no. of coils, d = dia of wire

D = Dia of coil

② Free length- It is the length of spring in uncompressed state

$$\text{Free length} = L + \Delta_{max}$$
$$= n \times d + \Delta_{max}$$



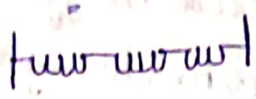
* ③ Spring index- Ratio of mean diameter of coil to diameter of wire

$$C = \frac{D}{d}$$

④ Spring Rate (or) Spring Constant (or) Stiffness:- load acting per unit deflection

$$k = \frac{W}{\Delta}$$

(1) IN SERIES:-

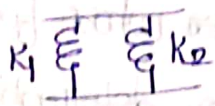


$$\frac{1}{k_{equ}} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3}$$

(OR)

$$\boxed{k_{eqn} = \frac{k_1 k_2}{k_1 + k_2}}$$

(2) IN PARALLEL:-



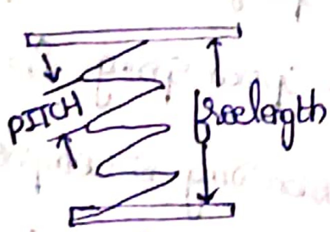
$$\boxed{k_{eq} = k_1 + k_2}$$

NOTE:-

Closed coil helical spring is cut into two equal parts stiffness of each spring compared to original spring is doubled.

& n equal parts stiffness increases by "n" times.

⑤ Pitch:- It is the axial distance b/w coils in uncompressed state.



$$\text{Pitch} = \frac{\text{free length}}{n-1}$$

⑥ DESIGN OF SPRINGS:-

Closed coil helical spring is designed similar to shaft subjected to torque

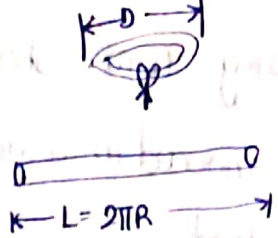
WKT $\tau = \frac{16T}{\pi d^3}$

$$\boxed{\tau = \frac{16WR}{\pi d^3}}$$

⑦ Angle of twist:-

WKT, $\frac{T}{\theta} = \frac{GJ}{l}$

$\Rightarrow \theta = \frac{Tl}{GJ}$ $\Rightarrow \theta = \frac{WR(2\pi R)}{G \times \frac{\pi}{32} d^4}$



$\theta = \frac{64WR^2}{Gd^4}$, $\boxed{\theta = \frac{64WR^2 n}{Gd^4}}$

where n = no. of Coils.

We know that displacement of linear $= r\theta$

linear Velocity $= r\omega$

linear Acceleration $= r\alpha$

Then ⑧ DEFLECTION:- $S = R\theta$

$\Delta = R\left[\frac{64WR^2 n}{Gd^4}\right]$ then $\boxed{\Delta = \frac{64WR^3 n}{Gd^4}}$

⑨ Stiffness:- $K = \frac{W}{\Delta} = \frac{W}{\frac{64WR^3 n}{Gd^4}}$

$$\boxed{K = \frac{Gd^4}{64R^3 n}}$$

⇒ LEAF SPRINGS:- These Springs are used in railway wagons, Coaches and road vehicles

2 Centre line of all the leafs are initially Circular with Same radius

3 All leafs becomes flat when Spring is Subjected to maximum load Called proof load.

① $\boxed{\sigma_b = \frac{3WL}{2nbt^2}}$ where b, t are breadth & thickness of plate

② $\boxed{\Delta = \frac{3WL^3}{8nEbt^3}}$ where

POINTS:-

1. Flat Spiral Spring is used in watches

2. Closed Coil helical Spring is Subjected to torque about its axis

› Spring wire should experience bending stress

3. Stress induced in a wire of closed coil helical spring subjected to axial loads

(a) torsional shear (b) bending stress (c) Transverse direct s

(d) all of the above

4. Maximum shear stress occurs on the outermost fibres in closed coil helical spring [Similar to shaft]

⇒ SIMPLE σ & ε ⇐

1. Strain energy for sudden load = $\frac{W^2L}{AE}$ & $\frac{P^2L}{AE}$ = $P\times\delta l$

2. For beam carrying u.d.l the strain energy will be maximum in case of cantilever beam.

3. A linear force deformation relation is obtained in materials having & following hooke's law

4. The ratio of stresses produced by suddenly applied & gradual load on a bar is $1+1=2$

5. The strain energy produced by suddenly applied & gradual load on a bar is $2+2=4$

6. Tangent modulus of elasticity is the slope of tangent drawn at a point in σ & ε curve

7. strain energy of beam depends upon
   - axial force
   - bending moment
   - torsional moment
   - shear force

8. when a member is subjected to axial tensile loads, the greatest normal σ is equal to $2\times\tau$

9. If P= Total load on Composite member

$$\text{then } P_1 = \frac{PA_1E_1}{A_1E_1+A_2E_2+\cdots}$$

$$P_2 = \frac{PA_2E_2}{A_1E_1+A_2E_2\cdots}$$

10. The strain energy stored in a spring when subjected to greatest load without going permanently distorted is called proof resilience

11. The greatest load which a spring can carry without getting permanently distorted is proof load

12. If the percentage of elongation is > 5% material is ductile & if it is < 5% material is brittle

13. In a composite beam, a couple is produced

14. Strain energy when subjected to B.M.M is $\int_0^L \frac{M^2}{2EI} dx$ = Clapeyron's theorem equal also

15. In Izod test specimen is supported as Cantilever beam & In charpy test specimen is supported as simply supported beam

16. Total strain energy upto fracture is "Toughness"

17. Strain energy is inversely proportional to bulk modulus.

18. Spring constant is the ratio of load per unit deflection.

19. Beams subjected to transverse force

20. The yield moment of a cross section is defined as the moment that will just produce the yield stress at outermost fibers of section

21. If the stress in each cross section of pillar is equal to its working stress it is called body of equal ~~stabilit~~ strength

22. The stress along the contact surface of rivet & member is bearing

23. In Brinell hardness test the type of intender is hard steel ball

24. In compression test the fracture in cast iron would occur along oblique 45° plane

25. $\tau = \frac{\sigma_{Normal}}{2}$ & $\left[\frac{\phi}{2} = \epsilon\right]$ → Half of shear strain = Normal ϵ

26. Strain energy = Just storing work done energy

Resilience = storing work done energy & releasing upon unloading

27. A prismatic bar of volume v and is subjected to a tensile force in longitudinal direction. If μ is μ and longitudinal ϵ then final volume of bar is $(1+e)(1-\mu e)^2 V$

(28) If young's modulus of elasticity is determined for mild steel in tension & compression, the two values will have $E_t/E_c = 1$

29. A rubber band is elongated to double its initial length, its true strain is 0.693

(30) If modulus of elasticity is zero then material is plastic.

(31) Compressibility is reciprocal of K

(32) Rectangular CS obtained from circular section then $\frac{b}{d} = 0.707$

(33) In creep test, specimen is subjected to Uniaxial tension.

(34) A tapering bar [dia of end sections being d_1 & d_2] & bar of uniform cross section 'd' have the same length and are subjected to same axial pull. Both the bars will have the same extension if $d = \sqrt{d_1 d_2}$

(35) for elastic material $E=K$

(37) young's modulus do not change with increase in Carbon Content

(38) If all the dimensions of a bar are increased in the proportion $n:1$, the proportion with which the Max σ produced in prismatic bar by own weight will increase in ration $n:1$

(39) True stress σ is related with Engg stress (σ_0) as $\frac{\sigma}{\sigma_0} = \frac{1}{1+E}$

(40) strain energy is ∝ to changes in strain.

41. strain energy is always a +ve scalar quantity

42. strain energy is +ve whether it is compression or tension.

43. As per elastic theory, $FS = \frac{\text{Yield } \sigma}{\text{Working } \sigma}$

(44) The stress along the contact surface of a rivet and the members is bearing σ

(45) The actual breaking stress of a material is greater than the ultimate strength

(46) For the materials which do not have a yield point from a tension test yield point is referred as the stress at which permanent set reaches the value 0.2%

(47) The lower yield point is more significant than upper yield point, bcoz it is less influenced by shape of specimen

(48) The brittleness test is done on brittle material & crack is 45° cross in oblique plane
↓
Compression

(49) The assumption that the cross section plane before bending remain plane after bending means the strain in the fibres are proportional to their distances from neutral axis.

50. The assumption that material is homogeneous and isotropic and has same value of E in ten & comp implies that stress & strain in all fibres

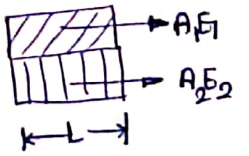
(51) Stress necessary to cause a non proportional or perimeter extension equal to a fixed percentage of gauge length is proof stress

(52) $\frac{AE}{L}$ = Axial stiffness of bar

(53) $\frac{EI}{L}$ = flexural stiffness

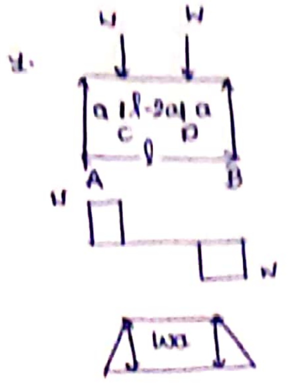
(54) Equivalent youngs modulus of parallel composite members

$$\boxed{E_{\text{Equivalent}} = \frac{A_1E_1 + A_2E_2}{A_1 + A_2}}$$



→ SFD & BMD ←

1.



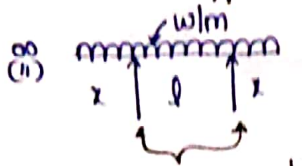
$SF)_{max}$ at A & B = W & -W

$BM)_{max}$ at C & D = Wa (+ve)

2. In over hanging beams :-

(i) B.M at Support is always -ve.

(ii)



Support moment is always -ve

$Bm)_{max}$ at Centre $= +\frac{w(l^2-4x^2)}{8}$ at mid span

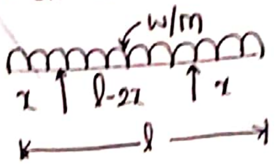
$Bm)_{max}$ at Support $= -\frac{wx^2}{2}$

P.O.C is $x = \frac{l}{2} - \frac{\sqrt{l^2-4a^2}}{2}$ from Supports

(iii) Max +ve B.M equal to Max -ve BM in below case

when $x = 0.207l$ →

$x = \frac{L}{2\sqrt{2}}$



3. B.M is max where SF is zero or changes its sign.

4. $\frac{dF}{dx} = -W$ & $\frac{dM}{dx} = F$, where F = shear force

Slope of BM Curve

5. If SF is Constant b/w two sections, B.M varies linearly

6. If SF is zero b/w two sections, B.M Constant b/w Sections

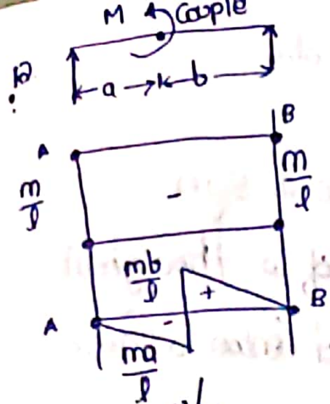
7. If BM is zero, then SF is zero

8. In a Cantilever the B.M at any section of beam is equals to the area of SFD b/w the free end and the section.

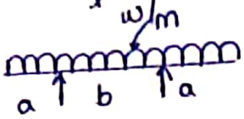
9. The shear force on a beam is proportional to Curvature of the axis

10. change in BM is the area of SFD

11. change in SF is the area of loading

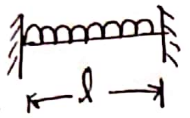
12. 

* Rectangular SFD
* Both +ve & -ve BM are max at point of application of the Couple

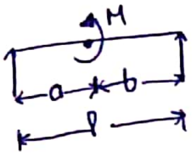
13. 

there BM at mid span is 0 if $\frac{a}{b} = 0.5$ & $a = \frac{b}{2}$

14. The expression for the elastic curve at free end of Cantilever beam when subjected to udl is $WL^4/8EI$

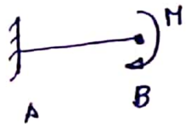
15. 

→ P.O.C is at $\frac{L}{2\sqrt{3}}$ from Centre.

16. 

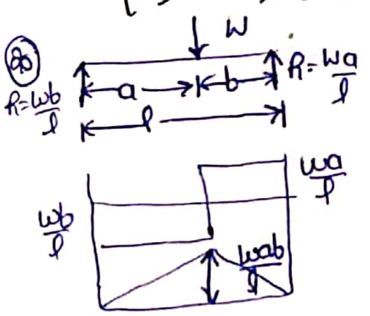
then SF at POC is $\frac{M}{L}$

17. In a rigid jointed frame the joints Considered as to rotate only as a whole

18. 

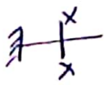
$\Rightarrow \delta_B = \frac{ML^2}{2EI}$

19. $M = \left(\frac{wl}{2} \cdot x - \frac{wx^2}{2}\right)$ } general expression for udl on beam

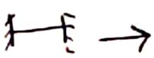
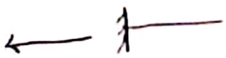
(20) 

(21) In SS beam under load SF is zero &

(21) when SF changes its sign, there BM is max

22. In  BM at any section = area of S.F.D b/w free end & Section xx

23. SF ∝ Curvature of axis i.e. $\frac{1}{R}$

(24)  → BM_{max} occurs at Support ← 

&  → Bm_{max} Occurs under load

8. BMD →  } ss beam & moment applied at c

(6) The slope of BM changes its sign when SF changes it sign

Q7. A Simply Supported beam AB carries udl of w throughout the span. what Concentrated load should be applied at Centre to cause Same bm as udl is $\frac{wl}{2}$

=> BENDING STRESSES <=

1. Due to bending moments, bending stresses are developed
2. when a beam is subjected to Constant bending moment, then it is uniform strength of beam then $\boxed{d \propto \sqrt{m}}$
3. when a beam is subjected to pure bending assumes a shape of arc of circle
4. Two beams one of Circular Section and the other a Square Section of Same length Same strength the ratio of length Same strength the ratio of weights of Circular Section to Square is 1.118
5. If two beams of Circular Section and the other Square Section have equal area of Cross Section If Subjected to bending then Square Section is more economical than Circular Section.
6. The ratio of flexural strength of Square Section with its two sides horizontal to its diagonal horizontal is $\sqrt{2}$
7. The intensity of direct longitudinal stress in the Cross Section at any point distant r from neutral axis, it is proportional to r
8. The Curvature at any point $\left(\frac{1}{R}\right)$ along the Curve representing the deflected shape of a beam is given by $\pm \dfrac{\frac{d^2y}{dx^2}}{\left[1+\left(\frac{dy}{dx}\right)^2\right]^{3/2}}$, here denominator has negligible value, hence $\frac{1}{R} = \frac{M}{EI} = \frac{d^2y}{dx^2} \pm$
9. Moment of resistance = strength $\propto Z$
10. from $\frac{M}{I} = \frac{F}{y} = \frac{E}{R}$ here $\boxed{F \propto y}$, Hence outermost fibre are having Max bending σ.
11. If Two beam of equal Cross Section area & Subjected to equal bending moment then Square Section is stronger than Circle

12. most efficient & economical Section of beam is I-Section to resist bending

13. The ratio of length and diameter of a Simply Supported uniform Circular beam which experiences max bending σ equal to tensile σ due to Same load at mid span is $\frac{1}{2}$

(14) The bending stress at the outer fibre, is Known as "principle σ"

(15) Keeping the breadth as Constant, depth of a Cantilever length 'l' of uniform strength loaded u.d.l is $\sqrt{\frac{3w}{\sigma b}} \times l$ at fixed end

(16) Keeping the depth 'd' Constant the width of Cantilever length 'l' of uniform strength loaded with u.d.l ~~at~~ is $\frac{3w}{\sigma d^2} \times l^2$ at fixed end

17. The ratio of length and depth of a SS beam which experiences max bending stress equal to tensile σ due to Same load at mid span is $\frac{2}{3}$

18. The ratio of moment of inertia about the neutral axis to the distance of the most distant point of Section from neutral axis is Section modulus

19. $F = \frac{dM}{dx}$ rather than $F = \frac{M}{Z}$

20. The permissible stress in fillet welds used during erection is reduced by 20%

(21) The Slenderness ratio of lacing bars should not be exceed 145

(22) The load Carrying Capacity is primarily governed by Slenderness Ratio

(23) The loss in prestress in the tendons due to Creep in Concrete is given as 5 to 8%

(24) Twisting moment is applied in plane of c.s about zz axis

(25) In the Case of thin Cylinders, the stress distribution Across the thickness of wall is uniform

(18) The spring used in spring balances is close coiled helical spring

(19) The stiffness factor for a beam fixed at one end & free at other is

$\frac{3EI}{L}$

(20) Thick cylinders are analysed based on poisson's theory

(21) for ductile materials, the most appropriate failure theory is
Maximum shear stress theory

(22) The maximum shear stress in a thin tube is $\frac{1}{2}$ half of Avg σ [shear stress]

⇒ SHEAR STRESSES ⇐

1. If the vertical shear force given rise to horizontal shear force. Then it is called <u>Complimentary shear</u>

2. $\tau = \frac{FA\bar{y}}{Ib}$ & Horizontal shear = $\tau_h = \frac{FA\bar{y}}{I}$ per unit width

3. shear is carried by web & bending is carried by flange.

4. The max stress is 50% more than τ_{avg} for rectangular section

5. Then max τ is 33.33% more than τ_{avg} for circular section

4. for Hollow circular section $q_{max} = \tau_{max} = 2\tau_{avg}$

⑦ τ is max at <u>Centroid</u>

8. for ▭ ^{les} τ at 'y' distance from N.A is $\frac{6F}{bd^3}\left[\frac{d^2}{4}-y^2\right]$ (shear force)

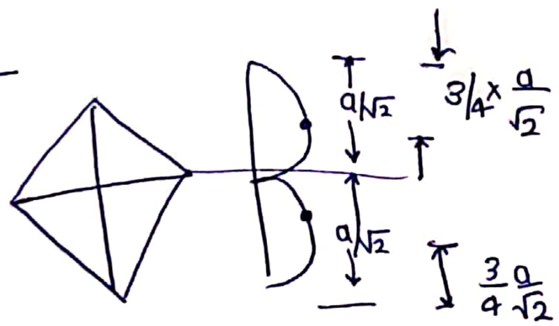
9. The variation of shear stress on a plane parallel to the neutral plane in a beam is caused by udl is <u>Linear</u>

10. for ◯ ^{les} τ at 'y' from NA is $\frac{16}{3}\frac{F}{\cancel{bd}4}\times\frac{1}{\pi}\left[d^2-4y^2\right] = \frac{16}{3}\frac{F}{\pi d^4}(d^2-4y^2)$

11. A beam of Δ^{les} cross section of base b & height h. The τ will be max at distance of <u>$\frac{h}{2}$ from bottom</u>

12. when a beam is subjected to bending the most economical section is <u>Square</u>

13. A bar of square section of area a^2 is held such that one of its diameter is vertical. The maximum τ will develop at a distance h where h is <u>$\frac{3}{4}\times\frac{a}{\sqrt{2}}$</u>



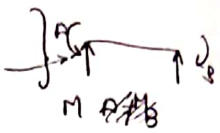
14 [(i) For most of section i.e Circular, Square, Rectangular & Δ^{le} Max τ is <u>at middepth</u>

⇒ DEFLECTION OF BEAMS ⇐

1. The $\underbrace{\text{Curved shaped}}_{\text{Curved shape of deflection points.}}$ of the axis is Called elastic Curve (or) elastic axis.

2. Beams of uniform strength ⇒ $b = \frac{6M}{Fd^2}$

3. $\delta l = \frac{l^2}{8R}$ at Centre If $\overset{S.S}{,}$ beam of length 'L' bending into Circular arc.

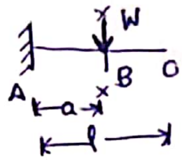
   & $\theta_A = \frac{Ml}{2EI}$ & $\theta_B = -\frac{Ml}{2EI}$ & $\Delta_{max} = y_{max} = \frac{ML^2}{8EI}$ = 

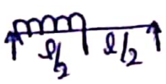
   $M_A = M_B$

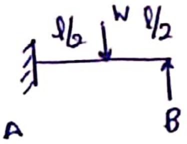
4. $-(M) = EI \frac{d^2y}{dx^2}$

   then $\int M = EI \iint \left(\frac{d^2y}{dx^2}\right)$ ⇒ $\int M = EI \frac{dy}{dx}$ } slope

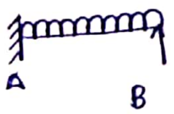
   $\iint -M = EI \iint \frac{d^2y}{dx^2}$ ⇒ $\int M = EI \cdot y$ } deflection.

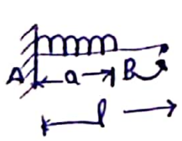
5.  $\Delta_C = \frac{Wa^3}{3EI} + \frac{Wa^2}{2EI}[l-a]$

6.  then δy_{max} at Centre $= \frac{1}{2}\left(\frac{5}{384}\frac{wl^4}{EI}\right) = \frac{wl^4}{EI} \times \frac{5}{768}$

7.  $R_B = \frac{5}{16} \cdot W$

   $P.O.C = \frac{3}{11} l$ from A [fixed end]

8.  $P.O.C = \frac{3}{4} l$ from free end. (or) $\frac{l}{4}$ from fixed end.

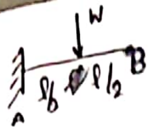
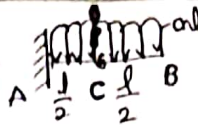
9.  then $\Delta_{B\,max} = \frac{wa^4}{8EI} + \frac{wa^3}{6EI}(l-a)$

10. The differentiation of elastic lines is <u>B.M</u>

11. The Second differentiation of elastic line is <u>load</u>

12. $\frac{d\theta}{dx} = SF$

13.  then $\theta_B = \frac{wl^3}{24EI}$ & $\Delta_B = \frac{wl^4}{30EI}$

14.  then $y_B = \delta_B = \Delta_B = \frac{5wl^3}{48EI}$ &  only udl then $y_C = \delta_B = \frac{7wl^4}{384EI}$

15. The ratio of the deflection of the free end of a Cantilever is due to an isolated load at $\frac{1}{3}$rd & $\frac{2}{3}$rd of Span is $\underline{2/7}$

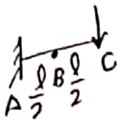
(16) In SS beam → Support - slope max & under load - Δy_{max} & $\theta = 0$

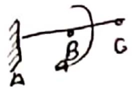
In Cantilever → free end - Δy_{max} & θ_{max}

fixed beam → At fixed end - slope & $\Delta y = 0$

→ At poc — slope is max

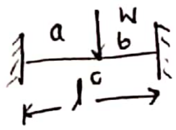
→ under load - Δy_{max}

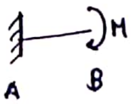
(11)  then $y_B = \delta_B = \frac{5wl^3}{48EI}$

(12)  then $y_C = \delta_C = \frac{3ML^2}{2EI}$

(13) A SS beam, Then $\frac{\Delta y_{max}}{f_{bending}} = \frac{L^2}{6Ed}$

(14) Slope and deflection of beam Varying flexural rigidity may be Computed by $\underline{\text{Conjugate mtd}}$ & Some times mohr's mtd also.

(15)  then $y_c = \frac{Wa^3b^2}{3EIl^3}$

(16)  then $\theta_B = \frac{ML}{EI}$ & $\Delta y_{B\,max} = \frac{ML^2}{2EI}$

(17) The deflection in any beam as per Castigliano's theorem is $\underline{\int \frac{M^2}{2EI}dx}$

(18) when $\theta = 0$ i.e y is max

=> TORSION <=

1. The ratio of strain energy stored by a hollow shaft of external dia 'D' and internal dia 'd' to that strain energy stored by a solid shaft of dia 'D' per unit vol is $\frac{D^2+d^2}{D^2}$

2. Torque required to produce unit angle of twist per unit length is Torsional rigidity

3. Torsional strength of a shaft is proportional to $\frac{J}{R}$ = polar section modulus

4. A Solid Circular shaft has been subjected to pure torsion moment. The ratio of max shear σ to max normal σ is 1:1

5. when a rectangular bar is subjected to torsion, max τ will occur at middle of longer side

6. A Circular shaft is subjected to torque T which is half of the bending moment applied, then the ratio of max bending stress & max shear stress is 2 } thappu undadhi

7. The statement that plane section before twisting will be plane even after twisting is applicable for only hollow & Circular Sections

8. A shaft is subjected to a bending moment M & torque T Simultaneously. The ratio of max bending stress to max shear stress is $\frac{2M}{T}$

9. The strength of the shaft = Maximum torque = power transmitted by shaft

10. The ratio of max shear stresses developed in a solid shaft of dia 'D' & a hollow shaft of external dia 'D' & internal dia of same torque is $\frac{D^4-d^4}{D^4}$

(11) The ratio of moment of resistance of solid to hollow shaft is $\frac{D^4}{D^4-d^4}$

(12) The ratio of $\frac{J}{R}$ = polar section modulus or Torsion section modulus

(13) $P = \frac{2\pi NT}{60}$ Watt & $P = \frac{2\pi NT}{60,000}$ KW

Here N = revolutions per minute

(13) $\boxed{P = T \times \omega}$ → ω = Angular Speed in rad/sec = $\frac{2\pi N}{60}$.

⇒ COLUMN & STRUT ⇐

1. Rankine's formula $= P_R = \dfrac{f_c A}{1+\alpha\lambda^2}$

where $\alpha = \dfrac{f_c}{\pi^2 E}$

2. Rankines formula for eccentric Columns

$$P = \frac{f}{\left(1 + \frac{e y_o}{k^2}\right)}$$

3. Secant formulae for eccentric Columns

$$f_{max} = P_o \left[1 + \frac{e y_c}{k^2} \sec \frac{1}{2}\sqrt{\frac{P}{EI}}\right]$$

4. The basis of I.S.I Code formula is Secant formula
5. Eulers formula is not valid when $\lambda < 80$
6. The Critical length of Column corresponds to neutral equillibrium.
7. Rankine's Constant for timber $= \frac{1}{750}$
8. for max strength of a Column $I_{xx} = I_{yy}$
9. If

$\lambda \leq 80 \rightarrow$ short colums

$80 \leq \lambda \leq 120 \rightarrow$ Medium Colomns

$120 \ngtr \lambda \rightarrow$ long Coloms

⇒ DAMS & RETAINING WALLS ⇐

① For water, the angle of repose is "0".

② To Avoid tension at base :-

(i) for Δ^{ler} $b = \frac{H}{\sqrt{s}}$

(ii) for $\square^{ler}$ $b = \frac{H}{\sqrt{s}}$

(iii) for trapezoidal $ab + b^2 = a^2 + \frac{H^2}{s}$

③ For No sliding Condition :-

(i) for Δ^{ler} $b = \frac{H}{\mu s}$

(ii) for $\square^{ler}$ $b = \frac{H}{2\mu s}$ ~~H/x~~

(iii) for trapezoidal $b = \frac{H}{\mu s} - a$

Here s is sp gravity of dam material

④ The plane of rupture is inclined at $\left(\frac{\pi}{4} + \frac{\phi}{2}\right)$ with horizontal

⑤ As per Rankines theory, the inclination of the resultant stress with the normal to the plane $> \phi$

⑥ As per Rankine's theory $\frac{P_{max} - P_{min}}{P_{max} + P_{min}} < \sin\phi$

⑦ min depth of foundation ⇒ $h = \frac{P}{A\gamma_s}\left[\frac{1-\sin\phi}{1+\sin\phi}\right]^2$

P = Total load on Wall

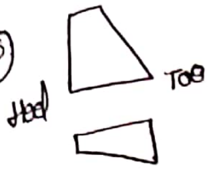
⑧ In Rebhann's graphical method the total active earth pressure is equal to the area of pressure Δ^{le} multiplyed by Specific wt of Earth

⑨ For Cohesive soils, $\phi = 0^\circ$

⑩ For Sand, $\phi = 30^\circ$

⑪ The total active Earth pressure for a retaining wall subjected to Surcharge is $\frac{1}{2} K_a w_e H^2 + K_a w H$

(12) Resultant force = $\sqrt{\text{pressure}^2 + \text{wt of dam}^2}$.

(13) 

Max Comp σ at Toe
Min σ Com at heel

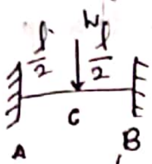
⇒ FRAMES ⇐

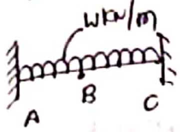
(1) Degree of indeterminacy = $D_S = 3c + r - 3$

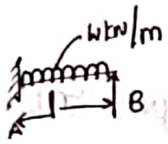
c = no. of closed rings

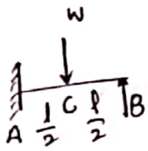
r = Total no. of Support reaction Components

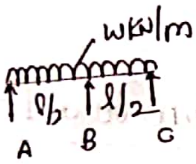
⇒ FIXED, CONTINOUS & PROPPED CANTILEVER ⇐

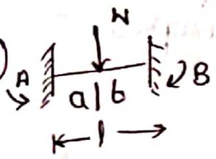
(1) 
then Max BM at A, B & C $= \frac{wl}{8}$ | p.o.c at $\frac{L}{4}$ from Supports [fixed Support]

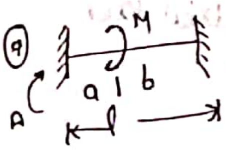
(2) 
$Max\ Bm)_{ABC} = \frac{wl^2}{12}$ & $Bm @ C = \frac{wl^2}{24}$ | p.o.c at $0.212L$ from supports & $\frac{L}{2\sqrt{3}}$ from Centre

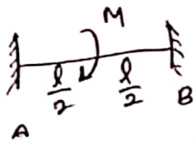
(3) 
$R_B = \frac{3wl}{8}$ | Max Bm occurs @ Centre | p.o.c is $\frac{l}{4}$ from fixed end & $\frac{3l}{4}$ from free end

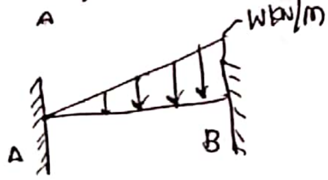
(4) 
$R_B = \frac{5}{16} W$ | Max Bm Occurs at $\frac{3}{8} l$ from free end | p.o.c is $\frac{3L}{11}$ from fixed end, " $\frac{3}{11}$ from fixed end

(5) 
$R_B = \frac{5wl}{8}$ & $M_B = \frac{[WL^2]}{32}$ [Hogging]

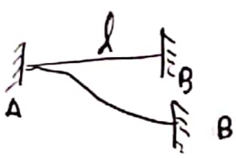
(6) 
$M_{AB} = \frac{-Wab^2}{l^2}$ & $M_{BA} = \frac{Wa^2b}{l^2}$

(7) 
$M_{AB} = \frac{Mb}{l^2}(2a-b)$ & $M_{BA} = \frac{Ma}{l^2}(2b-a)$

(8) 
then $M_{AB} = M_{BA} = \frac{M}{4}$

(9) 
$M_{AB} = -\frac{wl^2}{30}$

$M_{BA} = \frac{wl^2}{20}$

(10) 
⇒ $MF_{AB} = MF_{BA} = \frac{6EI\Delta}{l^2}$ ⇐ 

(11) 
⇒ $MF_{AB} = 0$ & $MF_{BA} = \frac{3EI\Delta}{l^2}$

→ OTHERS ←

1) The effect of arching a beam is to reduce bending moment throughout

2) Cylinders is thin - $l/d < 20$
thick - $l/d > 30$

3) Circumferential (or) hoop stress = $\frac{Pd}{2t}$
4) Longitudinal stress = $\frac{Pd}{4t}$
} p is internal fluid pressure causing tensile σ

5) Beams of uniform strength are preferred to those of uniform section because these are economical for large spans

⑥ Longitudinal cracks observed in timber beams are due to shear failure b/w layers

Cracks = shear failure.

⑦ The flexure formula $\frac{M}{I} = \frac{F}{y} = \frac{E}{R}$ is valid for static loads with no residual σ

⑧ When a close coiled helical spring is subjected to an axial compressive load the material will be subjected to shear σ

9. When an open coiled helical spring when subjected to an axial load, the material is subjected to B.M & Twisting moment

⑨ The $\frac{\delta V}{V} = \epsilon_v = \frac{\sigma d}{2tE}\left(\frac{5}{2} - \frac{2}{m}\right)$ in thin cylinders

(or)

$$\epsilon_v = \frac{Pd}{4tE}\left(5 - \frac{4}{m}\right)$$

⑩ Due to hoop stress longitudinal cracks are formed.

⑪ Max shear stress in cylindrical shed = $\tau_{max} = q_{max} = \frac{Pd}{8t}$

⑫ North light roof truss is used when light is criterion

13. When the stiffness of column increases, then its effective length decreases

14. Young's modulus of concrete is obtained from compressive strength test on concrete cube

6) The maximum BM for a purlin of length L and carrying a total vol of 'W' may be taken as $\frac{WL}{10}$

7) The ratio of GJ of a solid shaft to that of hollow shaft of same material and weight per unit length. If the internal diameter for hollow shaft is the half the external diameter is $\underline{3/5}$

8) The Conjugate beam for fixed beam is $\underline{\text{SS beam}}$

9) Thick Cylinders are analyzed by poisson's theory.

10) The Spring used in Spring balances in $\underline{\text{close coiled helical spring}}$

20) For ductile material, the most appropriate failure theory is

$\underline{\text{Maximum shear } \sigma \text{ theory}}$

21) The stiffness factor for a beam fixed at one end & other end free is $\frac{3EI}{L}$

22) A free body diagram is a the diagram of the body or a part of the body in isolated equillibrium

23) Compared to bending deformation, shear deformation is $\underline{\text{small}}$

24) In an overhanging beam with equal overhangs on either side

25) Conjugate beam of fixed beam is ssbeam

" of roller support is hinged support

26)

	Ductile	Brittle
Torsion test	45° crack	90° crack
Compression test	bulging	45° crack
Torsion test	90° crack	45° crack

Scanned with CamScanner