MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2013 Certified)

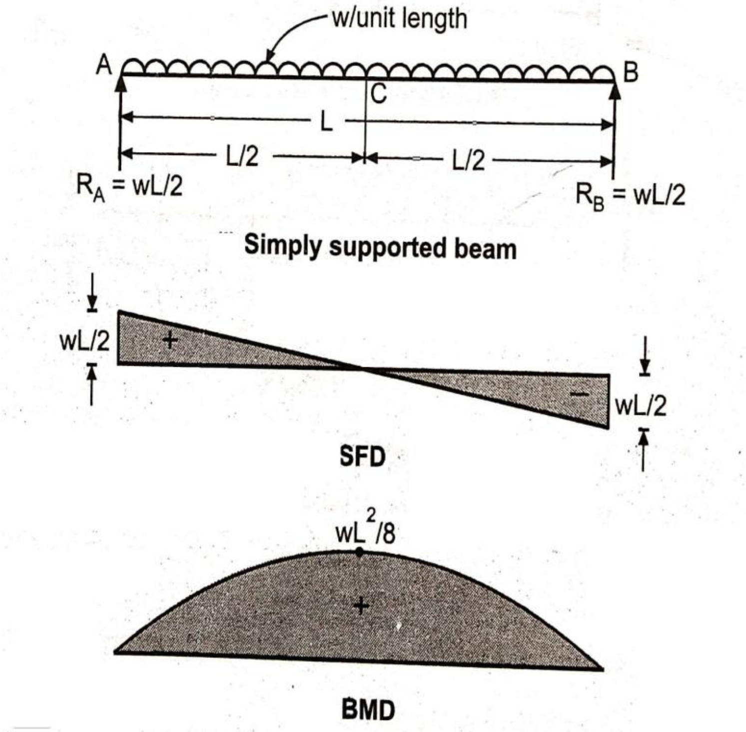
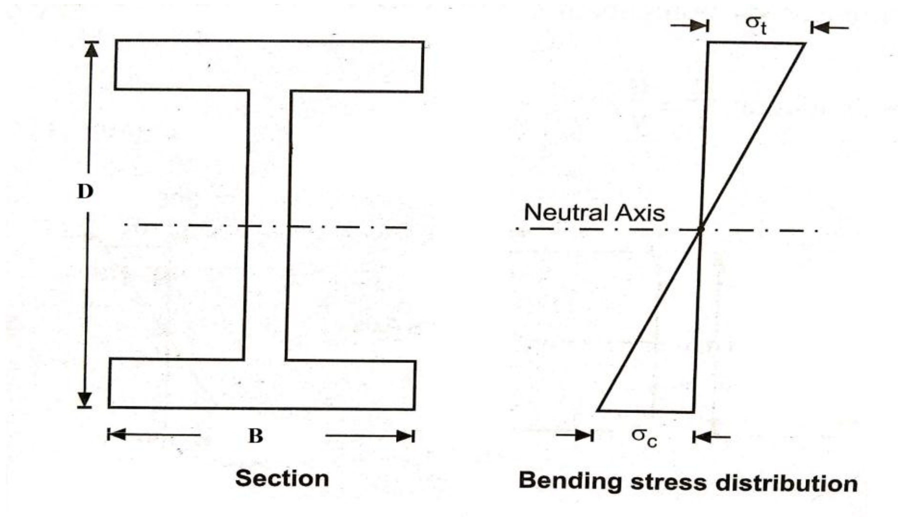
Model Answer: Winter-2019

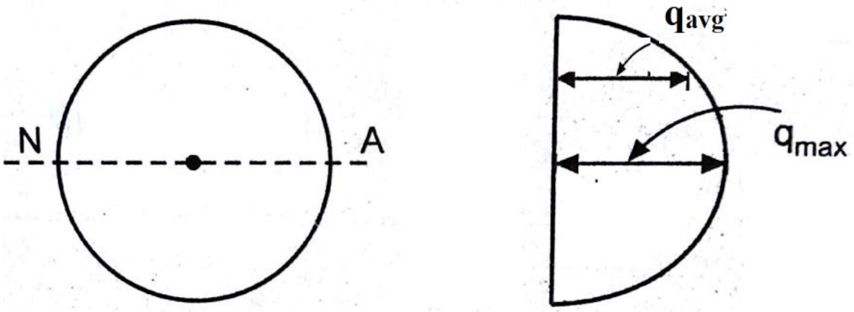
Subject: Mechanics of Structures | **Sub. Code: 17311**

Important Instructions to Examiners:

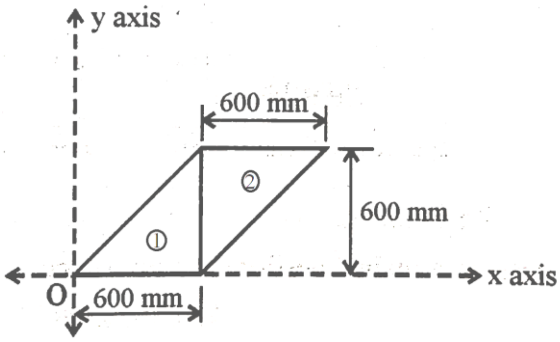
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance. (Not applicable for subject English and Communication Skills.)
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by the candidate and those in the model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and the model answer.
6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.1	**(A)**	**Solve any SIX of the following:**		**(12)**
	(a)	**State the parallel axis theorem.**		
	Ans.	**Parallel Axis Theorem:** The moment of inertia about any axis parallel to centroidal axis is equal to moment of inertia about that particular centroidal axis (Ixx or Iyy) plus product of area of figure and square of distance between these parallel axes.	2	2
	(b)	**State the Hook's law.**		
	Ans.	**Hook's Law:** It states that, stress developed is directly proportional to strain induced within the elastic limit of material.	2	2
	(c)	**Explain Bulk modulus and express it.**		
	Ans.	**Bulk Modulus (K):** It is the ratio of direct (normal) stress (σ) to the volumetric strain (e_v) of material, called as Bulk Modulus.	1	
		Expression of Bulk Modulus: $K = \frac{\sigma}{e_v}$	1	2

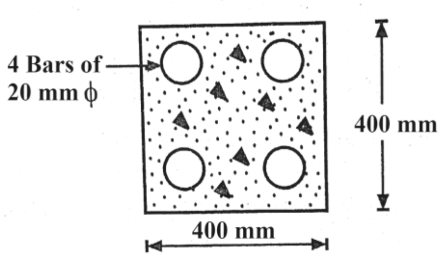
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.1	(d)	**Draw shear force and bending moment for simply supported beam subjected to udl W & length L.**		
	Ans.	**Shear force and bending moment for simply supported beam subjected to udl W and length L**		
			1 1	2
	(e)	**Draw bending stress distribution diagram for a I section used as cantilever beam.**		
	Ans.	**Bending stress distribution diagram for a I section used as cantilever beam.**		
			2	2

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.1	(f)	**Draw shear stress distribution for circular section in SSB.**		
	Ans.	**Shear stress distribution for circular section in SSB.** 	2	2
	(g)	**State meaning of slenderness ratio.**		
	Ans.	Slenderness ratio is defined as the ratio of effective length of a column and its minimum radius of gyration. As slenderness ratio increases buckling of column increases as it is proportional to effective length of column.	2	2
	(h)	**Define strain energy.**		
	Ans.	**Strain Energy:** The energy stored in the material, when it is loaded within its elastic limit, is called as strain energy.	2	2
Q.1	(B)	**Solve any TWO of the following:**		(8)
	(a)	**If polar moment of inertia of circular section is 2000 mm^4, then calculate diameter of the section.**		
	Ans.	*Given* : $I_P = 2000\ mm^2$ *for circular section*		
		$I_P = I_{xx} + I_{yy}$	1	
		$I_P = \frac{\pi}{64}D^4 + \frac{\pi}{64}D^4$	1	
		$2000 = 2\left(\frac{\pi}{64}D^4\right)$	1	
		$\boxed{D = 11.946\ mm}$	1	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 1	(b)	**Determine the tensile force on a steel bar of circular cross-section 25 mm diameter, if strain equal to 0.75×10^{-3}. Consider E for steel = 200 GPa.**		
	Ans.	Given: d = 25mm, $e = 0.75 \times 10^{-3}$, $E_s = 200$ GPa $= 200 \times 10^3$ N/mm^2		
		Find: P = ?		
		$E = (\sigma / e)$; $\therefore \sigma = E \times e = 200\times10^3\times0.75\times10^{-3}$		
		$\boxed{\sigma = 150 \text{ N/mm}^2}$	2	
		$P = \sigma \times A = 150 \times \frac{\pi}{4} \times 25^2 = 73631.07$ N		
		$\boxed{P = 73.631 \text{ kN}}$	2	4
	(c)	**Derive relationship between E, G and K.**		
	Ans.	We know the relationship between E, K and μ.		
		$E = 3K(1 - 2\mu) \rightarrow$ (i)	1	
		We know the relationship between E, G and μ.		
		$E = 2G(1+\mu) \rightarrow$ (ii)	1	
		From equation (ii) we get, $\mu = \frac{E}{2G} - 1$		
		Put the value of μ in equation (i)		
		$E = 3K\left[1 - 2\left(\frac{E}{2G} - 1\right)\right]$		
		$E = 3K\left[1 - \left(\frac{E}{G} + 2\right)\right]$		
		$E = 3K\left[3 - \frac{E}{G}\right]$		
		$E = 3K\left(\frac{3G - E}{G}\right)$		
		$EG = 3K(3G - E)$		
		$EG = 9KG - 3KE$		
		$EG + 3KE = 9KG$		
		$E(G + 3K) = 9KG$		
		$\boxed{E = \frac{9KG}{G + 3K}}$	2	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.2		**Solve any TWO of the following**		**(16)**
	(a)	**Determine the moment of inertia of given fig.**		
	Ans.			
		Find: I_{XX}, I_{YY} = ?		
		Solution: To find centroid G ($\bar{x},\bar{y}$)		
		$A_1=\frac{1}{2}\times 600\times 600 = 180000\ mm^2$, $A_2=\frac{1}{2}\times 600\times 600 = 180000\ mm^2$		
		$x_1=\frac{2}{3}\times 600 = 400\ mm$, $x_2= 600+\frac{1}{3}\times 600 = 800\ mm$		
		$y_1=\frac{1}{3}\times 600 = 200\ mm$, $y_2=\frac{2}{3}\times 600 = 400\ mm$	1	
		$\bar{x} = \frac{(180000\times 400)+(180000\times 800)}{180000+180000} = 600\ mm$	1	
		$\bar{y} = \frac{(180000\times 200)+(180000\times 400)}{180000+180000} = 300\ mm$	1	
		To find $I_{XX} = \left[\frac{b.h^3}{36}+A_1.\ h_1^{\ 2}\right]+\left[\frac{b.h^3}{36}+A_2.\ h_2^{\ 2}\right]$	1	
		Here, $h_1 = \bar{y} - y_1 = 300 - 200 = 100\ mm$; $h_2 = y_2 - \bar{y} = 400 - 300 = 100\ mm$		
		$I_{XX} = \left[\frac{600\times 600^3}{36}+180000\times 100^2\right]+\left[\frac{600\times 600^3}{36}+180000\times 100^2\right]$	1	
		$I_{XX} = (5.4\times 10^9)+(5.4\times 10^9)$		
		$\boxed{I_{XX} = 10.8\times 10^9\ mm^4}$	1	
		To find $I_{YY} = \left[\frac{h.b^3}{36}+A_1.\ h_3^{\ 2}\right]+\left[\frac{h.b^3}{36}+A_2.\ h_4^{\ 2}\right]$	1	
		Here, $h_3 = \bar{x} - x_1 = 600 - 400 = 200\ mm$, $h_4 = x_2 - \bar{x} = 800 - 600 = 200\ mm$		
		$I_{YY} = \left[\frac{600\times 600^3}{36}+180000\times 200^2\right]+\left[\frac{600\times 600^3}{36}+180000\times 200^2\right]$	1	8
		$I_{YY} = (1.08\times 10^{10})+(1.08\times 10^{10})$		
		$\boxed{I_{YY} = 2.16\times 10^{10}\ mm^4}$		

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.2	(a)	**OR**		(16)
		Find: $I_{XX}, I_{YY} = ?$ About OX and OY		
		To find centroid G ($\bar{x}, \bar{y}$)		
		$A_1 = \frac{1}{2} \times 600 \times 600 = 180000 \text{ mm}^2$, $A_2 = \frac{1}{2} \times 600 \times 600 = 180000 \text{ mm}^2$		
		$x_1 = \frac{2}{3} \times 600 = 400 \text{ mm}$, $x_2 = 600 + \frac{1}{3} \times 600 = 800 \text{ mm}$		
		$y_1 = \frac{1}{3} \times 600 = 200 \text{ mm}$, $y_2 = \frac{2}{3} \times 600 = 400 \text{ mm}$		
		$\bar{x} = \frac{(180000 \times 400) + (180000 \times 800)}{180000 + 180000} = 600 \text{ mm}$		
		$\bar{y} = \frac{(180000 \times 200) + (180000 \times 400)}{180000 + 180000} = 300 \text{ mm}$	1	
		To find I_{XX},	1	
		$I_{XX} = \left[\frac{b.h^3}{36} + A_1.\ h_1^{\ 2}\right] + \left[\frac{b.h^3}{36} + A_2.\ h_2^{\ 2}\right]$	1	
		Here, $h_1 = y_1 = 200$ mm		
		$h_2 = y_2 = 400$ mm	1	
		$I_{XX} = \left[\frac{600 \times 600^3}{36} + 180000 \times 200^2\right] + \left[\frac{600 \times 600^3}{36} + 180000 \times 400^2\right]$		
		$I_{XX} = (1.08 \times 10^{10}) + (3.24 \times 10^{10})$		
		$\boxed{I_{XX} = 4.32 \times 10^9 \text{ mm}^4}$	1	
		To find I_{YY},		
		$I_{YY} = \left[\frac{h.b^3}{36} + A_1.\ h_3^{\ 2}\right] + \left[\frac{h.b^3}{36} + A_2.\ h_4^{\ 2}\right]$	1	
		Here, $h_3 = x_1 = 400$ mm		
		$h_4 = x_2 = 800$ mm	1	
		$I_{YY} = \left[\frac{600 \times 600^3}{36} + 180000 \times 400^2\right] + \left[\frac{600 \times 600^3}{36} + 180000 \times 800^2\right]$		
		$I_{YY} = (3.24 \times 10^{10}) + (11.88 \times 10^{10})$		
		$\boxed{I_{YY} = 15.12 \times 10^{10} \text{ mm}^4}$		
			1	8

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.2	(b)	**A RCC column 400 mm x 400 mm is reinforced with 4 bars of 20 mm diameter. Determine stresses induced in steel and concrete. If it is subjected to an axial load of 500 kN. Take modular ratio (E_s/E_c) = 13.33.**		
	Ans.			
		Given: Column 400 mm x 400 mm, Reinforcement- 4 bars of 20 mmΦ,		
		$P = 500kN,\ \frac{E_s}{E_c} = m = 13.33.$		
		Find: $\sigma_c, \sigma_s = ?$		
		$m = \frac{E_s}{E_c} = \frac{\sigma_s}{\sigma_c} = 13.33$	1	
		$\sigma_s = 13.33 \times \sigma_c$ - - - - - - - - - - - - - (i)	1	
		$A = 400 \times 400 = 160000\ mm^2$		
		$A_s = 4 \times \frac{\pi}{4}(20)^2 = 1256.63 mm^2$	1	
		$A_c = A - A_s = 160000 - 1256.63 = 158743.37 mm^2$	1	
		$P = P_s + P_c$		
		$P = \sigma_s \cdot A_s + \sigma_c \cdot A_c$	1	
		$500 \times 10^3 = (13.33 \times \sigma_c \times 1256.63) + (\sigma_c \times 158743.37)$	1	
		$\boxed{\sigma_c = 2.849\ N/mm^2}$		
		From (i), $\sigma_s = 13.33 \times 2.849$	1	
		$\boxed{\sigma_s = 37.978\ N/mm^2}$	1	8

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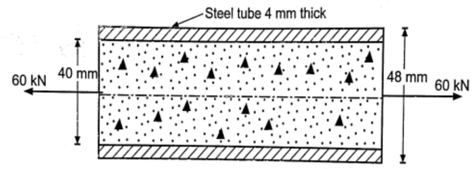
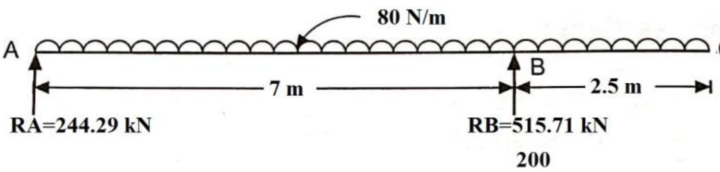
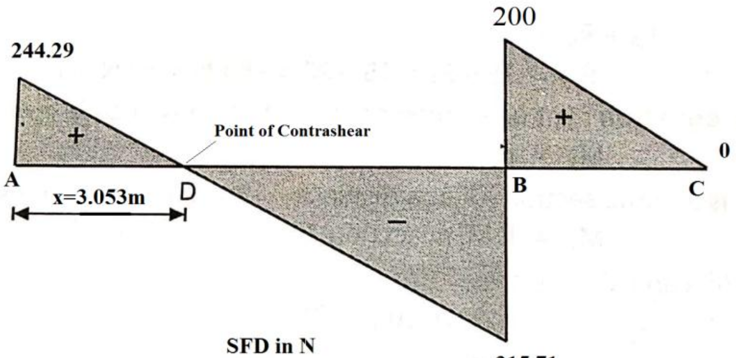
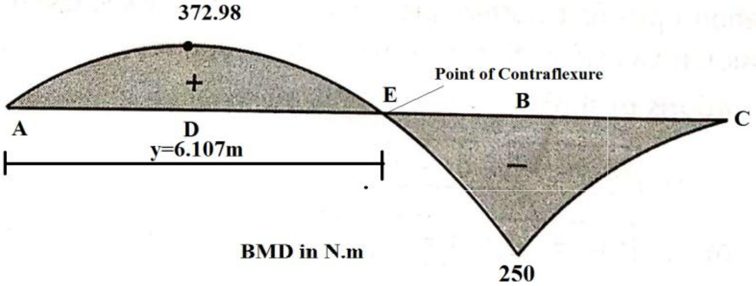
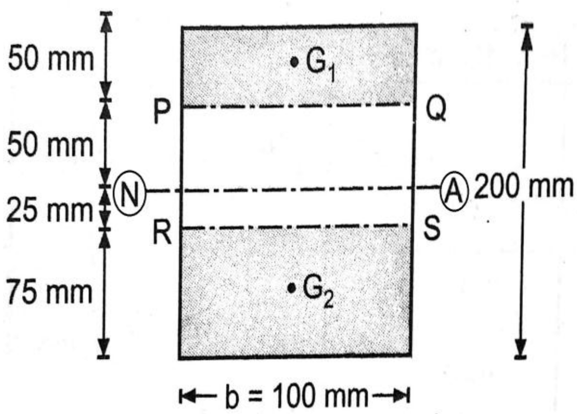
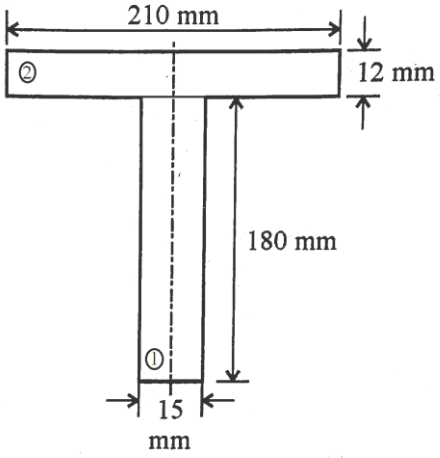
Q.2	(c)	**A metal rod of 20 mm diameter and 2.5 m long when subjected to a tensile force 70 kN showed an elongation of 2.5 mm and reduction in diameter 0.006 mm. Calculate modulus of elasticity and modulus of rigidity.**		
	Ans.	Given: d = 25 mm, L = 250 mm, P = 200 kN, δ_L = 0.45 mm, δ_d = 0.0052 mm		
		Find: E, G = ?		
		$\mu = \frac{\text{Lateral Strain}}{\text{Linear Strain}} = \frac{\left(\frac{\delta_d}{d}\right)}{\left(\frac{\delta_L}{L}\right)}$	1	
		$\mu = \frac{\left(\frac{0.006}{20}\right)}{\left(\frac{2.5}{2500}\right)} = \frac{3\times10^{-4}}{1\times10^{-3}}$	1	
		$\boxed{\mu = 0.3}$	1	
		$E = \frac{\sigma}{E} = \frac{\left(\frac{P}{A}\right)}{\left(\frac{\delta_L}{L}\right)}$	1	
		$E = \frac{\left(\frac{70\times10^3}{\frac{\pi}{4}\times20^2}\right)}{\left(\frac{2.5}{2500}\right)} = \frac{222.817}{1\times10^{-3}}$	1	
		$\boxed{E = 2.228\times10^5 \text{ N/mm}^2}$	1	
		As, E = 2G (1+μ)	1	
		$G = \frac{E}{2(1+\mu)} = \frac{2.228\times10^5}{2(1+0.3)}$		
		$\boxed{G = 0.857\times10^5 \text{ N/mm}^2}$	1	8

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.3		**Attempt any TWO of the following:**		(16)
	(a)	**A steel tube 40 mm inside diameter and 4 mm metal thickness is filled with concrete. Determine stress in each material due to an axial thrust of 60 kN. Take E for steel = 2.1 x 10^5 N/mm^2 and E for concrete = 0.14 x 10^5 N/mm^2.**		
	Ans.			
		Given: d = 40 mm, t = 4 mm, P = 60 kN = 60×10^3 N $E_S = 2.1 \times 10^5$ N/mm^2, $E_c = 0.14 \times 10^5$ N/mm^2 Find: $\sigma_c, \sigma_s = ?$ Here external diameter D = d + 2 t = 40 + 2 x 4 = 48 mm. $A_S = \frac{\pi}{4}(D^2 - d^2) = \frac{\pi}{4}(48^2 - 40^2) = 552.92 \text{ mm}^2.$ $A_c = \frac{\pi}{4}(d^2) = \frac{\pi}{4}(40^2) = 1256.64 \text{ mm}^2.$	1	
		We know that, $\frac{\sigma_s}{E_s} = \frac{\sigma_c}{E_c}$	1	
		$\sigma_s = \frac{E_s}{E_c}\sigma_c$ $\sigma_s = \frac{2.1 \times 10^5}{0.14 \times 10^5}\sigma_c$ $\sigma_s = 15 \,.\, \sigma_c \rightarrow \text{(i)}$	1	
		Now, P = $\sigma_s . A_s + \sigma_c . A_c$ $60 \times 10^3 = (15 \times \sigma_c \times 552.92) + (\sigma_c \times 1256.64)$ $60 \times 10^3 = (8293.8 \times \sigma_c) + (1256.64 \times \sigma_c)$ $60 \times 10^3 = 9550.44 \times \sigma_c$ $\sigma_c = \frac{60 \times 10^3}{9550.44}$	1	
		$\boxed{\sigma_c = 6.282 \text{ N/mm}^2 (T)}$	2	
		Put σ_c in (i) $\sigma_s = 15 \times 6.282$ $\boxed{\sigma_s = 94.236 \text{ N/mm}^2 (T)}$	2	8

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.3	(b)	**An overhanging beam is supported at A and B with AB = 7m & BC = 2.5m. BC being overhang. The beam is subjected to udl 80 N/m over entire span. Draw bending moment diagram and state maximum value of bending moment and point of contra flexure.**		
	Ans.	Step 1: Calculation of reactions: $\sum M_A = 0$ $+ (80 \times 9.5 \times 4.75) - (R_B \times 7) = 0$ $\boxed{R_B = 515.71\ N}$	1	
		$\sum F_y = 0\ \uparrow + \downarrow -$ $R_A + R_B - (80 \times 9.5) = 0$ $R_A + R_B = 760$ $R_A + 515.71 = 760$ $\boxed{R_A = 244.29\ N}$	1	
		Step 2: Calculation of Shear Forces from left: SF at A = 0 A_R = + 244.29 N B_L = + 244.29 - (80×7) = -315.71 N B_R = -315.71 +515.71 = 200 N C_L = + 200 - (80 ×2.5) = 0 C = 0	1	
		To find position (x) of Point of Contrashear i.e. pt. D from A, $\frac{244.29}{x} = \frac{315.71}{7-x}$ 1710.03 = 560 x $\boxed{x = 3.053\ m\ from\ A}$	1	
		Step 3: Calculation of Bending Moments from left: BM at A = 0 and C = 0 D = + (244.29 × 3.053) - (80×3.053×1.526) = +372.98 N.m B = + (244.29 × 7) - (80×7×3.5) = –249.97 N-m or B = - $80 \times 2.5 \times \frac{2.5}{2} = -250$ N-m $\boxed{Maximum\ Bending\ Moment = +372.98\ N.m}$	1	
		To find position (y) of Point of Contraflexure i.e. pt. E from A, apply $\sum M_E = 0$ $+ (244.29 \times y) - (80 \times y \times \frac{y}{2}) = 0$ $+ (244.29) = (40 \times y)$ $\boxed{y = 6.107\ m\ from\ A}$	1	8

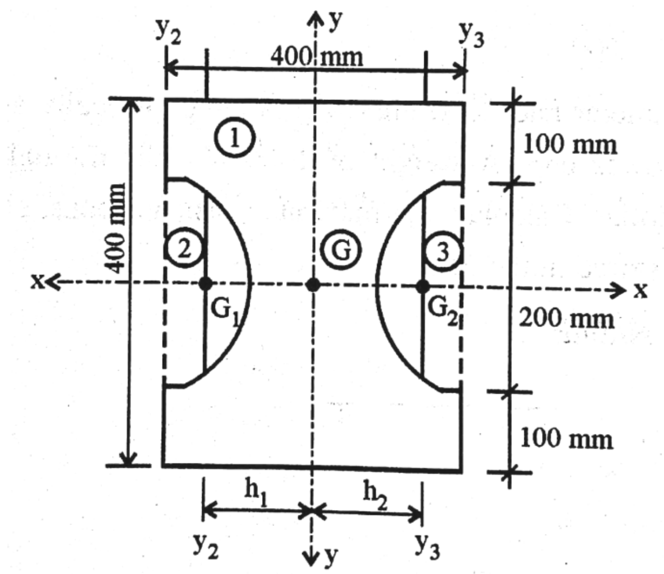
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.3	**(b)**	 **Beam**  **SFD in N**  **BMD in N.m**	1 1	8

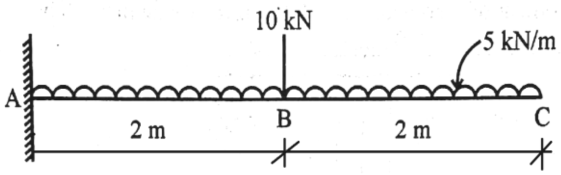
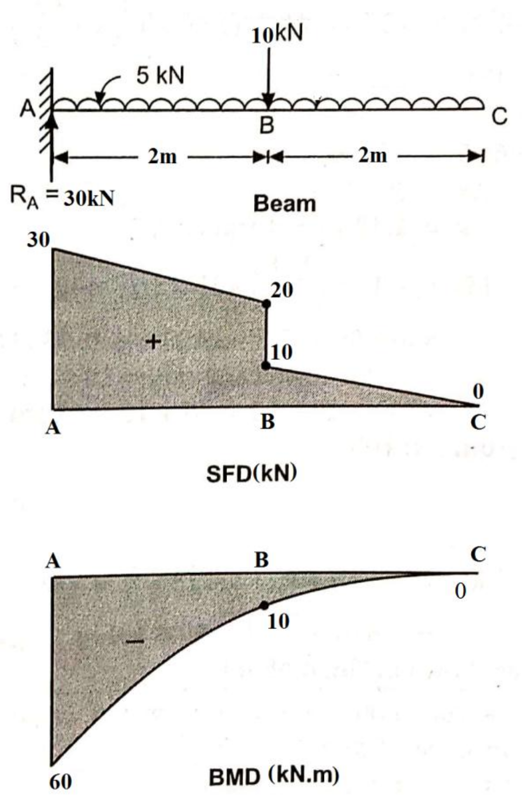
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.3	(c)	**A beam section 100 mm X 200 mm is subjected to a shear force of 60 kN. Determine the shear stresses induced on a layer at 50 mm above NA and 25 mm below NA.**		
	Ans.			
		Given: b = 100 mm, d = 200 mm, S = 60 kN = 60×10^3 N.		
		Find: q at 50 mm above N.A. and q at 25 mm below N.A.		
		$A = 100 \times 50 = 5000\ mm^2$	1	
		$\bar{y} = 50 + \frac{50}{2} = 75$ mm	1	
		$I_{NA} = \frac{100 \times 200^3}{12} = 66.666 \times 10^3 mm^4$	1	
		$q = \frac{SA\bar{y}}{bI}$	1	
		$q_{50} = \frac{60 \times 10^3 \times 5000 \times 75}{100 \times 66.666 \times 10^3}$		
		$q_{50} = 3.375\ N/mm^2$	1	
		$A = 100 \times 75 = 7500\ mm^2$	1	
		$\bar{y} = 50 + \frac{75}{2} = 62.5$ mm	1	
		$I_{NA} = \frac{100 \times 200^3}{12} = 66.666 \times 10^3 mm^4$		
		$q = \frac{S.A.\bar{y}}{b\ .\ I}$		
		$q_{25} = \frac{60 \times 10^3 \times 7500 \times 62.5}{100 \times 66.666 \times 10^3}$		
		$q_{25} = 4.218\ N/mm^2$	1	8

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.4		**Attempt any TWO of the following:**		(16)
	(a)	**A tee section has a flange 210 mm X 12 mm and a vertical web 180 mm X 15 mm. Calculate moment of inertia about both the axis passing through its centroid.**		
	Ans.			
		Given: Flange (210×12)mm, Web (180×15)mm. Find: I_{XX}, I_{YY},= ? To find centroid G $(\bar{x},\bar{y})$ $\bar{x}=\frac{210}{2}=105$ mm (Due to symmetry) $A_1=15\times180=2700\ mm^2$ $A_2=210\times12=2520\ mm^2$ $y_1=\frac{180}{2}=90$ mm $y_2=180+\frac{12}{2}=186$ mm $\bar{y}=\frac{(2700\times90)+(2520\times186)}{2700+2520}=136.34$ mm (From base of T- section)	2	

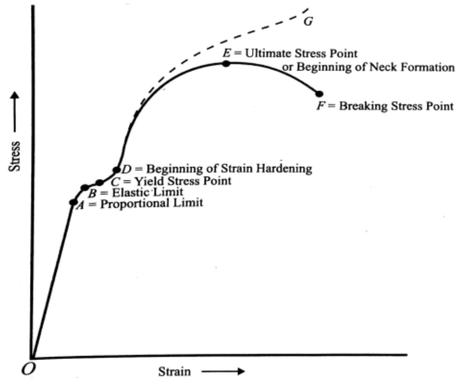
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.4	(a)	To find I_{XX}, $I_{XX} = (I_{XX})_1 + (I_{XX})_2$ $I_{XX} = \left(\frac{bd^3}{12} + Ah^2\right)_1 + \left(\frac{bd^3}{12} + Ah^2\right)_2$ Here, $h_1 = \bar{y} - y_1 = 136.34 - 90 = 46.34$ mm $h_2 = y_1 - \bar{y} = 186 - 136.34 = 49.66$ mm	2	
		$I_{XX} = \left(\frac{15\times180^3}{12} + 2700\ \times 46.34^2\right)_1 + \left(\frac{210\times12^3}{12} + 2520\ \times 49.66^2\right)_2$ $I_{XX} = (13089219.37)_1 + (6243599.943)_2$ $\boxed{I_{XX} = 19.33282\times10^6\ mm^4}$	2	
		To find I_{YY}, $I_{YY} = (I_{YY})_1 + (I_{YY})_2$ $I_{YY} = \left(\frac{db^3}{12}\right)_1 + \left(\frac{db^3}{12}\right)_2$	1	
		$I_{YY} = \left(\frac{180\times15^3}{12}\right)_1 + \left(\frac{12\times210^3}{12}\right)_2$ $I_{YY} = (50625)_1 + (9261000)_2$ $\boxed{I_{YY} = 9.311625\times10^6\ mm^4}$	1	8

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.4	(b)	**A square bar 400 mm^2, 2 m long elongates 1mm under an axial load of 40 kN. Modulus of rigidity is 80GPa. Calculate (i) Bulk Modulus (ii) Poissons ratio.**		
	Ans.	Given: A= 400 mm^2, L = 2m = 2000 mm, δ_L = 1mm,		
		P = 40 kN = 40×10^3 N, G = 80 GPa = 80×10^3 N/mm^2.		
		Find: (i) K= ?, (ii) μ = ?		
		To find Young's Modulus, $\delta_L = \dfrac{P.L}{A.E}$	1	
		$\therefore E = \dfrac{P.L}{A.\delta_L} = \dfrac{40\times10^3\times2000}{400\times1} = 200\times10^3 N/mm^2$	1	
		To find Poisson's Ratio,		
		E = 2 G (1+μ)	1	
		$200 \times10^3 = 2 \times 80 \times10^3 \ (1+\mu)$		
		$\dfrac{200 \times10^3}{160 \times10^3} = (1+\mu)$	2	
		$1.25 = 1+\mu \ \therefore \boxed{\mu = 0.25}$		
		To find Bulk Modulus,	1	
		E = 3 K (1- 2μ)		
		$200 \times10^3 = 3 K (1- 2 \times 0.25)$	2	8
		$200 \times10^3 = 1.5 K \ \therefore \boxed{K = 133.33\ 10^3\ N/mm^2}$		
	(c)	**A rectangular beam is simply supported over a span 4 m. What udl the beam can carry if the permissible stress in bending is not to exceed 90 N/mm^2. Assume depth = 280 mm and Ixx = 9 x 10^6 mm^4.**		
	Ans.	Given: L=4m, σ_b =90 N/mm^2, d=280 mm, $I_{XX} = 9\times10^6 mm^4$.		
		Find: w = ?	2	
		Here, $M_{max} = \dfrac{w\times L^2}{8} = \dfrac{w\times4^2}{8}$ = (2.w) N.m = (2000.w) N.mm	1	
		$y_{max} = \dfrac{d}{2} = \dfrac{280}{2} = 140mm$	1	
		Flexural formula, $\dfrac{M_{max}}{I_{xx}} = \dfrac{\sigma_{b\,max}}{y_{max}}$		
		$\dfrac{2000.w}{9\times10^6} = \dfrac{90}{140}$	2	
		$w = \dfrac{90\times9\times10^6}{140\times2000}$	2	8
		w = 2892.85N/m		
		$\boxed{w = 2.893\ kN/m}$		

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5		**Attempt any TWO of the following**		**(16)**
	(a)	**Determine M. I. of fig. given below about centroidal *xx* and centroidal *yy* axis.**		
				
	Ans.	$Ixx = (I)_{Square} - (I)_{Semicircle}$		
		$Ixx = \left(\frac{b^4}{12}\right)_1 - 2\left(\frac{\pi d^4}{128}\right)_{2,3}$	1	
		$Ixx = \left(\frac{400^4}{12}\right)_1 - 2\left(\frac{\pi \times 200^4}{128}\right)_{2,3}$	1	
		$Ixx = (2.13\times10^9)_1 - (78.54\times10^6)_{2,3}$		
		$\boxed{Ixx = 2.055\times10^9 mm^4}$		
			1	
		$Iyy = (I)_{Square} - (I)_{Semicircle}$	1	
		$Iyy = \left(\frac{b^4}{12}\right)_1 - 2\left(I_G + Ah^2\right)_{2,3}$		
		$Iyy = \left(\frac{b^4}{12}\right)_1 - 2\left(0.11R^4 + \frac{\pi R^2}{2}\times\left(\frac{b}{2}-\frac{4R}{3\pi}\right)^2\right)_{2,3}$	1	
		$Iyy = \left(\frac{400^4}{12}\right)_1 - 2\left(0.11\times100^4 + \frac{\pi\times100^2}{2}\times\left(\frac{400}{2}-\frac{4\times100}{3\pi}\right)^2\right)_{2,3}$	2	
		$Iyy = \left(2.133\times10^9\right)_1 - \left(0.802\times10^9\right)_{2,3}$	1	8
		$\boxed{Iyy = 1.331\times10^9 mm^4}$		

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5	(b)	**Draw S.F. and B.M. diagram for the cantilever beam as shown in fig. given below indicate the value of important points.**		
				
	Ans.	**I. Reaction Calculation:**		
		$\sum Fy = 0$		
		RA = (5 × 4) +10 = 30 kN	1	
		II. SF Calculation:		
		A = + 30 kN		
		B_L = + 30 – (5×2) = + 20 kN	1	
		B_R = + 20 – 10 = + 10 kN		
		C = + 10 – (5×2) = 0		
		III. BM Calculation:		
		BM at C = 0 (C is Free end)		
		B = – (5×2)×1 = – 10kN-m	2	
		A = – (5×4)×2 – 10×2 = – 60 kN-m		
			2 2	8

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5	(c)	**Compare the crippling loads by Euler's and Rankine's formula for a strut with both ends fixed 3.0m long, 40mm & 30mm internal diameter, Take E = 200 GPa, α = 1/7500, σ_c = 320 MPa.**		
	Ans.	$Given: D = 40\ mm,\ d = 30\ mm,\ L = 3m,$		
		$E = 200\ GPa,\ \alpha = \frac{1}{7500},\ \sigma_c = 320 MPa$		
		Find: $\frac{P_E}{P_R} = ?$		
		Le = $\frac{3000}{2}$ = 1500 mm (∵ Both ends are fixed)	1	
		$A = \frac{\pi}{4}\left(D^2 - d^2\right) = \frac{\pi}{64}\left(40^2 - 30^2\right) = 549.779\ mm^2$	1	
		$I_{min} = \frac{\pi}{64}\left(D^4 - d^4\right) = \frac{\pi}{64}\left(40^4 - 30^4\right) = 85902.924\ mm^4$	1	
		$K_{min} = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{85902.924}{549.779}} = 12.5mm$	1	
		$\lambda = \frac{Le}{K_{min}} = \frac{1500}{12.5} = 120$	1	
		$P_E = \frac{\pi^2 EI_{min}}{(Le)^2} = \frac{\pi^2 \times 200 \times 10^3 \times 85902.924}{(1500)^2} = 75362.478\ N$	1	
		$P_R = \frac{\sigma_c.A}{1+\alpha\lambda^2} = \frac{320 \times 549.779}{1+\frac{(120)^2}{7500}} = 60249.721\ N$	1	
		$\frac{P_E}{P_R} = \frac{75362.478}{60249.721} = 1.251$	1	8

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6		**Attempt any TWO of the following:**		**(16)**
	(a)	**Draw stress-strain curve for mild steel under tensile loading. Also explain behavior of the material respect to salient points on the graph.**		
	Ans.	**Stress-strain curve for mild steel under tensile loading** 	**2**	
		As we increase the load on the material stress will induce and correspondingly strain will also increase.		
		Point A: Proportional Limit Tensile force is applied on the material then there is some elongation. The ratio of stress and strain will remain in proportion and graph is a straight line upto point A. It is called as limit of Proportionality.	**1**	
		Point B: Elastic Limit Elastic deformation takes place upto point B. The mild steel materials regain its original size and shape after removal of load applied. Material has some elastic properties upto point B. It is called as Elastic limit.	**1**	
		Point C: Yield Stress point Yielding takes place at point C. There is upper yield and lower yield point. The stress at this point is called yield stress. The material will reach in plastic stage. If load is removed the material will not regain its original size and shape.	**1**	
		Point D:Beginning of Strain Hardening point Strain hardening takes place between point D to E. After Strain hardening the material reach upto maximum stress point	**1**	
		Point E: Ultimate Stress point It is the maximum value of stress is known as ultimate stress. Material will take maximum load at this stage. It is the peak point on the graph.	**1**	
		Point F: Breaking Stress point After the maximum value of stress, there is a neck formation in the material. At that point cross sectional area is reduced. Therefore stress is reduced. Hence graph drops down and the material fails.	**1**	**8**

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6	(b)	**A hollow circular column 6m long has to transmit a load of 900 kN, using Rankine's formula and factor of safety 4. Design a suitable section if both ends of column are fixed. Take internal diameter = 0.8 x external dia. fc = 550 MPa, α = 1/1600.**		
	Ans.	$A=\frac{\pi}{4}(D^2-d^2)=\frac{\pi}{4}(D^2-(0.8D)^2)=0.283D^2$	½	
		$I=\frac{\pi}{64}(D^4-d^4)=\frac{\pi}{64}(D^4-(0.8D)^4)=0.02898D^4$	½	
		$K^2=\frac{I}{A}=\frac{0.02898D^4}{0.283D^2}=0.1025D^2$ $\boxed{K^2=0.1025D^2}$	½	
		$Crippling\ load = Safe\ load \times FOS = (900\times10^3)\times4$ $\boxed{Crippling\ load = 36\times10^5\,N}$	½	
		$L_e=\frac{L}{2}=\frac{6000}{2}=3000\ mm$	½	
		$P=\frac{\sigma_c.A}{1+\alpha\left(\frac{L_e}{K}\right)^2}$	½	
		$36\times10^5=\frac{550\times0.283D^2}{1+\frac{1}{1600}\times\left(\frac{(3000)^2}{0.1025D^2}\right)}$	½	
		$36\times10^5=\frac{155.65D^2}{1+\frac{54878.049}{D^2}}$	½	
		$36\times10^5=\frac{155.65D^4}{D^2+54878.049}$		
		$155.65D^4=(36\times10^5)\times D^2+1.9756\times10^{11}$	½	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6	(b)	$let, D^2 = x$	½	
		$155.65x^4 = (36\times10^5)x + 1.9756\times10^{11}$		
		$x^2 - 23128.815x - 1.26925795\times10^9 = 0$		
		$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$	½	
		$x = \frac{23128.815 \pm \sqrt{(23128.815)^2 + 4\times1\times1.26925795\times10^9}}{2\times1}$		
		$x = \frac{23128.815 \pm 74913.1089}{2}$	½	
		$\boxed{x = 49020.962}$	½	
		$D^2 = 47231$		
		$D = 221.406\ mm$	½	
		$\boxed{D = 222\ mm}$	½	
		$d = 0.8D$		
		$d = 0.8\times 221.406$		
		$d = 177.125\ mm$		
		$\boxed{d = 178\ mm}$	½	8

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6	(c)	**A bar 20 mm diameter and 1000 mm long is hung vertically and a collar is attached at the lower end. A weight of 1000 N falls through a height of 250 mm on the collar. Calculate maximum instantaneous stress, elongation and the strain energy stored in the bar. Take E = 2x10^{5}N/mm^2.**		
	Ans.	Given: d = 20 mm, L = 1000 mm, P = 1000 N, h = 250 mm, E = 2 x10^5 N/mm^2 Find: σ_{max}, δ_L, U = ? To find instantaneous stress:		
		$\sigma_{max} = \left(\frac{P}{A}\right) + \sqrt{\left(\frac{P}{A}\right)^2 + \frac{2.h.E}{L}\left(\frac{P}{A}\right)}$	1	
		Here, A = $\frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 20^2 = 314.16$ mm^2	1	
		and V = A × L = 314.16 × 1000 = 314160 mm^3	1	
		and $\left(\frac{P}{A}\right) = \left(\frac{1000}{314.16}\right) = 3.183$ $\therefore \sigma_{max} = (3.183) + \sqrt{(3.183)^2 + \frac{2 \times 250 \times 2 \times 10^5}{1000}(3.183)}$ $\sigma_{max} = (3.183) + (564.189)$		
		$\boxed{\sigma_{max} = 567.372 \text{ N/mm}^2}$	1	
		To find elongation:		
		$\delta_L = \frac{\sigma \times L}{E} = \frac{567.372 \times 1000}{2 \times 10^5}$	1	
		$\boxed{\delta_L = 2.836 \text{ mm}}$	1	
		To find strain energy:		
		$U = \frac{\sigma^2 . V}{2.E} = \frac{567.372^2 \times 314160}{2 \times 2 \times 10^5}$ U = 252828.88 N.mm	1	
		$\boxed{U = 252.828 \text{ N.m or Joule}}$	1	8