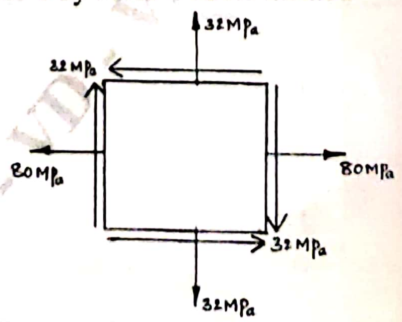
CBCS SCHEME

USN | | | | | | | | | | BME301

Third Semester B.E./B.Tech. Degree Examination, June/July 2024
Mechanics of Materials

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	M	L	C
Q.1	a.	Define the following with necessary equations: (i) Normal stress (ii) Shear stress (iii) Poisson's ratio (iv) Young's modulus (v) Thermal stress	10	L1	CO1
	b.	The tensile test was conducted on a mild steel bar. The following was obtained from the test: Diameter of steel bar = 16 mm ; Gauge length of the bar = 80 mm ; Load at proportionality limit = 72 kN ; Extension at a load of 60 kN = 0.115 mm ; Load at failure = 80 kN ; Final gauge length of bar = 104 mm ; Diameter of the bar at failure = 12 mm Determine: (i) Young's modulus (ii) Proportionality limit (iii) True breaking stress (iv) Percentage elongation (v) Percentage decrease in area	10	L3	CO1
		OR			
Q.2	a.	Write the relation between the following with usual notations and meaning: (i) Modulus of elasticity and bulk modulus (ii) Modulus of elasticity and modulus of rigidity (iii) Modulus of elasticity, modulus of rigidity and bulk modulus	06	L1	CO1
	b.	Define the following: (i) Gradual load (ii) Sudden load (iii) Impact load (iv) Shock load	04	L1	CO1
	c.	Rails laid such that there is no stress in them at 24°C. If the rails are 32 m long, determine: (i) The stress in the rails at 80°C, when there is no allowance for expansion. (ii) The stress in the rails at 80°C, when there is an expansion allowance of 8 mm per rail (iii) The expansion allowance for no stress in the rails at 80°C. Take $\alpha = 11 \times 10^{-6}$/°C, E = 205 GPa.	10	L3	CO1
		Module – 2			
Q.3	a.	Derive the expression for normal stress and shear stress on a plane inclined at 'θ' angle to the vertical axis in a biaxial stress system with shear stress.	10	L2	CO2
	b.	For the two-dimensional stressed element, shown in Fig.Q3(b), determine the value of: (i) Maximum and minimum principal stress (ii) Principal planes (iii) Maximum shear stress and its plane Verify the answer's by Mohr's circle method  Fig.Q3(b)	10	L3	CO2

OR

Q.No		Question	Marks	Level	CO
Q.4	a.	Derive an expression for circumferential stress and longitudinal stress for a thin cylinder subjected to an internal pressure 'P'.	10	L2	CO2
	b.	A thick cylinder of internal diameter 160 mm is subjected to an internal fluid pressure of 40 N/mm^2. If the allowable stress in the material is 120 N/mm^2, find the required wall thickness of the cylinder.	10	L3	CO2

Module – 3

Q.No		Question	Marks	Level	CO
Q.5	a.	Draw the shear force and bending moment diagrams for the cantilever shown in Fig.Q5(a).	10	L4	CO3

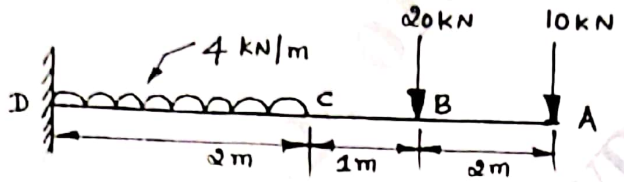


Fig.Q5(a)

Q.No		Question	Marks	Level	CO
	b.	Draw the bending moment and shear force diagram for the overhanging beam shown in Fig.Q5(b). Clearly indicate the point of contraflexure.	10	L4	CO3

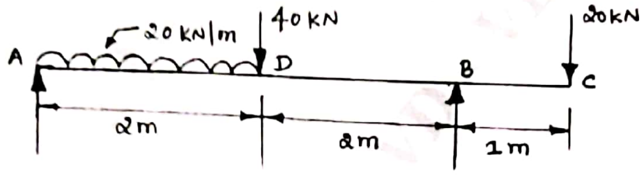


Fig.Q5(b)

OR

Q.No		Question	Marks	Level	CO
Q.6		A simply supported beam of 7m span with overhangs rests on supports which are 4m apart. The left end overhang is 2 m. The beam carries loads of 30 kN and 20 kN on the left and the right ends respectively apart from a uniformly distributed load of 25 kN/m between the supporting points. Draw the shear force and bending moment diagrams. Locate point of contraflexure if any.	20	L4	CO3

Module – 4

Q.No		Question	Marks	Level	CO
Q.7	a.	Derive the bending equation in the form of $\frac{M}{I}=\frac{\sigma}{Y}=\frac{E}{R}$.	10	L2	CO4
	b.	A square beam 20 mm × 20 mm in section and 2 m long is supported at the ends. The beam fails when a point load of 400 N is applied at the centre of the beam. What uniformly distributed load per metre length will break a cantilever of the same material 40 mm wide, 60 mm deep and 3 m long?	10	L3	CO4

OR

Q.No		Question	Marks	Level	CO
Q.8	a.	Derive an expression for section modulus of solid rectangular and circular sections.	10	L2	CO4
	b.	Fig.Q8(b) shows the cross-section of a beam which is subjected to a shear force of 20 kN. Draw the shear stress distribution across the depth making values at salient points.	10	L3	CO4

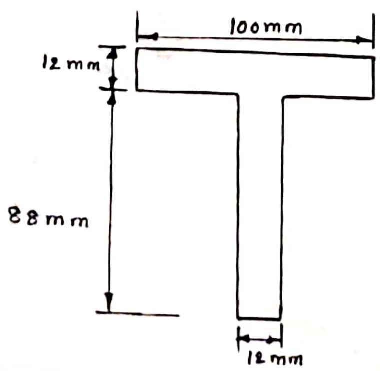


Fig.Q8(b)

		Module – 5			
Q.9	**a.**	Define the following with necessary equations: (i) Torque (ii) Polar modulus (iii) Torsional rigidity	**06**	**L1**	**CO5**
	b.	State the assumptions made in theory of torsion.	**04**	**L1**	**CO5**
	c.	Derive torsion equation in the form of $\frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{L}$.	**10**	**L2**	**CO5**
		OR			
Q.10	**a.**	Define the following: (i) Column (ii) Buckling load (iii) Slenderness ratio (iv) Long column (v) Short column	**10**	**L1**	**CO5**
	b.	Derive an expression for Euler buckling load when both ends of the column are fixed.	**10**	**L2**	**CO5**

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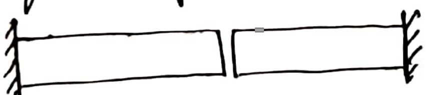
Solution and Scheme for award of marks

AY: 2023-24

Department: Mechanical Engineering
Subject with Sub. Code: Mechanics Of Materials (BME 301)
Name of Faculty: Prof.G.R.Sattigeri

Exam: June/July 2024
Semester / Division: III

Q.No	Solution and Scheme	Mks
	Module-1	
Q.1(a)	(i) Normal stress: The stress perpendicular to the plane (ii) Shear stress: The stress parallel to the plane (iii) Poisson's ratio: Ratio of lateral strain to longitudinal strain (iv) Young's modulus: The ratio of stress to strain within elastic limit (v) Thermal stress: Stress generated due to variation of temperature	10
(b)	Given: $d = 16\,mm$, $l = 80\,mm$, Load at proportional limit $= 72\,kN$, dl at $60\,kN = 0.115\,mm$ Load at failure $= 80\,kN$, $l_f = 104\,mm$, $d_f = 12\,mm$ Soln: (i) $E = \frac{\sigma}{\epsilon}$, $\sigma = \frac{60\times10^3}{\pi/4\,(16)^2} = 298.41\,N/m^2$ $= \frac{298.41}{1.43\times10^{-3}}$ $\epsilon = \frac{dl}{l} = \frac{0.115}{80} = 1.43\times10^{-3}$ $= 207.589\times10^3\,N/mm^2$ (ii) Proportional limit $\sigma = \frac{72\times10^3}{\pi/4\,(16)^2} = 358.09\,N/mm^2$	

Q.No.	Solution and Scheme	Mks
Q1 b	(iii) True breaking stress $\sigma = \frac{80\times10^3}{\pi/4\,(12)^2} = 707.35\ N/mm^2$	
	(iv) % elongation $= \frac{l_f - l}{l}\times100 = \frac{104-80}{80}\times100 = 30\%$.	
	(v) % decrease in area $= \frac{A-A_f}{A_f}\times100 = \frac{16^2-12^2}{16^2}\times100 = 43.75\%$	10
	OR	
Q2 a.	(i) Modulus of elasticity & Bulk modulus	
	$E = 3K(1-2\mu)$	
	(ii) E & G $\Rightarrow$ $E = 2G(1+\mu)$	06
	(iii) E, G & K $\Rightarrow$ $E = \frac{9KG}{G+3K}$	
b.	(i) Gradual load: Load which increases from zero to its full value in over time.	
	(ii) Sudden load: Load which is applied suddenly	
	(iii) Impact load: Load which falls through some height, Load with certain velocity.	04
	(iv) Shock load: shock load is measured in terms of energy.	
c	 Given: $T_1 = 24^\circ C$, $l = 32\,m = 32\times10^3\,mm$, $\alpha = 11\times10^{-6}/^\circ C$, $E = 205\,GPa$.	
	(i) $\sigma = \alpha t E = 11\times10^{-6}\times(80-24)\times205\times10^3 = 126.28\ N/mm^2$	
	(ii) When expansion allowance is 8 mm & $80^\circ C$	
	$\Delta = \alpha l \Delta t - 8 = \frac{\sigma l}{E} \Rightarrow \sigma = \frac{E}{l}(\alpha l \Delta t - 8)$	
	$\sigma = 205\times10^3(11\times10^{-6}\times32\times10^3\times(80-24) - 8) = 75.03\ N/mm^2$	
	(iii) Expansion allowance for no stress at $80^\circ C$	
	$= \alpha l \Delta t = 11\times10^{-6}\times32\times10^3\times(80-24) = 19.71\ mm$	10

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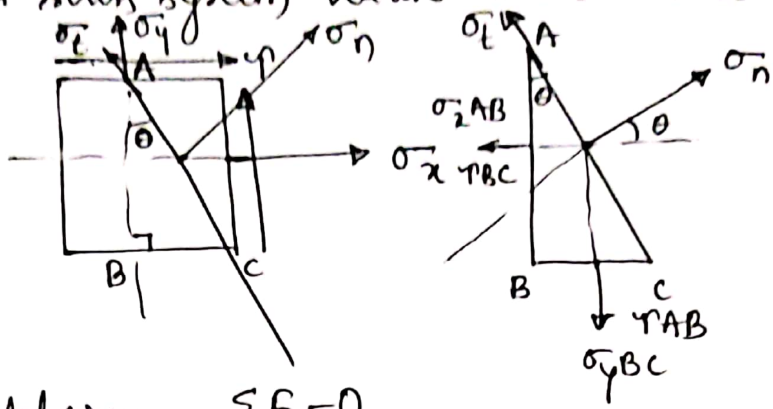
Q.No.	Solution and Scheme Module-2.	Mks

Q3a. Expression for normal stress & shear stress on a plane inclined at θ angle to vertical axis in a biaxial stress system with shear stress



For Equilibrium $\Sigma F_n = 0$

$$\sigma_n AC = \sigma_x AB\cos\theta + \tau BC\cos\theta + \sigma_y BC\sin\theta + \tau AB\sin\theta$$

$$\sigma_n = \sigma_x \frac{AB}{AC}\cos\theta + \tau\frac{BC}{AC}\cos\theta + \sigma_y\frac{BC}{AC}\sin\theta + \tau\frac{AB}{AC}\sin\theta$$

$$\sigma_n = \sigma_x\cos^2\theta + \tau\, 2\sin\theta\cos\theta + \sigma_y\sin^2\theta$$

$$\sigma_n = \sigma_x\left(\frac{1+\cos 2\theta}{2}\right) + \sigma_y\left(\frac{1-\cos 2\theta}{2}\right) + \tau\sin 2\theta$$

$$\boxed{\sigma_n = \left(\frac{\sigma_x+\sigma_y}{2}\right) + \left(\frac{\sigma_x-\sigma_y}{2}\right)\cos 2\theta + \tau\sin 2\theta}$$

Similarly $\Sigma F_t = 0$.

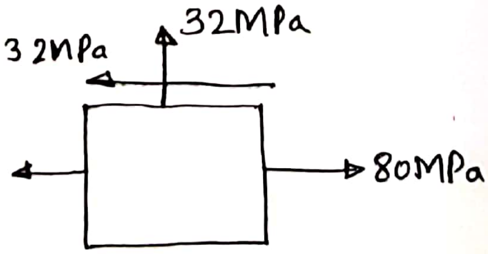
$$\sigma_t AC = -\sigma_x AB\sin\theta - \tau BC\sin\theta + \sigma_y BC\cos\theta + \tau AB\cos\theta$$

$$\sigma_t = -\sigma_x\frac{AB}{AC}\sin\theta - \tau\frac{BC}{AC} + \sigma_y\frac{BC}{AC}\cos\theta + \tau\frac{AB}{AC}\cos\theta$$

$$\sigma_t = -(\sigma_x - \sigma_y)\sin\theta\cos\theta + \tau(\cos^2\theta - \sin^2\theta)$$

$$\boxed{\sigma_t = \left(\frac{-\sigma_x-\sigma_y}{2}\right)\sin 2\theta + \tau\cos 2\theta}$$ 10

b.



$\sigma_x = 80\,MPa$

$\sigma_y = 32\,MPa$

$\tau = -32\,MPa$.

Q.No.	Solution and Scheme	Mks
Q 3.b.	(i) Maximum & Minimum Principal stresses	

$$\sigma_{n_{1,2}} = \frac{\sigma_x+\sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2+\tau^2} = \left(\frac{80+32}{2}\right) \pm \sqrt{\left(\frac{80-32}{2}\right)^2+(-32)^2}$$

$$= 56 \pm \sqrt{(24)^2+(32)^2} = 56 \pm 40$$

$$\sigma_{n_1} = 96 \text{ MPa} \qquad \sigma_{n_2} = 14 \text{ MPa}.$$

(ii) Principal planes.

$$2\theta_p = \tan^{-1}\left\{\frac{\tau}{\frac{\sigma_x-\sigma_y}{2}}\right\} = \tan^{-1}\left\{\frac{-32}{56}\right\} = -29.74^\circ$$

$$\theta_{p_1} = -14.87 \qquad \theta_{p_2} = -14.87+90 = 75.12^\circ$$

(iii) Maximum shear stress & its plane.

$$\text{Max shear stress } \sigma_{t_{max}} = \pm\sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2+\tau^2} = \sqrt{\left(\frac{80-32}{2}\right)^2+(-32)^2}$$

$$= \pm 40 \text{ MPa}.$$

$$2\theta_s = \tan^{-1}\left\{\frac{-\left(\frac{\sigma_x-\sigma_y}{2}\right)}{\tau}\right\} = \tan^{-1}\left\{\frac{-56}{-32}\right\} = 60.25^\circ$$

$$\theta_{s_1} = 30.12^\circ \qquad \theta_{s_2} = 120.12^\circ$$

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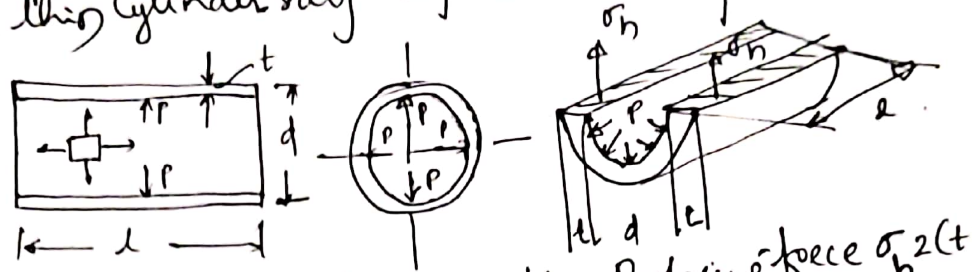
Q.No.	Solution and Scheme	Mks

OR

Q.4a. Expression for Circumferential & Longitudinal stress for a thin Cylinder subjected to internal pressure P



$\Sigma F_v = 0$ Bursting force $= p d l =$ Restoring force $\sigma_h 2(tl)$

$\therefore \boxed{\sigma_h = \frac{Pd}{2t}}$

Circumferential hoop stress

$\Sigma V = 0$ Bursting force $= p d l =$ Restoring force $= \sigma_c (2tl)$ 10

$\boxed{\sigma_C = \frac{Pd}{2t}}$

b. Given:

$d_i = 160\,mm$

$p = 40\,N/mm^2$

Allowable stress $= 120\,N/mm^2$

$p = \frac{b}{r^2} - a \Rightarrow 40 = \frac{b}{80^2} - a$ — (i)

Hoop stress is max at inner radii

$120 = \frac{b}{80^2} + a$ — (ii)

from ① & ② $b = 512000$ & $a = \frac{512000}{80^2} - 40 = 40$

Let external radius r_o Since external pr. is zero We get $0 = \frac{512000}{r_o^2} - 40 \Rightarrow r_o^2 = \frac{512000}{40} = 12800$

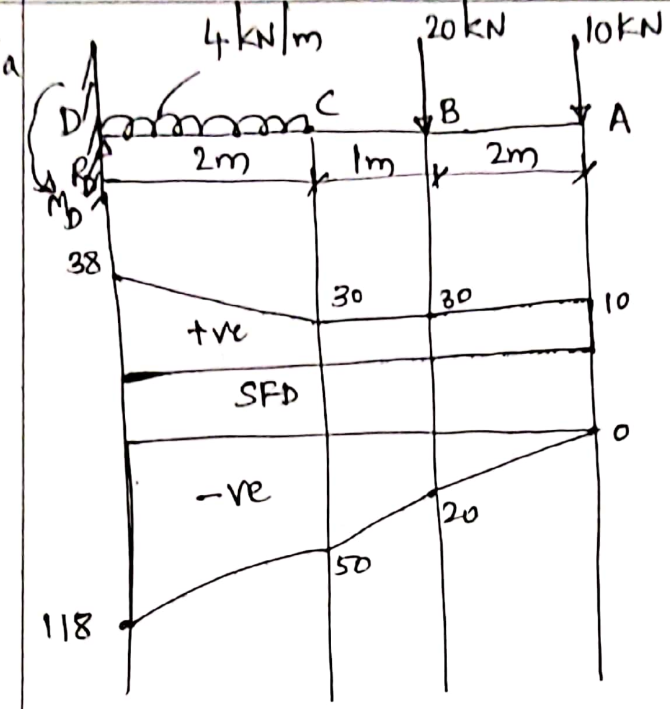
$r_o = 113.137\,mm$ Thickness of Cylinder $= 113.137 - 80$

$= 33.137\,mm$

Q.No.	Solution and Scheme	Mks

Module-3.

Q.5a



SFD

At A = +10 kN

AB = 10 kN

At B = 10+20 = 30 kN

BC = 30 kN.

AD = +38 kN.

BMD

At A = 0 kN-m.

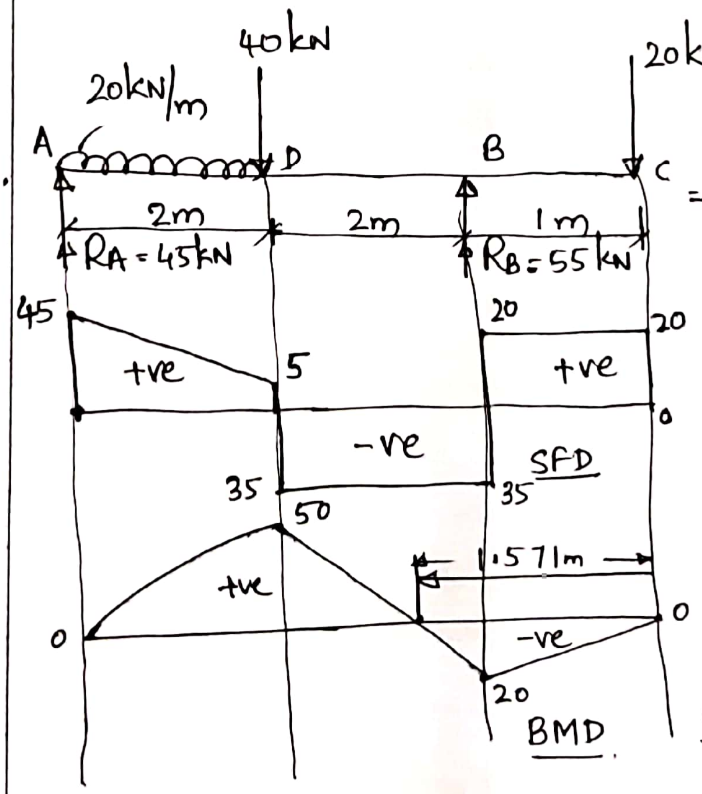
At B = -20 kN-m

At C = -10×3 - 20×1 = -50 kN-m

At D = -10×5 - 20×3 - 8×1

= -118 kN-m. 10

b.



M_B @ B

$= R_A \times 4 - 20\times2\times3 - 40\times2 + 20\times1 = 0$

$R_A = 45$ kN

$R_B = 40+40+20-45$

$= 55$ kN

SFD

At C = +20 kN

At B = +20 kN

At B = +20-55 = -35 kN

BD = -35 kN

At D = -35+40 = +5 kN

DA = 5+40 = 45 kN

BMD 10

At C = 0

At B = -20×1 = -20 kN-m

At D = -20×3 + 55×2 = +50 kN-m

At A = 0

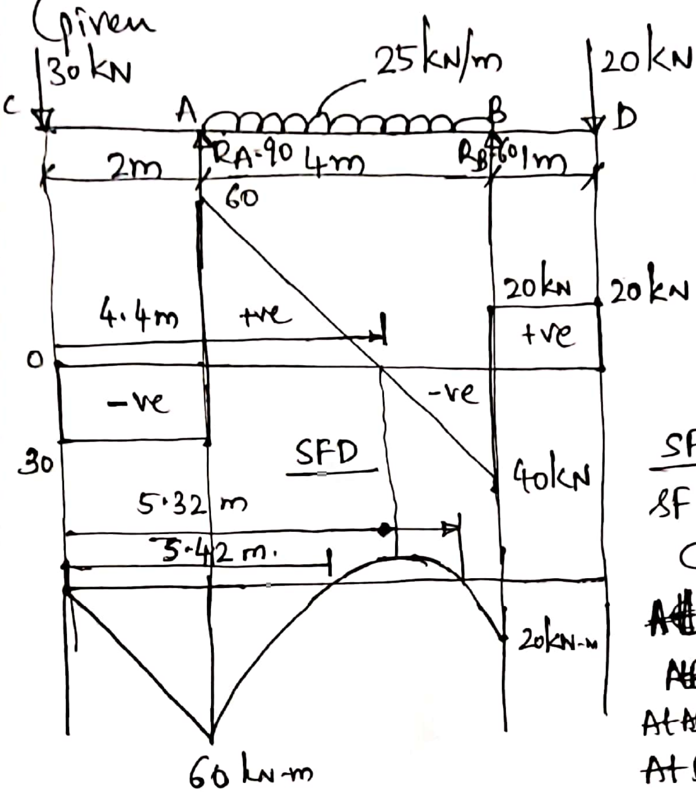
Point of Contraflexure

~~35x-55~~ $-20x + 55(x-1) \Rightarrow 35x - 55 = 0 \Rightarrow x = 1.571$ m

Q.No.	Solution and Scheme	Mks

OR

Q.6 Given



Taking moment @ B

$R_A \times 4 - 30\times 6 - 25\times 4\times 2 + 20\times 1 = 0$

$R_A = 90\,kN$

$R_B = 30+20+25\times 4 - 90$

$= 60\,kN$

SFD

SF at C = −30 kN

CA = −30 kN

~~At A~~ At A = −30 + 90 = +60 kN.

~~AB = −30 + 90 − (25×4) + 60~~

At AB = −30 + 90 − 25×4 = −40 kN

At B = −40 + 60 = +20 kN.

BD = +20 kN

At D = 20 − 20 = 0.

Shear force zero at $-30+90-25(x-2)=0$

$60+50-25x=0 \Rightarrow \quad x = 4.4\,m$

BMD

BM at C $\quad M_C = 0$

A $\quad M_A = -30\times 2 = -60\,kN\text{-}m.$

B $\quad M_B = -30\times 6 + 90\times 4 - 100\times 2 = -20\,kN\text{-}m$

D $\quad M_D = 0$

At $x = 4.4\,m$ $\quad M_{4.4} = -30\times 4.4 + 90(4.4-2) - 25\dfrac{(4.4-2)^2}{2}$

$= 5.5\,kN\text{-}m$

Point of Contraflexure points

$-30x + 90(x-2) - \dfrac{25(x-2)^2}{2} = 0$

$-30x + 90(x-2) - 12.5(x^2-4x+4) = 0$

$-30x + 90x - 180 - 12.5x^2 + 50x - 50 = 0$

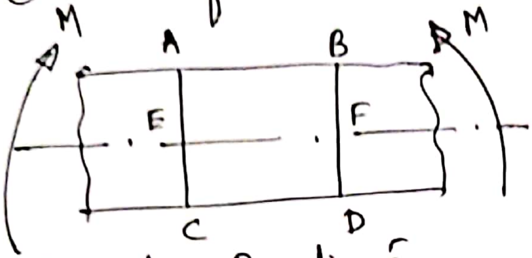
$12.5x^2 - 110x + 230 = 0. \qquad x_{1,2} = \dfrac{110 \pm \sqrt{110^2 - 4\times 12.5\times 230}}{2\times 12.5}$

$x = 5.38\,m \quad \& \quad x = 3.42\,m$ — 20M

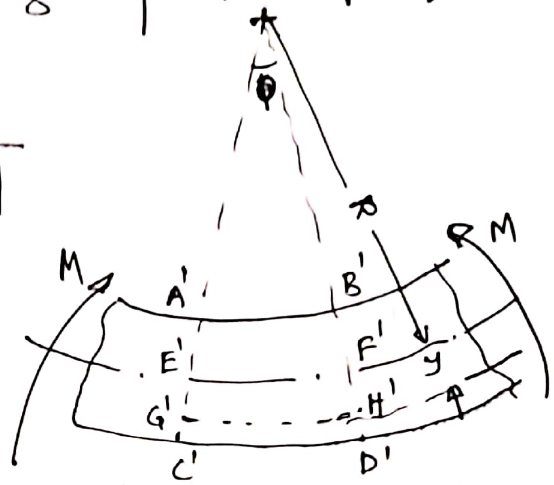
Q.No.	Solution and Scheme Module-4	Mks

Q.7a Derivation of Bending Equation. $\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$.

Assumptions
1. Stresses are within elastic limit
2. Plane sections remain plane even after bending.
3. Radius of Curvature is large compared to depth of beam



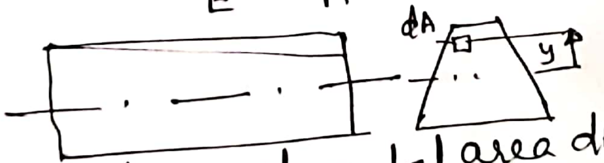
(A) Before Bending



Strain in the layer GH $= \frac{G'H' - GH}{GH} = \frac{(R+y)\theta - R\theta}{R\theta} = \frac{y}{R} = \epsilon$ — (1)

If σ_b is bending stress & E then $\epsilon = \frac{\sigma_b}{E}$ — (2)

Hence $\frac{\sigma_b}{E} = \frac{y}{R}$ — (3) or $\sigma_b = \frac{E}{R} y$ $\sigma_b \propto y$. $\frac{E}{R} = \frac{\sigma_b}{y}$ — (3)



Consider an elemental area dA at distance y from NA

stress σ on this element $\sigma = \frac{E}{R} y$

Force on element $= \sigma dA = \frac{E}{R} y dA$

Moment of this resisting force @ NA $= \frac{E}{R} y\, dA \cdot y$

$= \frac{E}{R} y^2 dA$.

Total Moment of resistance of C/s area $= \Sigma \frac{E}{R} y^2 dA$

$= \frac{E}{R} \Sigma y^2 dA = \frac{E}{R} I$ $(\because I = \Sigma y^2 dA)$

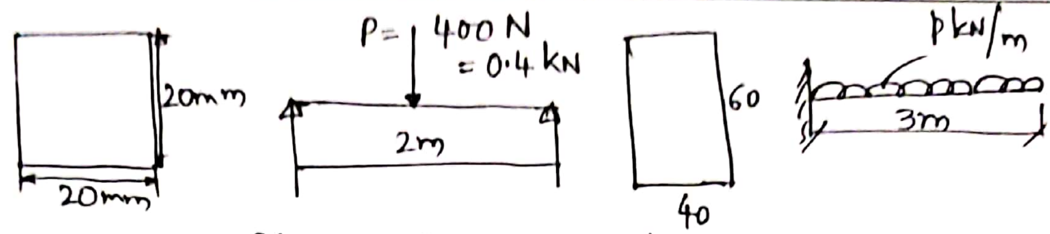
For Equilibrium Moment of resistance = Applied.

$\therefore M = \frac{E}{R} I \Rightarrow \frac{M}{I} = \frac{E}{R}$ — (4)

From (3) & (4) $\boxed{\frac{M}{I} = \frac{E}{R} = \frac{\sigma_b}{y}}$ 10

Q.No.	Solution and Scheme	Mks

Q7b.



(i)

Max BM $= \frac{Pl}{4} = \frac{0.4 \times 2}{4} = 0.2$ kN-m

Max B stress occurs at extreme fibers i.e at the top-flange. $\sigma_{max} = \frac{M_{max} \times y_{max}}{I} = \frac{M}{Z} \Rightarrow M = \sigma_{max} Z$.

$Z = \frac{bd^2}{6} = \frac{0.2 \times 0.2^2}{6} = 1.33 \times 10^{-3} m^3$

$M = \sigma_{max} Z \Rightarrow \sigma_{max} = \frac{M}{Z} = \frac{0.2 \text{ kNm}}{1.33 \times 10^{-3} m^3} = 150$ kPa

(ii) $Z = \frac{bd^2}{6} = \frac{0.4 \times 0.6^2}{6} = 0.024 m^3$

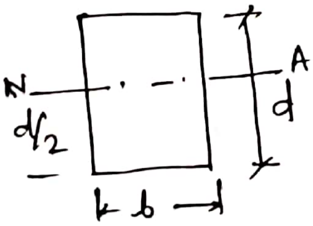
$M_{max} = \frac{pl^2}{4} = \frac{p \times 3^2}{4} = p2.25$ kN-m.

$2.25 P = 150 \times 0.024 = 1.6$ kN/m.

$P = 1.6$ kN/m. — 10

OR

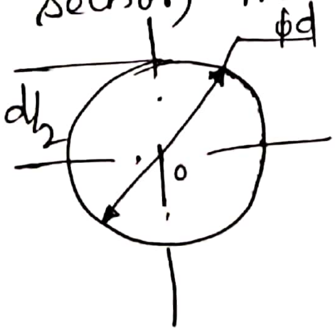
Q.8 a. Section modulus of Solid rectangular section



$I = \frac{bd^3}{12}$ Section modulus $= \frac{I}{y_{max}}$

$= \frac{bd^3}{12} \times \frac{2}{d} = \frac{bd^2}{6}$

Section modulus of Solid circular section

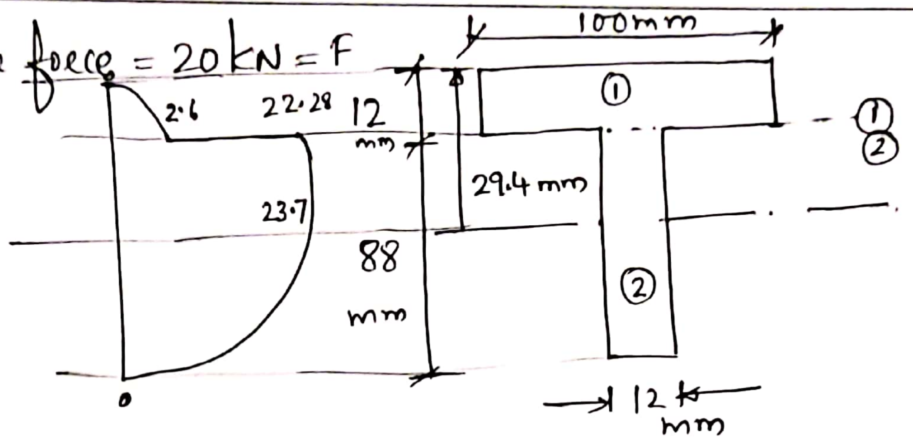


$I = \frac{\pi d^4}{64}$ $y = d/2$ $Z = \frac{I}{y}$

$Z = \frac{\pi d^4}{64} \times \frac{2}{d} = \frac{\pi d^3}{32}$ — 10

Q.No.	Solution and Scheme	Mks

Q8b. Shear force = 20 kN = F



$$\bar{y} = \frac{\Sigma Ay}{y} = \frac{100\times12\times6 + 12\times88\,(44+12)}{100\times12 + 88\times12} = 29.40 \text{ mm}$$

$$I = \Sigma \frac{bd^3}{12} + A(\bar{y}-y)^2$$

$$= \frac{100\times12^3}{12} + 100\,(29.4-6)^2 + \frac{12\times88^3}{12} + 12\times88\times(56-29.4)^2$$

$$= 2100127.3 \text{ mm}^4$$

Shear stress at bottom of flange

$$q = \frac{F}{bI}a\bar{y} = \frac{20\times10^3\times100\times12\times(29.40-6)}{100\times2100127.3} = 2.675 \text{ N/mm}^2$$

Shear stress at upper layer of web

$$q = \frac{20\times10^3\times100\times12\times(29.40-6)}{12\times2100127.3} = 22.288 \text{ N/mm}^2$$

Shear stress at neutral axis

$$a\bar{y} = 12\times100\times(29.40-6) + 12\times(29.4-12)\times\left(\frac{29.4-12}{2}\right)$$

$$= 29902.195 \text{ mm}^3$$

$$q_{NA} = \frac{20\times10^3\times29902.195}{12\times2100127.3} = 23.730 \text{ N/mm}^2 \qquad 10$$

~~Module~~

Q.No.	Solution and Scheme	Mks

Q.9a (i) Torque: A force that produces or tends to produce rotation or torsion $\frac{T}{J} = \frac{f_s}{R} = \frac{G\theta}{l}$, $P = \frac{2\pi NT}{60}$

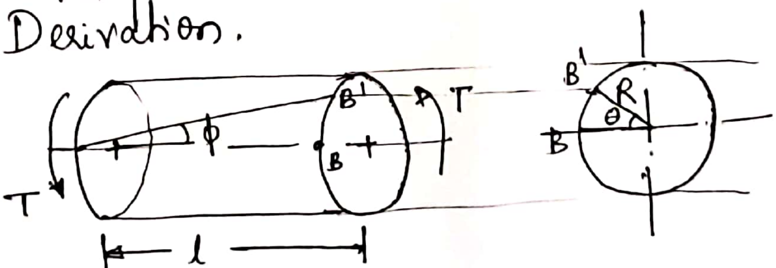
(ii) Polar modulus: Ratio of polar MI to the radius of the shaft $J_s = \frac{J_p}{R}$.

(iii) Torsional Rigidity: It is defined as how much an object of specified material resists twisting force or torque. $K_t = \frac{T}{\theta} = \frac{GJ}{l}$. — 06

b. Assumptions

1. Material is homogeneous and isotropic
2. Stresses are within elastic limit
3. Crosssections, which are plane before, they remain plane even after the application of torque
4. Radial lines remain radial even after applying torque — 04

c. Derivation.



$R\theta = BB' = L\phi$

If q_s be shear stress & G - modulus of rigidity

$\phi = \frac{q_s}{G}$

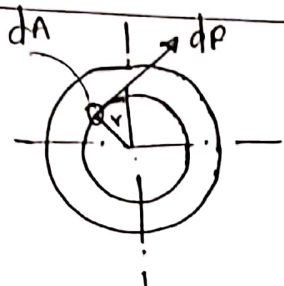
$R\theta = L\frac{q_s}{G}$

$\frac{q_s}{R} = \frac{G\theta}{l}$ —— (1)

IIIly if B is at distance r from zero at axis to the maximum value q_s at surface.

$\frac{q}{r} = \frac{G\theta}{l} \Rightarrow \frac{q_s}{R} = \frac{G\theta}{l}$ $\therefore \frac{q_s}{R} = \frac{q}{r}$ —— (2)

Department:Mechanical Engineering **AY: 2023-24**
Subject with Sub. Code:Mechanics Of Materials (BME 301) **Exam:**
Name of Faculty: Prof.G.R.Sattigeri **Semester / Division:III**

Q.No.	Solution and Scheme	Mks
Q9c		

If q is the shear stress developed in the element

resisting force $= dF = q\,da$.

resisting internal moment $dT = dF \cdot r$

$= q\,r\,da$

From Eqn (2)

$$q = q_s \frac{r}{R}$$

$$\therefore\ dT = q_s \frac{r^2}{R} da$$

$\therefore$ Total resisting torsional moment

$$T = \Sigma q_s \frac{r^2}{R} da = \frac{q_s}{R} \Sigma r^2 da$$

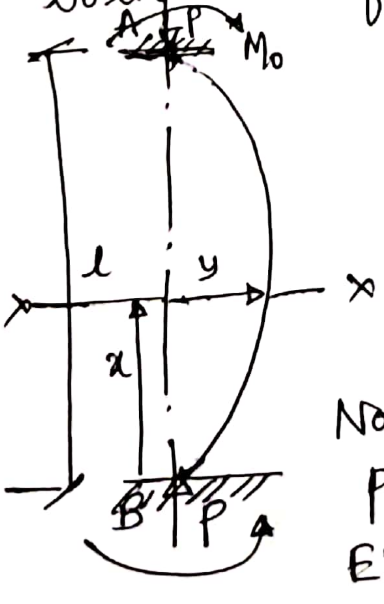
$$T = \frac{q_s}{R} J_p \qquad \because J_p = \Sigma r^2 da$$

$$\frac{T}{J_p} = \frac{q_s}{R} \text{ ——— } (3)$$

from (1) & (3)

$$\boxed{\frac{T}{J_p} = \frac{q_s}{R} = \frac{G\theta}{l}}$$

10

Q.No.	Solution and Scheme	Mks
Q.10 a	(i) Column: Vertical structural members subjected to compressive load.	
	(ii) Buckling load: The load which causes bending of beam	
	(iii) Slenderness Ratio: The ratio of effective length of column to least moment of inertia of ~~col~~ cross section of column.	
	(iv) Long column: Columns which fail only because of buckling load whose slenderness ratio is more than 100	
	(v) Short column: Columns which fail only because of compressive force not because of buckling load, whose slenderness ratio is less than 30.	
b.	Expression for Euler buckling load when both ends of the column are fixed.	
		
	Consider column ~~of~~ AB of length 'l' with fixed ends as shown in fig. Let the end moments developed be M_0	
	Now the bending moment at any point is given by.	
	$EI\frac{d^2y}{dx^2} = M_0 - Py$ ——— (1)	
	$\frac{d^2y}{dx^2} + \frac{Py}{EI} = \frac{M_0}{EI}$ ——— (2)	

Q.No.	Solution and Scheme	Mks
	The solution of above differential equation $y = C_1 \cos\sqrt{\frac{P}{EI}}x + C_2 \sin\sqrt{\frac{P}{EI}}x + \frac{M_0}{P}$ — (3) C_1 & C_2 are evaluated by applying initial conditions in below eqn (i) From At $x=0$ $\frac{dy}{dx}=0$ We get $\frac{dy}{dx} = -C_1\sqrt{\frac{P}{EI}}\sin\sqrt{\frac{P}{EI}}x + C_2\cos\sqrt{\frac{P}{EI}}x\sqrt{\frac{P}{EI}}$ $C_2\sqrt{\frac{P}{EI}} = 0 \Rightarrow C_2 = 0$ — (4) (ii) At $x=0$ $y=0$ in eqn — (3) $0 = C_1 + \frac{M_0}{P} \Rightarrow C_1 = -\frac{M_0}{P}$ — (5) Sub (4) & (5) in eqn 3 $y = -\frac{M_0}{P}\cos\left(\sqrt{\frac{P}{EI}}x\right) + \frac{M_0}{P}$ From BCs $y=0$ at $x=l$. $0 = -\frac{M_0}{P}\cos\sqrt{\frac{P}{EI}}\cdot l + \frac{M_0}{P}$ $\cos\sqrt{\frac{P}{EI}}\cdot l = 1$ $\therefore \sqrt{\frac{P}{EI}}\cdot l = \cos^{-1}(1) = 0, 2\pi, 4\pi \ldots\ldots$ $\sqrt{\frac{P}{EI}}\, l = 2\pi$ $\boxed{P = \frac{4\pi^2 EI}{l^2}}$	10