9	A simple beam of 4m span is carrying a point load of 40 kN at a distance of 3m from the left end. Calculate the slope at the two supports and deflection under the load. Take : $EI = 2.6 \times 10^7$ N-m^2.	L4	CO3	10 M
	UNIT-V			
10	A cylindrical shell 3 m long which is closed at the ends has an internal diameter of 1 m and a wall thickness of 15 mm. Calculate the circumferential and longitudinal stresses induced and also change in the dimensions of the shell if it is subjected to an internal pressure of 1.5 MN/m^2. Take: E= 200 GN/m^2 and μ= 0·3	L3	CO4	10 M
	OR			
11	Calculate the safe crippling load on a hollow cast iron column (one end rigidly fixed and the other hinged) of 150 mm external diameter, 100 mm internal diameter and 10 m length. Use Euler's formula with a factor of safety of 5, and E = 95 GN/m^2.	L3	CO4	10 M

Code: 23ME3301

II B.Tech - I Semester – Regular Examinations - DECEMBER 2024

MECHANICS OF SOLIDS
(MECHANICAL ENGINEERING)

Duration: 3 hours Max. Marks: 70

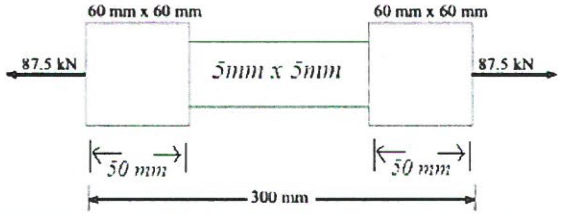
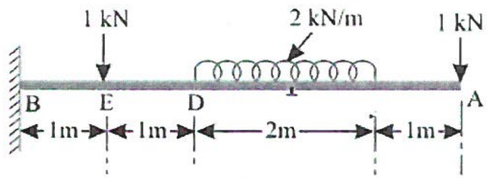
Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level CO – Course Outcome

PART – A

		BL	CO
1.a)	Define Young's Modulus.	L1	CO1
1.b)	Define Principal stress.	L1	CO1
1.c)	Define Bending Moment.	L1	CO1
1.d)	Write Torsion equation.	L1	CO1
1.e)	Define Pure bending.	L1	CO1
1.f)	What is the ratio of maximum to average shear stress in a rectangular section?	L2	CO1
1.g)	Write the governing differential equation of beams.	L1	CO1
1.h)	What is the maximum deflection when a point load 'W' is acting at the middle of the simply supported beam of length 'L'.	L2	CO1
1.i)	Define circumferential stress in thin cylinders.	L1	CO1
1.j)	What is slenderness ratio?	L2	CO1

PART – B

		BL	CO	Max. Marks
	UNIT-I			
2	A tie bar has enlarged ends of square section 60 mm x 60 mm as shown in fig. If the middle portion of the bar is also of square section of 5mm x 5mm. Find the stress in each section and the total extension of the bar. Take $E = 2 \times 10^5$ N/mm^2. 	L3	CO1	10 M
	OR			
3	The principal stresses at a point across two perpendicular planes are 75 MN/m^2 (tensile) and 35 MN/m^2 (tensile) and shear stress is zero. Find the stresses on a plane at 20° with the major principal plane.	L3	CO1	10 M
	UNIT-II			
4	Draw *SFD* and *BMD* for the following beam. 	L4	CO2	10 M
	OR			

5	What must be the length of a 5 mm diameter aluminum wire so that it can be twisted through one complete revolution without exceeding a shearing stress of 42 MN/m^2 ? Take: G = 27 GN/m^2.	L3	CO2	10 M
	UNIT-III			
6	A hollow circular bar having outside diameter twice the inside diameter is used as a beam. From the bending moment diagram of the beam, it is found that the bar is subjected to a bending moment of 40 kNm. If the allowable bending stress in the beam is to be limited to 100 MN/m^2, find the inside diameter of the bar.	L3	CO3	10 M
	OR			
7	A simply supported beam of 2-m span carries a uniformly distributed load of 140 kN per m over the whole span. The cross-section of the beam is a T-section with a flange width of 120 mm, web and flange thickness of 20 mm and overall depth of 160 mm. Determine the maximum shear stress in the beam and draw the shear stress distribution for the section.	L3	CO3	10 M
	UNIT-IV			
8	A simply supported beam 5 m long carries concentrated loads of 10 kN each at points 1m from the ends. Calculate: (i) Maximum slope and deflection of the beam, and (ii) Slope and deflection under each load. Take : $EI = 1.2 \times 10^4$ kNm^2.	L4	CO3	10 M
	OR			

II B. Tech – I Semester – Regular Examinations – December – 2024

Scheme of Evaluation

23ME3301 – Mechanics of Solids

PART – A

1. Each question carries 1 mark	1 X 10 = 10M

PART – B

Unit – 1

2. Stress equation	3 M
Deflection equation	3 M
Stress and defection calculation in each section	1 M x 3 sections = 3M
Total elongation	1 M

(OR)

3. Given data	3 M
Normal stress on oblique plane formula	2 M
Calculation of Normal stresses	2 M
Shear stress on Oblique plane formula	2 M
Calculation of Shear stress	1 M

Unit – II

4. Given diagram	2 M
Shear force in each region 1 M	1 M x 4 regions = 4M
Bending moment in each region 1 M	1 M x 4 regions = 4 M

(OR)

5. Given data	3 M
Corresponding formula	4 M
Calculation of length	3 M

Unit – III

6. Given data	3 M
Calculation of y	2 M
Calculation of I	2 M
Calculation of inside diameter	3 M

(OR)

7. Simply Supported Beam diagram	1 M
Shear force value	1 M
Calculation of CG for I cross section	2 M
Calculation of MoI for I cross section	2 M

Shear stress at Top and bottom	1 M
Shear stress at Junction of flange and web	2 M
Shear stress distribution diagram	1 M

Unit – IV

8. SSB with loads diagram	1 M
Reactions	2 M
Bending moment equation	2 M
Differential equation	1 M
Solution of slope and deflection with constants	1 M
Constant values using boundary conditions	1 M
Maximum slope and deflection	1 M
Slope and deflection under each load	1 M

(Note: Double Integration or Maculay's or Moment area any method can be used)

(OR)

9. SSB with load diagram	1 M
Reactions	2 M
Bending moment equation	2 M
Differential equation	1 M
Solution of slope and deflection with constants	1 M
Constant values using boundary conditions	1 M
Slope at the supports	1 M
Deflection under the load	1 M

(Note: Double Integration or Maculay's or Moment area any method can be used)

Unit – V

10. Given data	2 M
Circumferential and longitudinal stress formula	2 M
Calculation of stresses	2 M
Change in length formula	1 M
Calculation of change in length	1 M
Change in diameter formula	1 M
Calculation of change in diameter	1 M

(OR)

11. Given data	3 M
Crippling load formula	3 M
Calculation of Moment of Inertia	2 M
Calculation of Equivalent length	1 M
Calculation of Crippling load	1 M

II B.Tech - I Semester - Regular

23ME3301

Mechanics of Solids

Solutions to

PART-A

1) a) The ratio between to stress to strain within Elastic limit is Young's modulus of Elasticity.

$$E = \frac{\sigma}{\epsilon}.$$

2) b) • The maximum normal stress

• The normal stress on principal plane

• The stress on plane where shear stress is zero

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

3) c) • The algebric sum of moments of all the forces acting on one side of section of a beam.

4) d) $\frac{T}{J} = \frac{G\theta}{l} = \frac{\tau}{r}$

T → Torsion, J → polar M I

θ → angle of twist, l → lengenth

τ → shear stress, r → radius

G → Modulus of rigidity

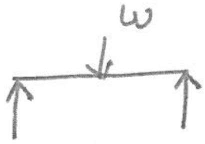
e) The load on a beam such that shear force is zero (or) bending moment is constant.

f) $\frac{\text{Max. shear stress}}{\text{Avg. shear stress}} = 1.5$

g) Differential equation of beam

$$EI \frac{d^2y}{dx^2} = -M$$

h)



$$\delta = \frac{wL^3}{48EI}.$$

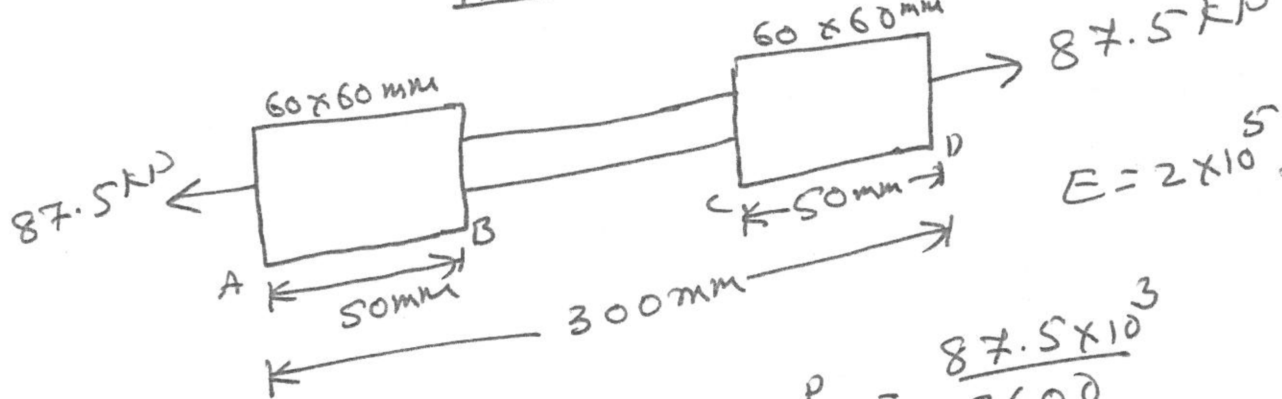
i) . The stresses that are acting perpendicular to the length (or) along the radius.

$$\sigma = \frac{Pd}{2t}.$$

j) The ratio between length to least radius of gyration of a column is known as slenderness ratio $\lambda = \frac{l}{k}$.

PART-B

2)



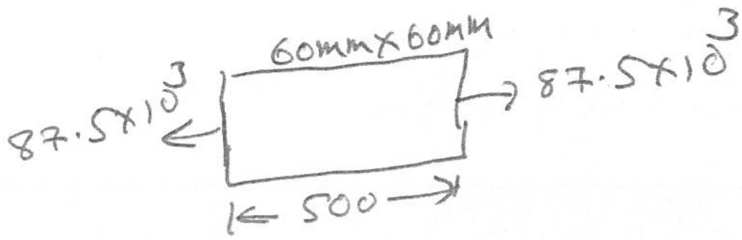
$E = 2\times10^5 \ N/mm^2$

for section AB:- stress $\sigma_{AB} = \frac{P}{A} = \frac{87.5\times10^3}{3600}$

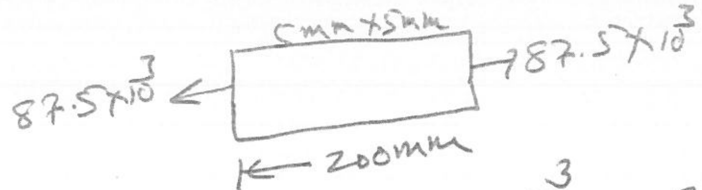
$= 24.31$ MPa. Ans

deflection $\delta_{AB} = \frac{PL}{AE} = \frac{87.5\times10^3\times50}{3600\times2\times10^5}$

$= 6.076\times10^{-3}$ mm



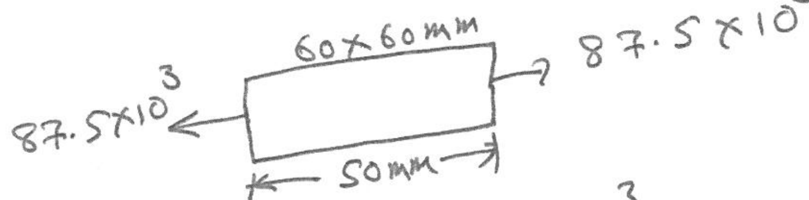
∴ for Section BC



stress $\sigma_{BC} = \frac{P}{A} = \frac{87.5\times10^3}{25} = \underline{3500\ MPa}$ Ans

deflection $\delta_{BC} = \frac{PL}{AE} = \frac{87.5\times10^3\times200}{25\times2\times10^5} = 3.5mm.$

Section CD



stress $\sigma_{CD} = \frac{P}{A} = \frac{87.5\times10^3}{3600} = \underline{24.31\ MPa}$ Ans

deflection $\delta_{CD} = \frac{PL}{AE} = \frac{87.5\times10^3\times50}{3600\times2\times10^5} = 6.076\times10^{-3}$

Net elongation $\delta = 6.076\times10^{-3} + 3.5 + 6.076\times10^{-3}$

$= \underline{3.512mm}$ Ans

(OR)

3) $\sigma_x = 75\frac{N}{mm^2}$; $\sigma_y = 35\frac{N}{mm^2}$; $\tau_{xy} = 0$; $\theta = 20^\circ$

$\sigma_{x_1,y_1} = \frac{\sigma_x+\sigma_y}{2} \pm \frac{\sigma_x-\sigma_y}{2}\cos2\theta \pm \tau_{xy}\sin2\theta$

$= \frac{75+35}{2} \pm \left(\frac{75-35}{2}\right)\cos40 \pm 0$ ∴ $\sigma_{x_1} = 70.32\ MPa$, $\sigma_{y_1} = 39.68\ MPa$ } Ans

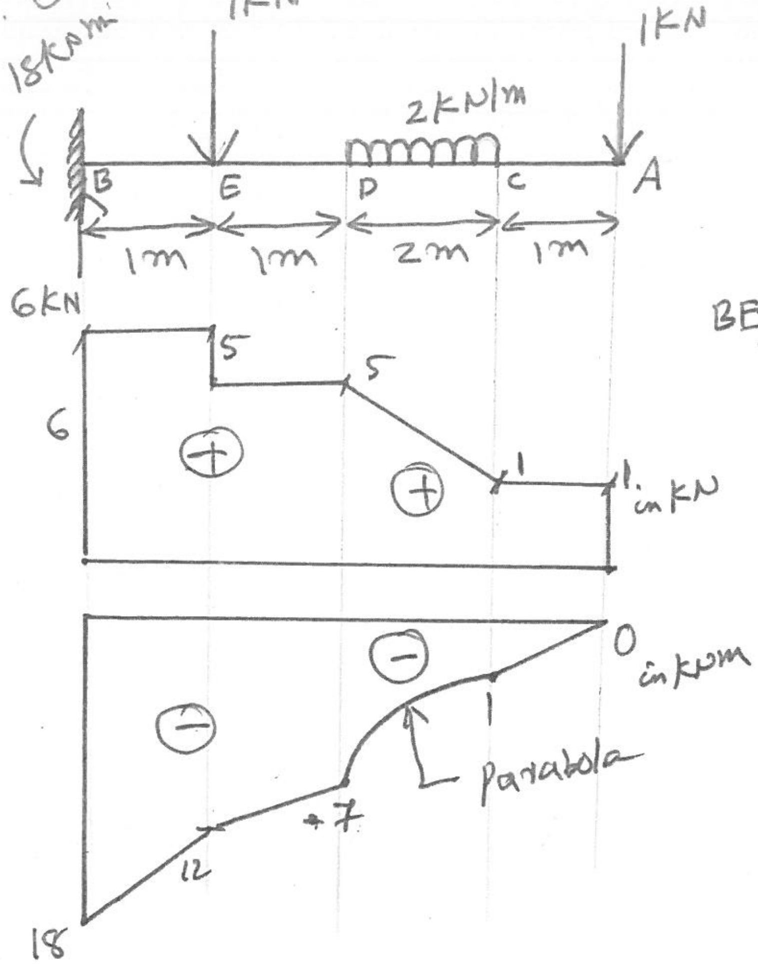
$= 55 \pm 15.32$

$\tau_{xy} = \frac{\sigma_y-\sigma_x}{2}\sin2\theta + \tau_{xy}\cos2\theta$

$= \frac{-40}{2}\sin40 + 0 = \underline{-12.86\ MPa}$ Ans

=

④ Unit – II



$F_y = 1+4+1 = 6KN$

$M = (1)(1) + (4)(3) + 1(5)$

$= 1 + 12 + 5 = 18KNm$

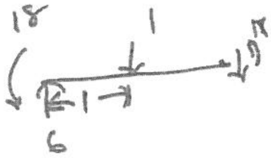
BE :-

$V = 6KN$

$M = 6x - 18KNm$

$M_B = 0 - 18;\ M_E = -12.$

ED :-



$V = 6 - 1 = 5$

$M = 6x - 1(x-1) - 18$

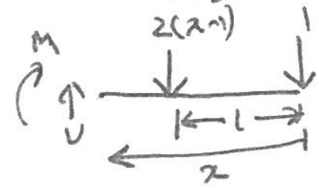
$= 6x - x + 1 - 18$

$= 5x - 17.$

$M_E = 5 - 17 = -12$

$M_D = 10 - 17 = -7.$

DC :-



$V = 2x - 2 + 1$

$= 2x - 1$

$V_D = 6 - 1 = 5$

$V_C = 2 - 1 = 1$

$M = -2\frac{(x-1)^2}{2} - 1(x)$

$M_D = -\frac{2}{2}(2)^2 - 1(3)$

$= -4 - 3 = -7$

$M_C = -1.$

(OR).

⑤ dia $d = 5mm$; angle $\theta = 2\pi^c$; shear stress $\tau = 42 \frac{N}{mm^2}$,

$\frac{G\theta}{l} = \frac{\tau}{r} \Rightarrow \frac{27 \times 10^3 \times 2\pi}{l} = \frac{42}{2.5}$

$l = 10.09 \times 10^3$ mm

$\Rightarrow$ $l = 10.09\,m$ Ans.

Unit - III

6) outside dia $d_o = 2d_i$

bending moment $M = 40 \times 10^6$ Nmm

bending stress $\sigma = 100$ MPa

Now, $\sigma = \frac{MY}{I}$; $Y = \frac{d_o}{2} = d_i$

where $I = \frac{\pi}{64}(d_o^4 - d_i^4)$

$= \frac{\pi}{64}(16 d_i^4 - d_i^4)$

$= \frac{15\pi}{64} \cdot d_i^4 = 0.7363 d_i^4$

$\therefore \quad 100 = \frac{40 \times 10^6 \times d_i}{0.7363 d_i^4}$

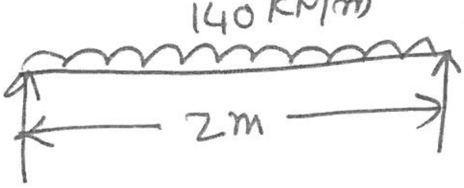
$\Rightarrow \quad d_i^3 = \frac{40 \times 10^6}{100 \times 0.7363} = 543.3 \times 10^3$

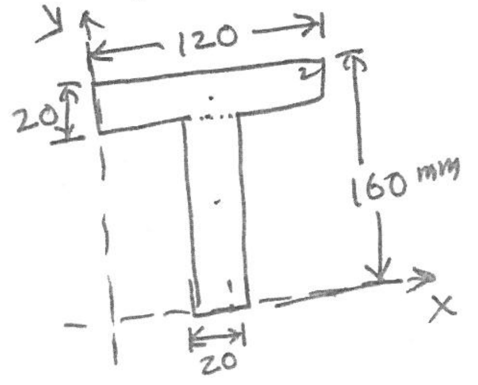
$\therefore \underline{d_i = 81.59 \text{ mm}}$

and $\underline{\underline{d_o = 163.19 \text{ mm}}}$ Ans

(OR)

7)





$\therefore \quad V = \frac{140 \times 2}{2} = 140$ kN.

$A_1 = 20 \times 140$
$= 2800 \text{ mm}^2$

$A_2 = 120 \times 20$
$= 2400 \text{ mm}^2$

$Y_1 = 70$

$Y_2 = 150$ mm

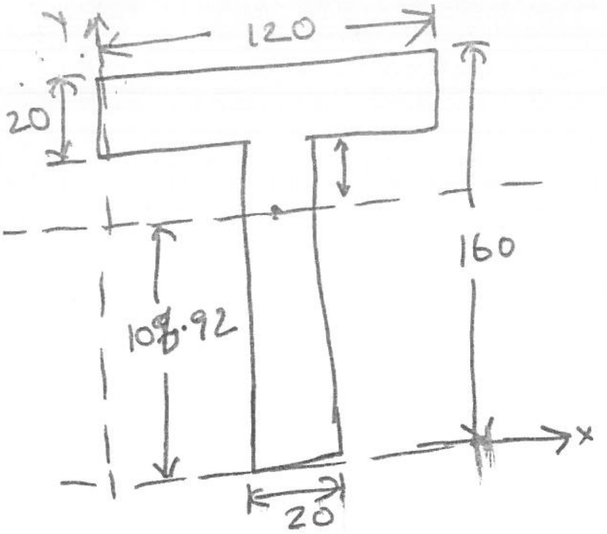
$Y_c = \frac{(2800)(70) + (2400)(150)}{5200}$

$= 106.92$ mm

$I = \frac{(20)(140)^3}{12} + 2800(36.92)^2 + \frac{(120)(20)^3}{12} + 2400(43.08)^2$

$12.92 \times 10^6 \text{ mm}^4$

12.92×10^6 40



Shear Stress:-

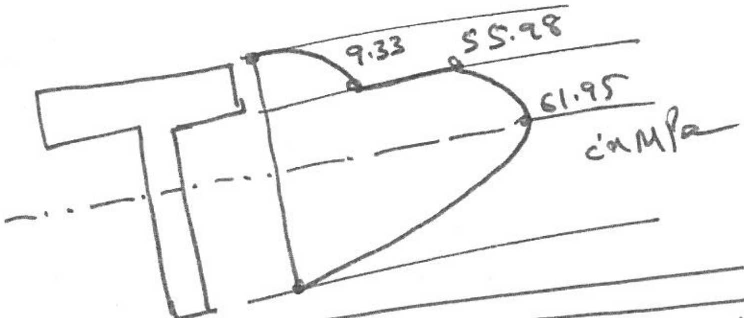
At Flange:- Top = 0.

junction
$$\tau = \frac{VA\bar{y}}{Ib}$$
$$= \frac{140\times10^{3}\times 2400\times(43.0\ldots)}{12.92\times10^{6}\times120}$$
$$= 9.33\,\text{MPa}$$

At N.A.
$$\tau = \frac{V[A_1\bar{y}_1 + A_2\bar{y}_2]}{Ib}$$
$$= \frac{140\times10^{3}[2400\times43.08 + 661.6\times16.54]}{12.92\times10^{6}\times20}$$
$$= 61.95\,\text{MPa}$$

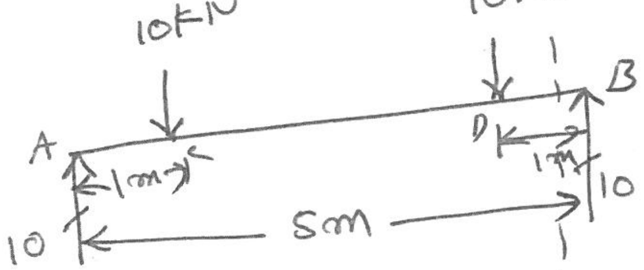
At web:-

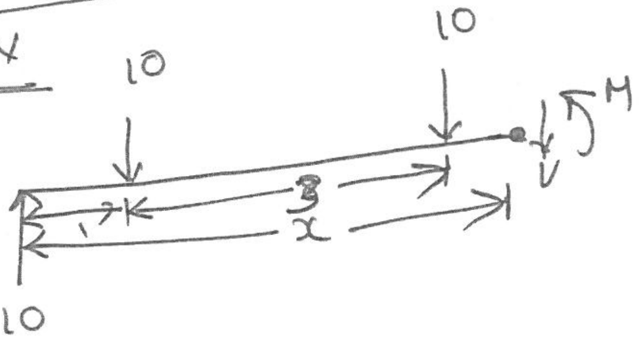
junction
$$\tau = \frac{VA\bar{y}}{Ib}$$
$$= \frac{140\times10^{3}\times2400\times43.08}{12.92\times10^{6}\times20}$$
$$= 55.98\,\text{MPa}$$



Unit-IV

8)





$$M = 10x - 10\langle x-1\rangle - 10\langle x-4\rangle$$

$$= 10x - 10\langle x-1\rangle - 10\langle x-4\rangle$$

$EI\ddot{y} = -M$

$EI\ddot{y} = -10x + 10\langle x-1\rangle + 10\langle x-4\rangle$

$EI\dot{y} = -10\dfrac{x^2}{2} + 10\dfrac{\langle x-1\rangle^2}{2} + \dfrac{10\langle x-4\rangle^2}{2} + C_1$

$EIy = -10\cdot\dfrac{x^3}{6} + 10\dfrac{\langle x-1\rangle^3}{6} + \dfrac{10\langle x-4\rangle^3}{6} + C_1x + C_2.$

Boundary conditions are

At $x=0$; $y=0 \Rightarrow \quad 0 = 0+0+0+C_2 \Rightarrow C_2 = 0.$

At $x=5$; $y=0 \Rightarrow \quad 0 = \dfrac{-10(5)^3}{6} + \dfrac{10(4)^3}{6} + \dfrac{10(1)^3}{6} + 5C_1 = 0$

$\Rightarrow -208.33 + 106.66 + 1.66 + 5C_1 = 0$

$\Rightarrow \quad 5C_1 = 100$

$C_1 = 20.$

$\therefore \quad EI\dot{y} = -10\dfrac{x^2}{2} + \dfrac{10\langle x-1\rangle^2}{2} + \dfrac{10\langle x-4\rangle^2}{2} + 20.$

$EIy = -10\cdot\dfrac{x^3}{6} + \dfrac{10\langle x-1\rangle^3}{6} + \dfrac{10\langle x-4\rangle^3}{6} + 20x.$

(i) Max. slope at supports.

$EI\dot{y}_{max}\big|_{x=0} = 20$

$\Rightarrow \dot{y}_{max} = \dfrac{20}{1.2\times10^4} = 1.66\times10^{-3}$ rad.

Max. deflection at mid point

$EIy_{max}\big|_{x=2.5} = -10\dfrac{(2.5)^3}{6} + \dfrac{10(1.5)^3}{6} + 0 + 20(2.5)$

$= -26.04 + 5.625 + 50$

$= 29.585$

$\therefore y_{max} = \dfrac{29.585}{[illegible]} = 2.464\times10^{-3}$ m

= 2.46 mm.

ii. slope and deflection at C (x=1)

$$EI\,\dot{y}|_{x=1} = \frac{-10(1)^2}{2} + 0 + 0 + 20$$

$$= -5$$

$$\therefore \dot{y}|_{x=1} = \frac{-5}{1.2\times10^4} = \underline{-4.17\times10^{-4}\ \text{rad}.}$$

$$EI\,y|_{x=1} = \frac{-10(1)}{6} + 0 + 0 + 20$$

$$= 18.33.$$

$$y|_{x=1} = \frac{18.33}{1.2\times10^4} = 1.53\times10^{-3}\ m$$

$$= \underline{1.53\ mm.}$$

• slope and deflection at D (x = 4m).

$$EI\,\dot{y}|_{x=4} = \frac{-10(16)}{2} + \frac{10(9)}{2} + 20$$

$$= -80 + 45 + 20 = -20.$$

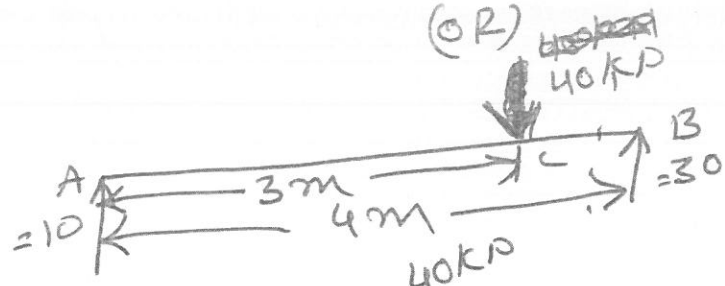
$$\dot{y}|_{x=4} = \frac{-20}{1.2\times10^4} = \underline{1.66\times10^{-3}\ \text{rad}.}$$

$$EI\,y|_{x=4} = \frac{-10(64)}{6} + \frac{10(27)}{6} + 20(4)$$

$$= -106.67 + 45 + 80 = 18.33.$$

$$y|_{x=4} = \frac{18.33}{1.2\times10^4} = \underline{1.53\ mm}$$

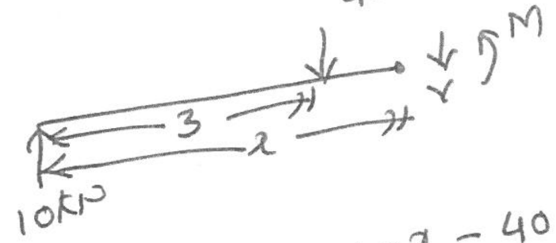
9)



Reactions:-

$R_A = \frac{(40)(1)}{4} = 10K$

$R_B = \frac{(40)(3)}{4} = 30K$



$M = 10x - 40\langle x-3 \rangle$

$EI = 2.6\times10^{7}\ Nm^2$
$= 2.6\times10^{4}\ kNm^2$

$EI\ddot{y} = -10x + 40\langle x-3 \rangle$

$EI\dot{y} = -10\cdot\frac{x^2}{2} + 40\frac{\langle x-3 \rangle^2}{2} + c_1.$

$EIy = -10\cdot\frac{x^3}{6} + 40\frac{\langle x-3 \rangle^3}{6} + c_1x + c_2.$

B.C's are at $x=0;\ y=0$

$\Rightarrow 0 = 0 + 0 + 0 + c_2 \Rightarrow c_2 = 0.$

at $x=4;\ y=0$

$\Rightarrow 0 = \frac{-10(64)}{6} + \frac{40(1)^3}{6} + 4c_1$

$\Rightarrow 0 = -106.67 + 6.67 + 4c_1$

$\Rightarrow c_1 = 25.$

slope at supports.

$EI\dot{y}|_{x=0} = 0 + 0 + 25 \Rightarrow \dot{y} = \frac{25}{2.6\times10^{4}} = 9.61\times$

$EI\dot{y}|_{x=4} = \frac{-10(16)}{2} + \frac{40(1)}{2} + 25;\ \dot{y} = \frac{-35}{2.6\times10^{4}} = -1.35\times$

Deflection under the load.

$EIy|_{x=3} = \frac{-10(27)}{6} + 0 + 3(25) + 0$

$= -45 + 75 = 30$

$\therefore y|_{x=3} = \underline{1.154\ mm}$ (or) $\underline{1.154\times10^{-3}\ m}$

Unit - V

10) length of cylinder $l = 3000\,mm$

Internal diameter $d = 1000\,mm$

wall thickness $t = 15\,mm$

Internal pressure $p = 1.5\,\frac{N}{mm^2}$

$E = 200 \times 10^3\,\frac{N}{mm^2}$

Circumferential stress $\sigma_1 = \frac{pd}{2t}$

$= \frac{(1.5)(1000)}{(2)(15)}$

$= 50\,MPa$

Longitudinal stress $\sigma_2 = \frac{pd}{4t}$

$= \frac{(1.5)(1000)}{(4)(15)}$

$= 25\,MPa$

change in dia $\delta d = \frac{pd}{4tE}(2-\mu)\cdot(dia)$

$= \frac{(1.5)(1000)(2-0.3)}{(4)(15)(2\times10^5)}(1000)$

$= 0.2125\,mm$

change in length $\delta l = \frac{pd}{4tE}(1-2\mu)\cdot(length)$

$= \frac{(1.5)(1000)}{(4)(15)(2\times10^5)}(1-0.6)(3000)$

$= 0.15\,mm$

(OR)

ii) External diameter $d_o = 150mm$

Internal diameter $d_i = 100mm$.

length $l = 10\times10^3 mm$.

FoS $n = 5$

$E = 95\times10^3 MPa$.

crippling load $P_{cr} = \frac{\pi^2 E I}{l_e^2}$.

where $I = \frac{\pi}{64}(d_o^4 - d_i^4)$

$= \frac{\pi}{64}(150^4 - 100^4)$

$= 19.94\times10^6 mm^4$.

$l_e = \frac{l}{\sqrt{2}} = \frac{10\times10^3}{\sqrt{2}}$

$= 7.07\times10^3 mm$.

$\therefore P_{cr} = \frac{(\pi^2)(95\times10^3)(19.94\times10^6)}{(7.07\times10^3)^2}$

$P_{cr} = 374.03 KN$

1m
1000
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