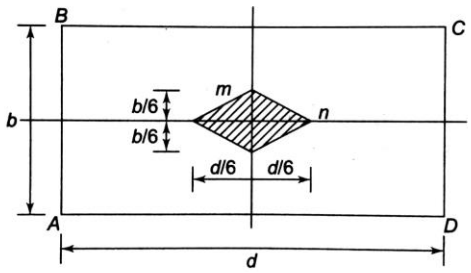
Model Answer: Winter-2018

Subject: Strength of Materials **Sub. Code: 17304**

Important Instructions to examiners:

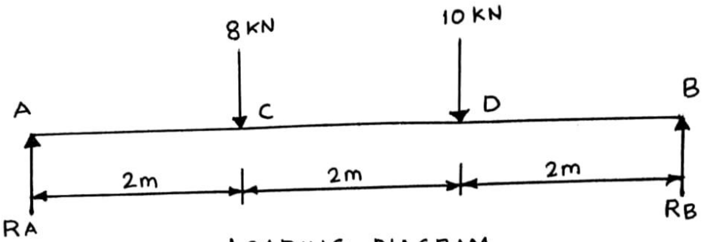
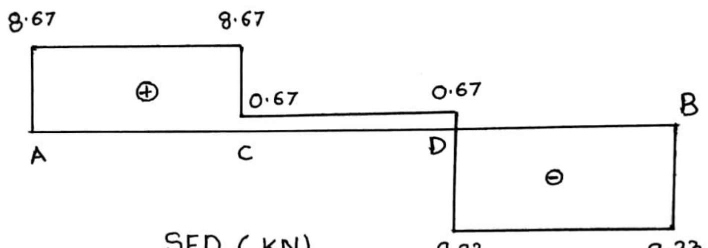
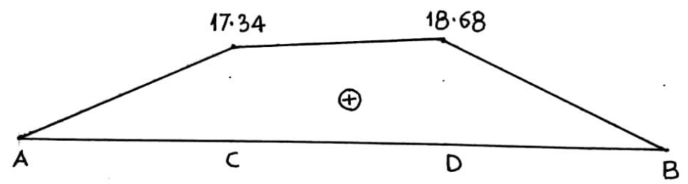
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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.

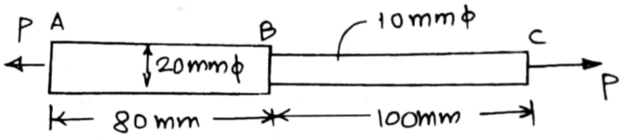
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1	a)	**Attempt any SIX of the following:**		**12**
	i)	**Define following properties of material.** **(1) Elasticity** **(2) Malleability**		
	Ans.	**1. Elasticity:** Elasticity is the property of material by virtue of it can regain its original shape and size after removal of deforming force.	**1**	**2**
		2. Malleability: Malleability is the property of material by virtue of which it can deformed in the form of thin sheets under the action of load.	**1**	
	ii)	**State 'Hooke's Law'. Define limit of proportionality.**		
	Ans.	**Hooke's Law:** It states that, when material is loaded within elastic limit, stress produced is directly proportional to the strain induced.	**1**	**2**
		Limit of proportionality: It is the point in stress strain curve up to which stress produced is directly proportional to strain induced obeying Hooke's law.	**1**	
	iii)	**State the relation between principal planes and the planes of maximum shear stress.**		
	Ans.	Planes of maximum shear stress are inclined at 45^0 to the principal planes.	**2**	**2**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1	**iv)**	**Find the radius of gyration of a circle of diameter'd'.**		
	Ans.	$I=\frac{\pi}{64}d^4$ and $A=\frac{\pi}{4}d^2$	**1**	
		$K=\sqrt{\frac{I}{A}}$		**2**
		$K=\sqrt{\frac{\frac{\pi}{64}d}{\frac{\pi}{4}d^2}}=\sqrt{\frac{d^2}{16}}=\frac{d}{4}$	**1**	
	v)	**Define:** (i) **Point of Contra-flexure and** (ii) **O.C. Neutral Axis**		
	Ans.	**i. Point of Contra-flexure:** It is the point in bending moment diagram where bending moment changes its sign from positive to negative and vice versa. At that point bending moment is equal to zero. This point is called as point of contra-flexure.	**1**	**2**
		ii. O.C. Neutral Axis: It is the axis shown in cross-section where bending stress is zero called as neutral axis. **OR** The intersection of the neutral layer with any normal cross section of a beam is called as neutral axis.	**1**	
	vi)	**State middle third rule with neat sketch.**		
	Ans.	According to middle third rule, in rectangular section, for no tension condition, the load must lie within the middle third shaded area of size $\frac{b}{3}$ and $\frac{d}{3}$.	**1**	**2**
			**1**	
	vii)	**What is the "No tension condition"? State.**		
	Ans.	The load acting in the middle third area or core of the section, then the material experiences only compressive stress without producing tensile stress. i.e. Direct stress is equal to bending stress. Minimum stress is zero, such condition is said to be "No tension condition".	**2**	**2**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.1	**viii)**	**State the assumptions in the theory of pure torsion of circular shaft.**		
	Ans.	**Assumptions in the theory of pure torsion of circular shaft.** 1. The material of the shaft is homogenous and isotropic and obeys Hook's law. 2. The twist along the shaft is uniform. 3. The shaft is straight and having uniform circular cross section throughout. 4. Cross sections of the shaft which are plane before twist remain plane after twist. 5. Stresses do not exceed the proportional limit.	**½ each (any four)**	**2**
	b)	**Attempt any <u>TWO</u> of the following:**		**8**
	i)	**A copper wire of length 500 mm is subjected to an axial pull of 5 kN. Find the minimum diameter if the stress is not to exceed 70 N/mm^2. Also calculate the elongation if E = 100 kN/ mm^2.**		
	Ans.	Data: L = 500 mm $P = 5 \times 10^3$ N $\sigma_{max} = 70$ N/mm^2 $E = 100 \times 10^3$ N/ mm^2 $\sigma_{\max} = \frac{P_{\max}}{A_{\min}}$		
		$A_{\min} = \frac{P_{\max}}{\sigma_{\max}} = \frac{5 \times 10^3}{70} = 71.428 mm^2$	**1**	
		$\frac{\pi}{4} d^2 = 71.428$ $d_{\min} = 9.536 mm$	**1**	**4**
		$\delta_L = \frac{PL}{AE}$	**1**	
		$\delta_L = \frac{5 \times 10^3 \times 500}{71.428 \times 100 \times 10^3} = 0.35 mm$	**1**	

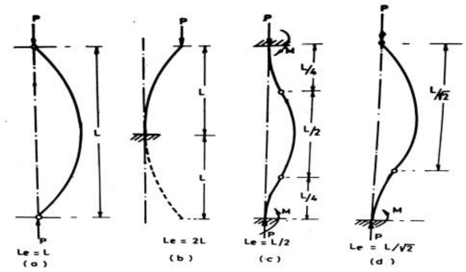
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.1	**b) ii)**	**A square bar 20mm size is subjected to an axial load. Find out maximum axial load the bar can carry if maximum principal stress is not to exceed 30 N/mm^2 tensile and maximum shear stress is not to exceed 12 N/mm^2.**		
	Ans.	Data: b = 20 mm d = 20 mm σ_n= 30 N/ mm^2 q_{max}= 12 N/ mm^2		
		$\sigma_{n_1} = \frac{\sigma_x}{2} + \sqrt{\left(\frac{\sigma_n}{2}\right)^2 + q^2}$	**1**	
		$30 = \frac{\sigma_x}{2} + \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + 12^2}$ $30 - \frac{\sigma_x}{2} = \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + 144}$ Squaring on both sides.		**4**
		$\left(30 - \frac{\sigma_x}{2}\right)^2 = \left(\frac{\sigma_x}{2}\right)^2 + 144$	**1**	
		$30^2 - 2\times 30\times\frac{\sigma_x}{2} + \left(\frac{\sigma_x}{2}\right)^2 = \left(\frac{\sigma_x}{2}\right)^2 + 144$ $900 - 30\times\sigma_x = 144$ $900 - 144 = 30\times\sigma_x$		
		$\sigma_x = 25.2$ N/mm^2	**1**	
		$P_{max} = \sigma_x \times A$ $P_{max} = 25.2\times 20\times 20$ $P_{max} = 10080$ N		
		$P_{max} = 10.08$ kN	**1**	
	iii)	**A simply supported beam of span 6 m carries two point loads of 8kN and 10kN at 2 m and 4 m from the left hand support respectively. Draw SFD and BMD showing all important values.**		
	Ans.	1. Calculation of support reactions $\sum M_A = 0$ $8\times 2 + 10\times 4 = 6R_B$ $R_B = 9.33$kN		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.1	**b) iii)**	$\sum F_y = 0$ $R_A + R_B = 8 + 10 = 18\text{kN}$ $R_A + 9.33 = 18$ $R_A = 8.67\text{kN}$ 2. SF calculations SF at A = +8.67kN C_L = +8.67kN C_R = +8.67-8= 0.67kN D_L = +0.67kN D_R = +0.67-10 = -9.33kN B_L = -9.33kN B = -9.33+9.33 = 0 kN (∴ ok)	1	4
		3. Bending moment calculations. BM at A and B = 0(∵ Supports are simple) BM at C = 8.67×2=17.34 kN-m D = 9.33×2=18.68 kN-m	1	
		LOADING DIAGRAM		
		SFD (KN)	1	
		BMD (KN-m)	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.2		**Attempt any FOUR of the following:**		**16**
	a)	**Determine the force and elongation of the compound bar shown in Figure No. 1 if the maximum stress induced in it is 100 N/mm^2. Both sections are circular. Take E = 200 kN/mm^2.**		
		 **Fig. No. 1**		
	Ans.	**Data:**		
		$\sigma_{max} = 100 \text{ N/mm}^2$		
		$E = 200 \text{ kN/mm}^2$		
		$A_{min} = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 10^2 = 78.54\text{mm}^2$		
		$\sigma_{max} = \frac{P}{A_{min}}$		
		$P = \sigma_{max} \times A_{min}$		
		$P = 100 \times 78.54 = 7854\text{N}$	1	
		To find total elongation		
		$\delta_L = (\delta_L)_{AB} + (\delta_L)_{AB}$		
		$(\delta_L)_{AB} = \left(\frac{PL}{AE}\right)_{AB}$	1	4
		$(\delta_L)_{AB} = \left(\frac{7854 \times 80}{\frac{\pi}{4} \times 20^2 \times 200 \times 10^3}\right)$		
		$(\delta_L)_{AB} = 0.01mm$		
		$(\delta_L)_{BC} = \left(\frac{PL}{AE}\right)_{BC}$	1	
		$(\delta_L)_{BC} = \left(\frac{7854 \times 100}{\frac{\pi}{4} \times 10^2 \times 200 \times 10^3}\right)$		
		$(\delta_L)_{BC} = 0.05mm$		
		$\delta_L = 0.01 + 0.05 = 0.06mm$	1	

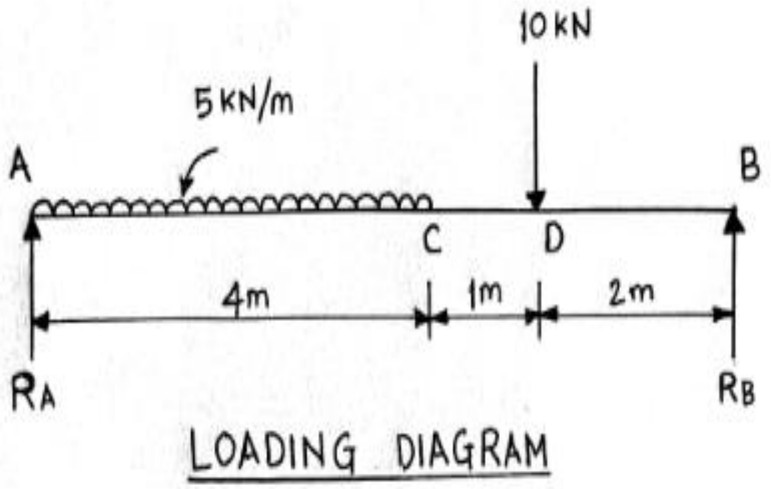
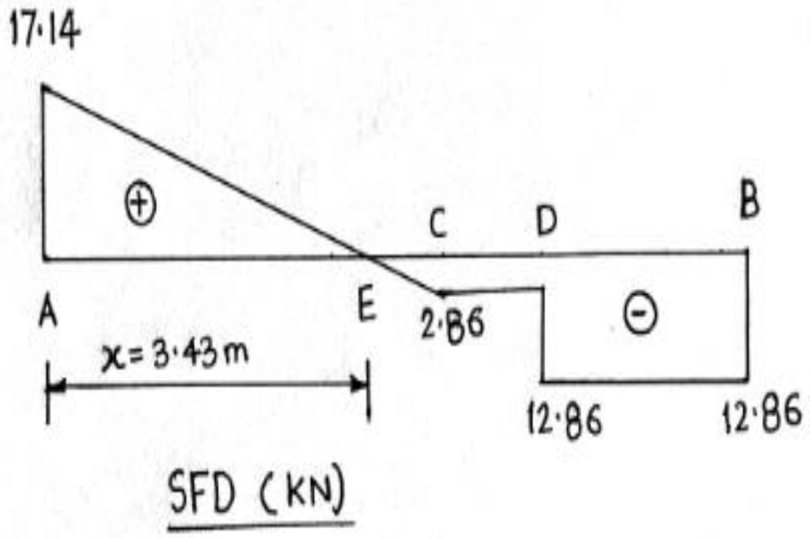
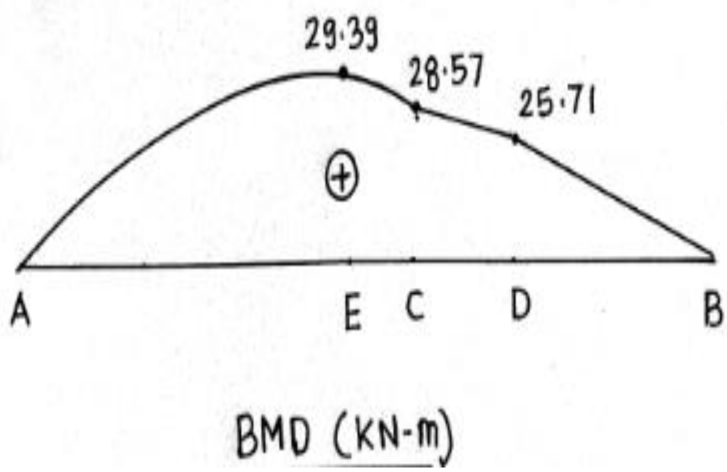
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.2	**b)**	**A copper tube having 20 mm inside diameter and 4 mm thickness of metal is pressed fit on a steel rod 20 mm diameter. Determine the stress induced in each metal due to temperature rise 60^{0}C .Take α_c= 16 x 10^{-6} /^{0}C, α_s= 11 x 10^{-6} /^{0}C. E_s = 200 kN/mm^2 E_c = 160 kN/mm^2.**		
	Ans.	$A_c = \frac{\pi}{4}(D^2 - d^2)$ $A_c = \frac{\pi}{4}(28^2 - 20^2)$ $A_c = 301.59 mm^2$ $A_s = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times 20^2 = 314.15 mm^2$	**1**	
		Under equilibrium condition $P_c = P_s$ $\sigma_c \times A_c = \sigma_s \times A_s$ $\sigma_c \times 301.59 = \sigma_s \times 314.15$ $\sigma_c = 1.0416\sigma_s$.................................. (i) $\frac{\sigma_s}{E_s} + \frac{\sigma_c}{E_c} = (\alpha_c - \alpha_s)t$	**1**	
		$\frac{\sigma_s}{200\times10^3} + \frac{1.0416\sigma_s}{160\times10^3} = (16\times10^{-6} - 11\times10^{-6})\times 60$ $\sigma_s\left(\frac{1}{200\times10^3} + \frac{1.0416}{160\times10^3}\right) = 3\times10^{-4}$ $\sigma_s \times 1.1506\times10^{-5} = 3\times10^{-4}$	**1**	**4**
		$\sigma_s = \frac{3\times10^{-4}}{1.1506\times10^{-5}} = 26.063 \text{ N/mm}^2 (T)$ *From* equation (i) $\sigma_c = 1.0416\times 26.063 = 27.148 \text{ N/mm}^2 (C)$	**1**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.2	**c)**	**A metal bar of 30 mm x 30 mm in section is subjected to an axial compressive load of 500kN. A contraction of 200 mm gauge length is found to be 0.6 mm and the increase in thickness is 0.04 mm. Find the value of Poisson's ration and the three elastic constants.**		
	Ans.	**Data:**		
		$b = 30 \quad t = 30$		
		$L = 200mm$		
		$P = 500KN = 500\times10^3 N$		
		$\delta L = 0.6mm$		
		$\delta t = 0.04mm$		
		$\delta L = \frac{PL}{AE}$		
		$E = \frac{P\times L}{b\times t\times \delta L}$		
		$E = \frac{500\times10^3\times200}{30\times30\times0.6}$	1	
		$E = 185185.185 = 1.85\times10^5 N/mm^2$		
		$\mu = \frac{\text{Lateral strain}}{\text{Linear strain}} = \frac{e_L}{e} = \frac{\left(\frac{\delta t}{t}\right)}{\left(\frac{\delta L}{L}\right)}$		
		$\mu = \frac{\left(\frac{0.04}{30}\right)}{\left(\frac{0.6}{200}\right)} = 0.44$	1	4
		$E = 2G(1+\mu)$		
		$185185.185 = 2G(1+0.44)$	1	
		$G = 0.643\times10^5 \text{ N/mm}^2$		
		$E = 3K(1-2\mu)$		
		$185185.185 = 3K(1-2\times0.44)$	1	
		$K = 5.144\times10^5 \text{ N/mm}^2$		
	d)	**State effective length of columns for different end conditions with neat sketches.**		
	Ans.	Effective Length of column for different end conditions:		
		a. When both ends of column are hinged. $L_e = L$		
		b. When one end of column is fixed and other is free. $L_e = 2L$	2	
		c. When both ends of column are fixed. $L_e = L/2$		
		d. When one end of column is hinged and other is fixed. $L_e = L/\sqrt{2}$		

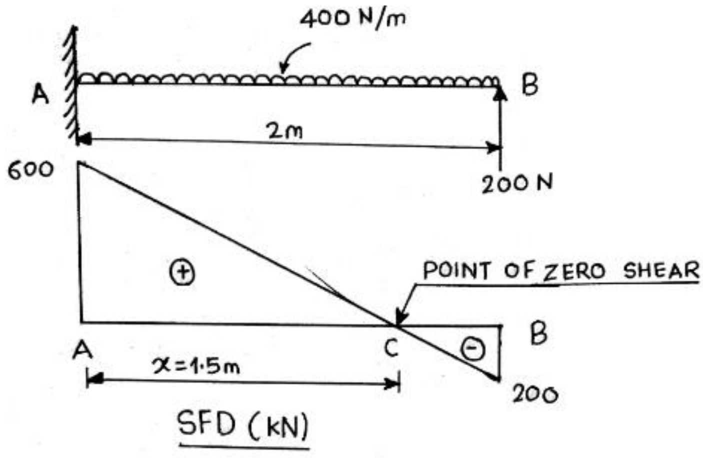
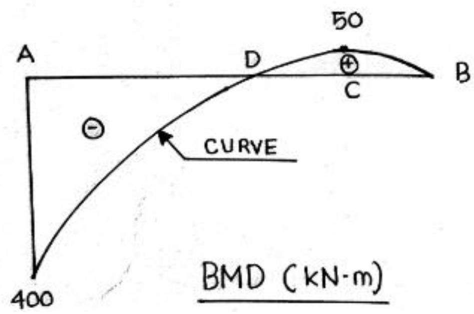
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.2	**d)**	 **Fig. Effective Length of Columns**	**2**	**4**
	e)	**The principal stresses at point in the section of the member are 100 N/mm^2 and 50 N/mm^2 both tensile. Find the normal and tangential stresses across a plane passing through that point inclined at 60^0 to the plane having 100 N/mm^2 stress.**		
	Ans.	$Data:$		
		$\sigma_x = 100 N/mm^2$		
		$\sigma_y = 50 N/mm^2$		
		$\theta = 60^0$		
		$\sigma_n = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 2\theta$	**1**	
		$\sigma_n = \frac{100+50}{2} + \frac{100-50}{2} \cos\left(2 \times 60^0\right)$		
		$\sigma_n = 75 + 25 \cos\left(120^0\right)$		
		$\sigma_n = 75 - 12.50$	**1**	
		$\sigma_n = 62.50 N/mm^2$		
		$\sigma_t = \frac{\sigma_x - \sigma_y}{2} \sin 2\theta$	**1**	
		$\sigma_t = \frac{100-50}{2} \sin\left(2 \times 60^0\right)$		**4**
		$\sigma_t = 25 \sin\left(120^0\right)$		
		$\sigma_t = 21.65 N/mm^2$	**1**	
		(Note: If problem solved by Mohr's Circle method, should be considered.)		

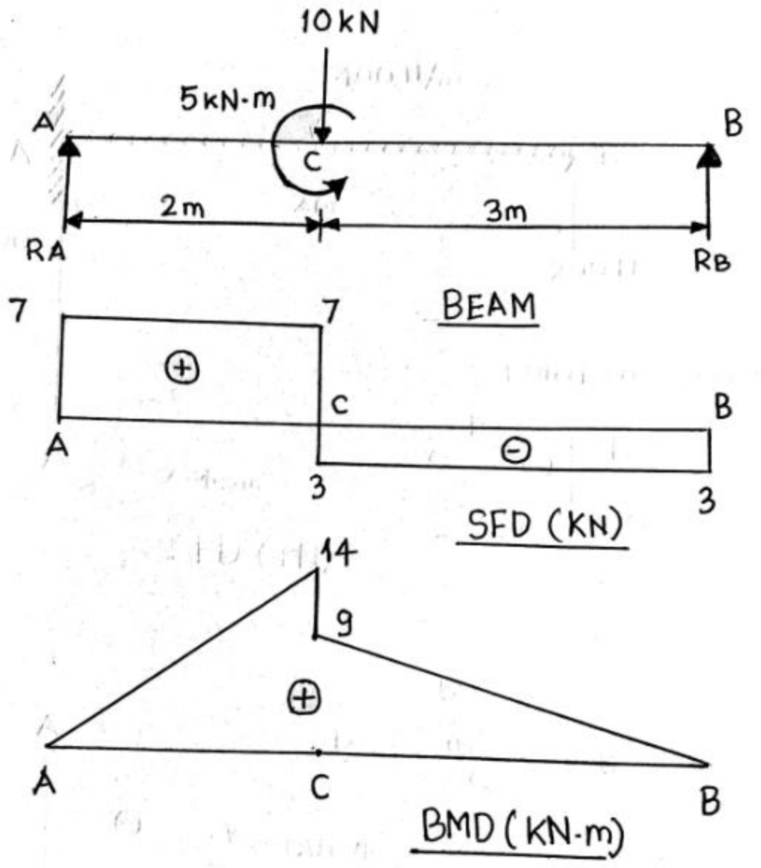
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.2	**f)**	**At a point in the web of the girder, bending stress σ_b and the shear stress is τ . The principal stresses at a point are 80MPa tensile and 20MPa compressive. Evaluate the values of σ_b and τ . Determine the direction of principal planes.**		
	Ans.	$\sigma_x = \sigma_b \quad \sigma_y = 0 \quad q = \tau$ $\sigma_{n_1} = 80 N/mm^2 (T)$ $\sigma_{n_2} = 20 N/mm^2 (C)$ Major principal stress $\sigma_{n_1} = \frac{\sigma_x}{2} + \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + q^2}$ $80 = \frac{\sigma_b}{2} + \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2}$ ....(i) Minor principal stress $\sigma_{n_2} = \frac{\sigma_x}{2} - \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + q^2}$ $-20 = \frac{\sigma_b}{2} - \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2}$ ....(ii)	**1**	
		Adding equation (i) and (ii) $80 - 20 = \frac{\sigma_b}{2} + \frac{\sigma_b}{2}$ $60 = \sigma_b$ Bending Stress $\sigma_b = 60 N/mm^2$ (T)	**1**	
		Substituting the Value of σ_b in equation (i) $80 = \frac{60}{2} + \sqrt{\left(\frac{60}{2}\right)^2 + \tau^2}$ $80 = 30 + \sqrt{900 + \tau^2}$ $(80-30)^2 = 900 + \tau^2$ $2500 = 900 + \tau^2$ $\tau^2 = 1600 \quad \therefore \tau = 40 N/mm^2$ Shear stress (τ) $= 40 N/mm^2$	**1**	**4**
		Direcion of principal planes $\tan 2\theta = \frac{2q}{\sigma_x} = \frac{2\tau}{\sigma_b}$ $\tan 2\theta = \frac{2\times 40}{60} = 1.33$ $2\theta_1 = \tan^{-1}(1.33)$ $\theta_1 = \frac{53.13^0}{2} = 26.56^0$...............Position of I^{st} plane $\theta_2 = \theta_1 + 90^0 = 26.56^0 + 90^0$ $\theta_2 = 116.56^0$...............Position of II^{nd} plane	**1**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3		**Attempt any FOUR of the following :**		**16**
	a)	**A simply supported beam of span 7m carries a udl of 5 kN over 4 m span from left support and a point load of 10 kN at 2 m from the right hand support. Draw SFD and BMD.**		
	Ans.	**1. Support Reaction Calculations:** Taking moment about A $\Sigma M_A = 0$ $[(5x4) \times 2] + (10 \times 5) - R_B \times 7 = 0$ $40 + 50 - 7 R_B = 0$ $R_B = 12.857$ kN $\Sigma F_Y = 0$ $R_A - (5 \times 4) - 10 + R_B = 0$ $R_A - 20 - 10 + 12.857 = 0$ $R_A = 17.143$ kN		
		2. Shear Force Calculations: SF at A = 0 kN $A_R = + 17.143$ kN $C_L = + 17.143 - (5 \times 4) = - 2.857$ kN $C_R = - 2.857$ kN $D_L = - 2.857$ kN $D_R = - 2.857 - 10 = - 12.857$ kN $B_L = - 12.857$ kN B = - 12.857 + 12.857 = 0 kN (∴ ok)	½	
		3. Bending Moment Calculations: At simply supported ends, $M_A = M_B = 0$ kN-m $M_C = +(17.143 \times 4) - [(5 \times 4) \times 2] = + 28.571$ kN-m $M_D = +(12.857 \times 2) = + 25.714$ kN-m	½	4
		4. Maximum Bending Moment Calculations: Maximum Bending Moment will occur at point 'E' Let 'x' be the distance of point 'E' from point 'A' From the similar triangles in SFD – $\frac{x}{17.143} = \frac{4-x}{2.857}$ $x = 3.4286m$	½	
		OR SF at E = 0 17.143 = 5 x $x = 3.4286m$ $M_{max} = M_E = +(17.143 \times 3.4286) - [(5 \times 3.4286) \times \frac{3.4286}{2}]$ $= + 29.388$ kN-m	½	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3	**a)**	**Diagram:** 		
			1	
			1	

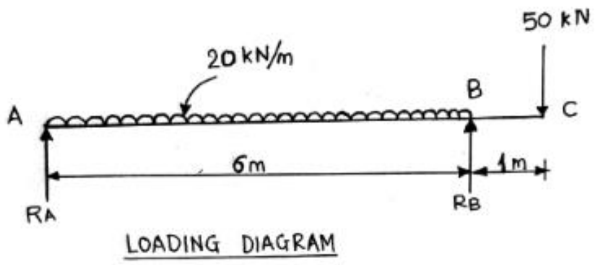
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3	**b)** **Ans.**	**A cantilever beam of span 2 m carries udl of 400 N/m over the entire span. It has also an upward reaction of 200 N at its free end. Find SFD and BMD. Also locate point of zero shear.** 1. **Support Reaction Calculations:** $\Sigma F_Y = 0$ $R_A – (400 \times 2) + 200 = 0$ $R_A = 600$ N 2. **Shear Force Calculations:** SF at A = 0 N $A_R = + 600$ N $B_L = + 600 – (400 \times 2) = - 200$ N B = - 200 + 200 = 0 N ($\therefore$ ok) 3. **Bending Moment Calculations:** At Free end, $M_B = 0$ N-m $M_A = +(200 \times 2) – [(400 \times 2) \times 1] = - 400$ N-m **4. Calculation of Point of Zero Shear Force i.e. Maximum Bending Moment** Point of Zero Shear Force i.e. Maximum Bending Moment will occur at point ‘C’ Let ‘x’ be the distance of point ‘C’ from point ‘A’ From the similar triangles in SFD – $\frac{x}{600} = \frac{2 - x}{200}$ $x = 1.5m$ Zero Shear Force point lies at 1.5 m from point ‘A’ and 0.5 m from point ‘B’. $M_{max} = M_C = +(200 \times 0.5) – [(400 \times 0.5) \times \frac{0.5}{2}]$ $= + 50$ N-m	 **1** **1**	 **4**

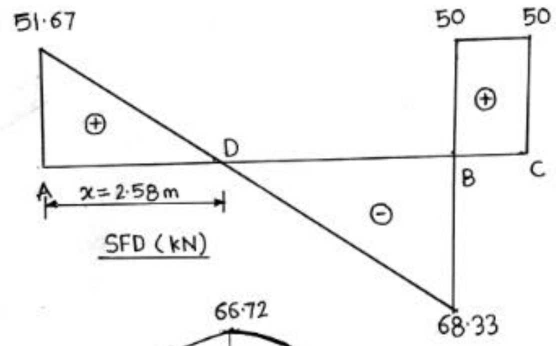
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.3	**b)**	**Diagram:**  	1	
		 	1	
	c)	**A simply supported beam 5 m long carries a point load of 10 kN and anticlockwise moment of 5 kN-m at a distance of 2 m from left hand support. Draw SFD and BMD.**		
	Ans.	**1. Support Reaction Calculations:** Taking moment about A $\Sigma M_A = 0$ $(10 \times 2) - 5 - R_B \times 5 = 0$ $20 - 5 - 5R_B = 0$ $R_B = 3$ kN $\Sigma F_Y = 0$ $R_A - 10 + R_B = 0$ $R_A - 10 + 3 = 0$ $R_A = 7$ kN		
		2. Shear Force Calculations: SF at A = 0 N $A_R = +7$ kN $C_L = +7$ kN $C_R = +7 - 10 = -3$ kN $B_L = -3$ kN $B = -3 + 3 = 0$ kN ($\therefore$ ok)	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.3	**c)**	**3. Bending Moment Calculations:** At simply supported ends, $M_A = M_B = 0$ kN-m BM at $C_L = +(7 \times 2) = +14$ kN-m $C_R = +(7 \times 2) - 5 = +9$ kN-m **4. Diagram** 	1 1 1	4
	d)	**A beam of span 7 m is simply supported at A and B. AB = 6 m, BC = 1 m, BC is overhang portion. Portion AB carries udl of 20 kN/m and a point load of 50 kN at C. Draw SFD and BMD.**		
	Ans.	**1. Support Reaction Calculations:** Taking moment about A $\Sigma M_A = 0$ $[(20 \times 6) \times 3] + (50 \times 7) - R_B \times 6 = 0$ $360 + 350 - 6 R_B = 0$ $R_B = 118.33$ kN $\Sigma F_Y = 0$ $R_A - (20 \times 6) - 50 + R_B = 0$ $R_A - 120 - 50 + 118.33 = 0$ $R_A = 51.67$ kN		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.3	**d)**	**2. Shear Force Calculations:** SF at A = 0 kN A_R =+ 51.67 kN B_L = + 51.67 – (20 x 6) = - 68.33 kN B_R = - 68.33 + 118.33 = + 50 kN C_L = + 50 kN C_R = + 50 – 50 = 0 kN ($\therefore$ ok)	½	
		3. Bending Moment Calculations: At Support 'A' and at Free end 'C', $M_A = M_C$ = 0 kN-m M_B = - (50 x 1) = - 50 kN-m	½	
		4. Maximum Bending Moment Calculations: Maximum Bending Moment will occur at point 'D' Let 'x' be the distance of point 'D' from point 'A' From the similar triangles in SFD – $\frac{x}{51.67} = \frac{6-x}{68.33}$ $x = 2.58m$ OR SF @ D = 0 51.667 – 20 x = 0 $x = 2.58m$	½	
		$M_{max} = M_D$ = +(51.67 x 2.58) – [(20 x 2.58) x $\frac{2.58}{2}$] = + 66.74 kN-m	½	**4**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.3	**d)**	**Diagram**		





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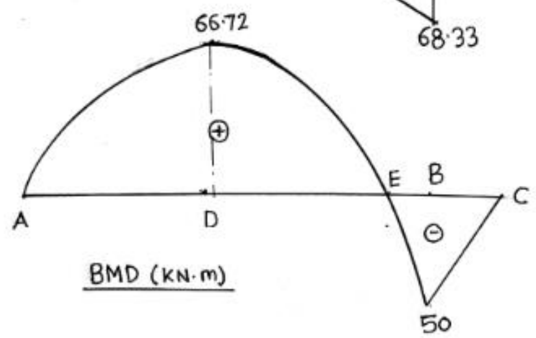


1

e) **Find the polar moment of inertia of a hollow circular section having external diameter 100 mm and thickness 10 mm. Also find the radius of gyration.**

Ans. Data: D = 100mm, t = 10mm Find: I_P ? and K=?

d = D – 2t = 100 – 2x10 = 80mm

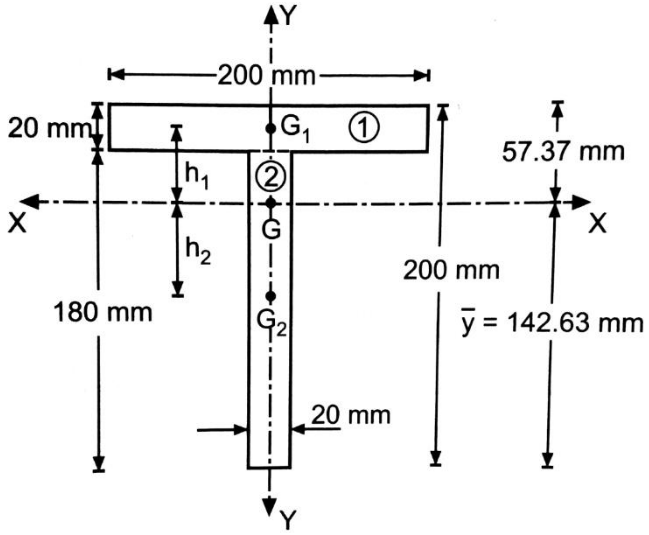
1. Polar Moment of Inertia of hollow circular section:

$I_P = I_{xx} + I_{yy}$

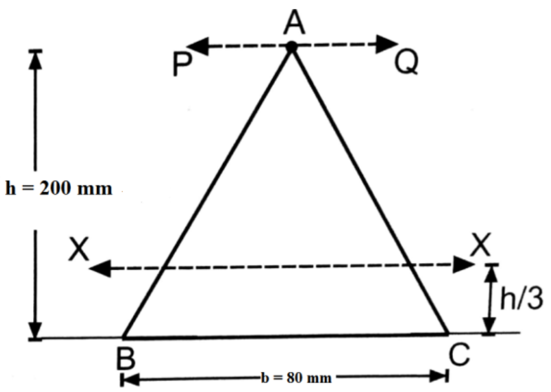
$I_{xx} = I_{yy} = \frac{\pi}{64}\left[D^4 - d^4\right]$

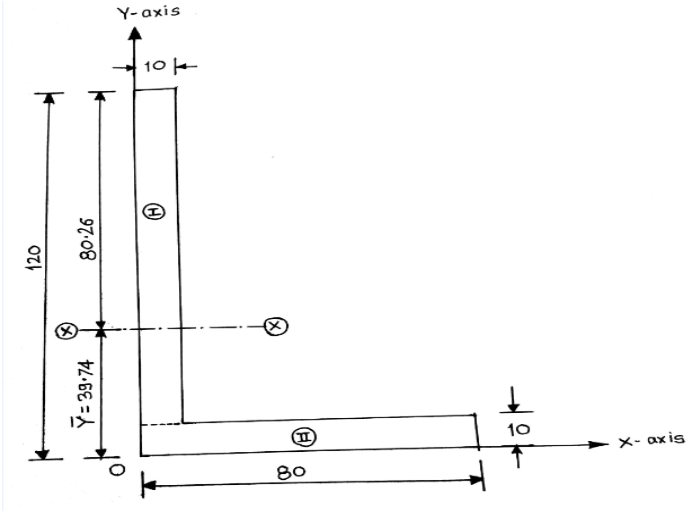
$= \frac{\pi}{64}\left[100^4 - 80^4\right]$

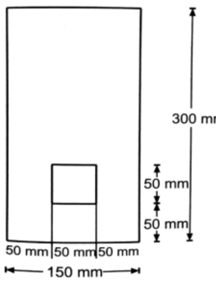
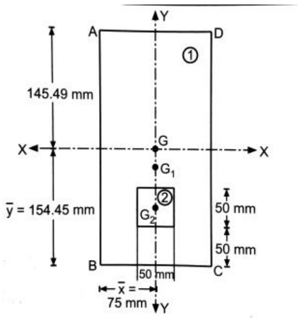
$I_{xx} = I_{yy} = 2.898119 \times 10^6\ mm^4$ 1

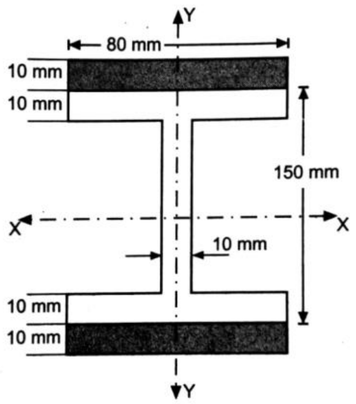
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.3	**e)**	$I_P = I_{xx} + I_{yy}$ $= 2.898 \times 10^6 + 2.898 \times 10^6$ $= 5.796238 \times 10^6 \text{ mm}^4$	**1**	
		2. Radius of Gyration: $K = \sqrt{\frac{I}{A}}$ $I = 2.898 \times 10^6 \text{ mm}^4$ $A = \frac{\pi}{4}\left(D^2 - d^2\right)$ $= \frac{\pi}{4}\left(100^2 - 80^2\right)$ $= 2827.433 \text{ mm}^2$	**1**	**4**
		$K = \sqrt{\frac{2.898 \times 10^6}{2826}}$ $K = 32.015$ mm	**1**	
		OR	**OR**	
		$K = \sqrt{\frac{D^2 + d^2}{16}}$ $K = \sqrt{\frac{100^2 + 80^2}{16}}$	**1**	
		$K = \sqrt{1025} = 32.015 mm$	**1**	
	f) **Ans.**	**Find moment of inertia of a 'Tee' section 200mm x 200 mm x 20 mm about the centroidal horizontal axis.** 		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3	**f)**	$a_1 = 200 \times 20 = 4000 mm^2$		
		$y_1 = 200 - \frac{20}{2} = 190 mm$	½	
		$a_2 = 180 \times 20 = 3600 mm^2$		
		$y_1 = \frac{180}{2} = 90 mm$		
		$\overline{y} = \frac{a_1 y_1 + a_2 y_2}{a_1 + a_2}$		
		$\overline{y} = \frac{4000 \times 190 + 3600 \times 190}{7600}$		
		$\overline{y} = 142.63 mm$ from the base	½	
		$I_{xx} = I_{xx_1} + I_{xx_2}$		
		$I_{xx} = (IG_1 + a_1 h_1^2) + (IG_2 + a_2 h_2^2)$		
		$h_1 = y_1 - \overline{y} = 190 - 142.63 = 47.37 mm$		
		$h_2 = \overline{y} - y_2 = 142.63 - 90 = 52.63 mm$	½	
		$IG_1 = \frac{200 \times 20^3}{12} = 133333.33 mm^4$	½	
		$IG_2 = \frac{20 \times 180^3}{12} = 9720000 mm^4$	½	**4**
		$I_{xx_1} = (133333.33 + 4000 \times 47.37^2) = 9109000.93 mm^4$	½	
		$I_{xx_2} = (9720000 + 3600 \times 52.63^2) = 19691700.84 mm^4$	½	
		$I_{xx} = 9109000.93 + 19691700.84 = 28.8 \times 10^6 mm^4$	½	

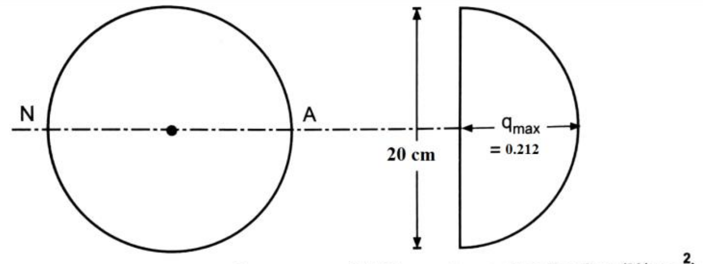
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.4.		**Attempt any <u>FOUR</u> of the following:**		**16**
	a)	**Find the M.I. of a triangular section having base 80mm and height 200mm about the horizontal axis parallel to the base. Also calculate the M.I. about the base and about an axis passing through its vertex and parallel to the base.**		
	Ans.	Data: b = 80mm, h = 200mm Find: I_{xx} , I_{base} and I_{apex}		
			**1**	
		(1) Moment of Inertia of triangular section about the horizontal axis parallel to the base i.e. about X-X axis $I_{xx} = \frac{bh^3}{36} = \frac{80\times200^3}{36} = 17.78\times10^6\, mm^4$	**1**	**4**
		(2) Moment of Inertia of triangular section about the base $I_{base} = \frac{bh^3}{12} = \frac{80\times200^3}{12} = 53.33\times10^6\, mm^4$	**1**	
		(3) Moment of Inertia of triangular section about the vertex i.e. apex $I_{apex} = \frac{bh^3}{4} = \frac{80\times200^3}{4} = 160\times10^6\, mm^4$	**1**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4	**b)**	**Find I_{xx} for an unequal angle section of size 120mm x 80mm x 10mm thick.**		
	Ans.			
		(1) Location of CG:		
		$a_1 = 10 \times 110 = 1100\ mm^2$		
		$x_1 = \frac{10}{2} = 5mm$		
		$y_1 = \frac{110}{2} + 10 = 65mm$		
		$a_2 = 80 \times 10 = 800\ mm^2$		
		$x_2 = \frac{80}{2} = 40mm$		
		$y_2 = \frac{10}{2} = 5mm$	½	
		$\overline{X} = \frac{a_1x_1 + a_2x_2}{a_1 + a_2} = \frac{(1100 \times 5) + (800 \times 40)}{1100 + 800} = 19.736mm$	½	
		$\overline{Y} = \frac{a_1y_1 + a_2y_2}{a_1 + a_2} = \frac{(1100 \times 65) + (800 \times 5)}{1100 + 800} = 39.736mm$		
		(2) Moment of inertia of the given section about X-X is given by –		
		$I_{xx} = I_{xx1} + I_{xx2}$		
		$I_{xx} = (I_{G1} + a_1h_1^2) + (I_{G2} + a_2h_2^2)$		
		$I_{G1} = \frac{bd^3}{12} = \frac{10 \times 110^3}{12} = 1.109 \times 10^6\ mm^4$	½	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4	**b)**	$I_{G2} = \frac{bd^3}{12} = \frac{80 \times 10^3}{12} = 6.67 \times 10^3 mm^4$	½	**4**
		$h_1 = \lvert \overline{Y} - y_1 \rvert = \lvert 39.736 - 65 \rvert = \lvert -25.26 \rvert = 25.26mm$		
		$h_2 = \lvert \overline{Y} - y_2 \rvert = \lvert 39.736 - 5 \rvert = \lvert 34.74 \rvert = 34.74mm$	½	
		$I_{xx1} = (1.109 \times 10^6 + 1100 \times 25.26^2) = 1.81 \times 10^6$ mm^4	½	
		$I_{xx2} = (6.67 \times 10^3 + 800 \times 34.74^2) = 0.97 \times 10^6$mm^4	½	
		$I_{xx} = 1.81 \times 10^6 + 0.97 \times 10^6$		
		$I_{xx} = 2.78 \times 10^6$ mm^4	½	
	c)	**Find moment of inertia about X-X axis for the section shown in Figure No. 2.**		
	Ans.	 		
		Figure No. 2.		
		(1) Location of CG point:		
		As the given section is symmetric about Y-Y axis		
		$\therefore \overline{X} = x_1 = x_2 = \frac{150}{2} = 75mm$		
		$a_1 = 150 \times 300 = 45000$ mm^2		
		$y_1 = \frac{300}{2} = 150mm$		
		$a_2 = 50 \times 50 = 2500$ mm^2	½	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4	**c)**	$y_2 = \frac{50}{2} + 50 = 75mm$		
		$\overline{Y} = \frac{a_1 y_1 - a_2 y_2}{a_1 - a_2} = \frac{(45000 \times 150) - (2500 \times 75)}{45000 - 2500} = 154.41mm$	½	
		(2) **Moment of inertia of the given section about X-X :**		
		$I_{xx} = I_{xx1} - I_{xx2}$		
		$I_{xx} = (I_{G1} + a_1 h_1^2) - (I_{G2} + a_2 h_2^2)$		
		$I_{G1} = \frac{bd^3}{12} = \frac{150 \times 300^3}{12} = 337.5 \times 10^6 mm^4$	½	**4**
		$I_{G2} = \frac{bd^3}{12} = \frac{50 \times 50^3}{12} = 520.83 \times 10^3 mm^4$	½	
		$h_1 = \lvert \overline{Y} - y_1 \rvert = \lvert 154.41 - 150 \rvert = \lvert 4.41 \rvert = 4.41mm$	½	
		$h_2 = \lvert \overline{Y} - y_2 \rvert = \lvert 154.41 - 75 \rvert = \lvert 79.41 \rvert = 79.41mm$	½	
		$I_{xx1} = (I_{G1} + a_1 h_1^2)$ $(337.5 \times 10^6 + 45000 \times 4.41^2) = 338.38 \times 10^6 mm^4$		
		$I_{xx2} = (I_{G2} + a_2 h_2^2) = (520.83 \times 10^3 + 2500 \times 79.41^2) = 16.29 \times 10^6 mm^4$	½	
		$I_{xx} = 338.38 \times 10^6 - 16.29 \times 10^6 mm^4$		
		$I_{xx} = 322.06 \times 10^6 mm^4$	½	
	d)	**A built up column section is made of an I-section 150 x 80 x 10 mm with one flange plate 80mm x 10mm riveted to each of the flanges. Find the minimum radius of gyration of the section.**		
				

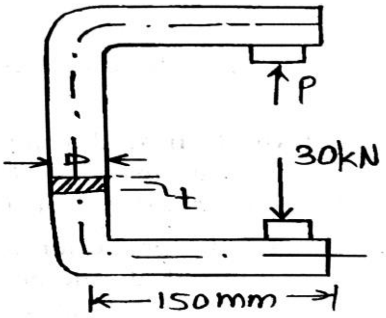
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4	**d) Ans.**	(1) Minimum Radius of Gyration:		
		$K_{min} = \sqrt{\frac{I_{min}}{A}}$		
		Given section is symmetric about both the cetroidal axes.		
		Moment of inertia of the given section about the horizontal centroidal axis:		
		$I_{xx} = \frac{BD^3}{12} - \frac{bd^3}{12}$		
		$= \frac{80 \times 170^3}{12} - \frac{70 \times 130^3}{12}$		
		$= 32.75 \times 10^6 - 12.82 \times 10^6$		
		$= 19.93 \times 10^6 \text{ mm}^4$	**1**	
		I_{yy} = 2(Combined MI of one plate and flange) + (MI of web)		
		$= 2\left(\frac{20 \times 80^3}{12}\right) + \left(\frac{130 \times 10^3}{12}\right)$		
		$= 1.71 \times 10^6 + 10.83 \times 10^3$		
		$= 1.72 \times 10^6 \text{ mm}^4$		
		$I_{min} = I_{yy} = 1.72 \times 10^6 \text{ mm}^4$	**1**	**4**
		Area of the section		
		A = 2(80 x 20) + (10 x 130)		
		$= 4500 \text{ mm}^2$		
		$\therefore K_{min} = \sqrt{\frac{I_{yy}}{A}}$	**1**	
		$= \sqrt{\frac{1.72 \times 10^6}{4500}}$		
		= 19.55 mm	**1**	
	e)	**A timber beam having rectangular section 80mm x 240mm. This beam is cantilever of length 2 m and subjected to udl. of 5 kN/m over entire length. Find extreme fiber stress at the section where bending moment is maximum.**		

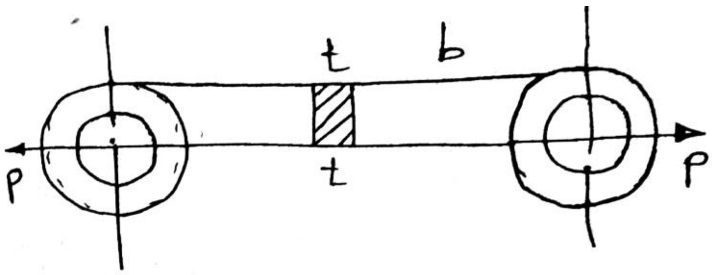
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4	**e)**	$M_{max} = \frac{WL^2}{2} = \frac{5\times 2^2}{2} = 10KNm = 10 \times 10^6$ N-mm	**1**	
		$I_{NA} = I_{xx} = \frac{bd^3}{12} = \frac{80\times 240^3}{12} = 92.16\times 10^6\, mm^4$	**1**	
		$\sigma_b = \frac{M}{I_{NA}}\times y_{max}$	**1**	**4**
		$\sigma_b = \frac{10\times 10^6}{92.16\times 10^6}\times 120 = 13.021 N/mm^2$	**1**	
	f)	**A circular section 20 cm diameter is subjected to a shear force of 5 kN when used as beam. Determine the maximum shear stress induced and draw the shear distribution diagram.**		
	Ans.	Data: d = 20cm = 200 mm, F= 5kN = 5 x 10^3 N Find: τ_{max}		
		$\tau_{avg} = \frac{F}{A} = \frac{5\times 10^3}{\frac{\pi}{4}\times 200^2} = 0.159 N/mm^2$	**1**	
		$\tau_{max} = \frac{4}{3}\tau_{avg}$	**1**	
		$\tau_{max} = \frac{4}{3}\times 0.159 = 0.212\ N/mm^2$	**1**	
		OR	**OR**	**4**
		b = d = 200 mm		
		$A = \frac{\pi}{8}d^2 = \frac{\pi}{8}\times 200^2 = 15707.96 mm^2$	½	
		$\bar{Y} = \frac{4R}{3\pi} = \frac{4\times 100}{3\pi} = 42.44 mm$	½	
		$I = \frac{\pi}{64}d^4 = \frac{\pi}{64}\times 200^4 = 78.54\times 10^6 mm^4$	**1**	
		$\tau_{max} = \frac{FA\bar{Y}}{Ib} = \frac{5\times 10^3\times 15707.96\times 42.44}{78.54\times 10^6\times 200} = 0.212 N/mm^2$	**1**	
		(a) Cross-section (b) Shear stress distribution (N/mm²)	**1**	

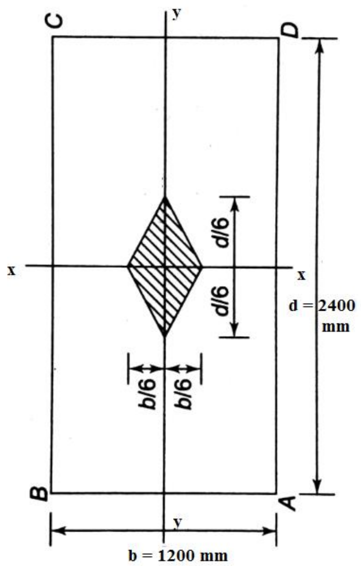
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.5		**Attempt any FOUR of the following:**		**16**
	a)	**Find diameter of circular section of a beam of 6 m span to carry load of 80 kN at the centre of span. If permissible bending stress is limited to 8.4 N/mm^2.**		
	Ans.	Data: L = 6m W = 80kN σ_b = 8.4 N/mm^2 Find: d = ?		
		$M = \frac{WL}{4} = \frac{80\times10^3\times6\times10^3}{4} = 120\times10^6$ N-mm	**1**	
		$I = \frac{\pi}{64}d^4$		
		$y = \frac{d}{2}$	**1**	
		$\frac{M}{I} = \frac{\sigma_b}{y}$		
		$\frac{120\times10^6}{\frac{\pi}{64}d^4} = \frac{8.4}{\frac{d}{2}}$	**1**	**4**
		$\frac{120\times10^6}{\frac{\pi}{32}d^3} = 8.4$		
		$d^3 = \frac{120\times10^6\times32}{8.4\times\pi}$		
		$d = 525.977$mm	**1**	
		(Note: Type of beam is not mentioned in question, if the question is solved by considering cantilever beam. It should be considered.)		
	b)	**A simply supported beam of span 2 m and cross section of 100 mm x 200 mm carries a u.d.l of 5 kN/m over the entire span. Find the maximum intensity of shear stress in the beam at a section 0.5 m to the right of the left hand support.**		
	Ans.	$R_A = \frac{wL}{2} = \frac{5\times2}{2} = 5$ KN		
		SF at 0.5 m from left support = R_A- (0.5w) =5- (0.5×5) =2.5kN = 2.5 x 10^{3}N	**1**	
		$q_{ava.} = \frac{S}{A} = \frac{2.5\times10^3}{100\times200} = 0.125$N/mm^2	**1**	
		$q_{max.} = 1.5q_{ava.}$	**1**	
		$q_{max.} = 1.5\times0.125 = 0.1875$N/mm^2	**1**	**4**
		OR		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.5	b)	$q_{max.} = \frac{SA\overline{Y}}{bI}$	1	
		$q_{max.} = \frac{2.5\times10^3\times(100\times100)\times50}{100\times\frac{1}{12}\times100\times200^3}$	1	
		$q_{max.} = 0.1875 N/mm^2$	1	
	c)	**A short column of external diameter 200 mm and internal diameter 150 mm carries an eccentric load. Find the eccentricity which the load can have without producing tension in the section of column.**		
	Ans.	Data: D=200mm, d=150mm Find: e=?		
		$A = \frac{\pi}{4}(D^2 - d^2)$		
		$A = \frac{\pi}{4}(200^2 - 150^2)$		
		$A = 13744.467\ mm^4$	1	
		$y = \frac{D}{2} = \frac{200}{2} = 100\ mm$		
		$I = \frac{\pi}{64}(D^4 - d^4)$		
		$I = \frac{\pi}{64}(200^4 - 150^4)$		
		$I = 53689327.58\ mm^4$	1	4
		$Z = \frac{I}{Y} = \frac{53689327.58}{100} = 536893.27 mm^3$	1	
		For no tension condition $\sigma_0 = \sigma_b$		
		$\therefore e \leq \frac{Z}{A}$		
		$e = \frac{536893.27}{13744.467} = 39.0625\ mm$	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.5	**d)**	**A hollow circular steel column having external diameter 300 mm and internal diameter 250 mm carries an eccentric load of 100kN acting at an eccentricity of 100 mm. Calculate minimum and maximum stresses.**		
	Ans.	Data: P=100kN, D=300mm, d=250mm, e=100mm. Find: $\sigma_{max}, \sigma_{min}$		
		$A=\frac{\pi}{4}\left(D^2-d^2\right)$ $A=\frac{\pi}{4}\left(300^2-250^2\right)$ $A=21598.45mm^2$	½	
		$I=\frac{\pi}{64}(D^4-d^4)$ $I=\frac{\pi}{64}(300^4-250^4)$ $I=205860221.7 \text{ mm}^4$	½	
		$y=\frac{D}{2}=\frac{300}{2}=150 \text{ mm}$		
		$Z=\frac{I}{Y}=\frac{205860221.7}{150}=1372401.478\text{mm}^3$	½	
		$M=P\times e=100\times 10^3\times 100=1\times 10^7 \text{ N-mm}$	½	**4**
		$\sigma_0=\frac{P}{A}=\frac{100\times 10^3}{21598.45}=4.63 \text{ N/mm}^2$	½	
		$\sigma_b=\pm\frac{M}{Z}=\pm\frac{1\times 10^7}{1372401.478}=\pm 7.2865\text{N/mm}^2$	½	
		$\sigma_{max}=\sigma_0+\sigma_b=4.63+7.2865=11.916\text{N/mm}^2(C)$	½	
		$\sigma_{min}=\sigma_0-\sigma_b=4.63-7.2865=2.6565\text{N/mm}^2(T)$	½	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.5	**e)**	**A C-clamp as shown in figure No. 3 carries a load of 30 kN. The cross section of the clamp at X-X is rectangular, having width equal to twice the thickness. Assuming that the C- clamp is made of steel causing with allowable stress of 120 N/mm^2. Find its dimensions.**		
				
		Fig. No. 3		
		(Note: In above figure eccentricity is not shown clearly).		
		Take eccentricity (e) = 150 mm.		
		Data: D = 2t , σ = 120 N/mm^2, e = 150 mm, P = 30 kN= 30 x 10^3 N		
	Ans.	Find: D and t		
		$A = D \times t = (2t) \times t = 2t^2 \text{mm}^2$		
		$I_{yy} = \frac{D^3 \times t}{12} = \frac{(2t)^3 \times t}{12} = 0.67t^4 \text{ mm}^4$	½	
		$Y = \frac{D}{2} = \frac{2t}{2} = t \text{ mm}$		
		$Z_{yy} = \frac{I_{yy}}{Y} = \frac{0.67t^4}{t} = 0.67t^3 \text{mm}^3$	½	
		$M = P \times e = 30 \text{ x } 10^3 \times 150 = 45 \text{ x } 10^5 N - mm$	½	
		$\sigma_0 = \frac{P}{A} = \frac{30 \text{ x } 10^3}{2t^2} = \frac{15000}{t^2} N/mm^2$	½	4
		$\sigma_b = \pm \frac{M}{Z} = \pm \frac{45 \text{ x } 10^5}{0.67t^3} = \pm \frac{67.5 \text{ x } 10^5}{t^3} N/mm^2$	½	
		$\sigma_{\max} = \sigma_0 + \sigma_b$		
		$120 = \frac{15000}{t^2} + \frac{67.5 \text{ x } 10^5}{t^3}$	½	
		$120t^3 = 15000\text{t} + 67.5 \text{ x } 10^5$		
		t^3-125t - 56250 = 0		
		By trial and error method		
		t = 83.05mm	½	
		D = 2t =2 x 83.05mm =166.10 mm	½	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.5	**f)**	**A M.S. link as shown in figure No. 4 by full lines, transmits a pull of 80 kN. Find dimensions b and t if b = 3t. Assume the permissible tensile stress as 75 MPa.**		
		 **Fig. No. 4**		
	Ans.	Data:		
		P = 80 kN, b = 3t, σ_t = 75 MPa.		
		$A = b \times t = (3t) \times t = 3t^2$		
		$I_{xx} = \frac{b^3 \times t}{12} = \frac{(3t)^3 \times t}{12} = 2.25t^4 \text{ mm}^4$	½	
		$Y = \frac{b}{2} = \frac{3t}{2} = 1.5t \text{ mm}$	½	
		$Z_{xx} = \frac{I_{xx}}{Y} = \frac{2.25t^4}{1.5t} = 1.5t^3 \text{mm}^3$	½	
		$e = \frac{b}{2} = \frac{3t}{2} = 1.5t \text{ mm}$		
		$M = P \times e = 80 \text{ x } 10^3 \times 1.5t = (12 \text{ x } 10^4)t \ N-mm$	½	**4**
		$\sigma_0 = \frac{P}{A} = \frac{80 \text{ x } 10^3}{b \times t} = \frac{80 \text{ x } 10^3}{3t^2} = \frac{26666.67}{t^2} N/mm^2$	½	
		$\sigma_b = \pm\frac{M}{Z} = \pm\frac{(12 \text{ x } 10^4)t}{1.5t^3} = \frac{8 \text{ x } 10^4}{t^2} N/mm^2$	½	
		$\sigma_{\max} = \sigma_0 + \sigma_b$		
		$75 = \frac{26666.67}{t^2} + \frac{8 \text{ x } 10^4}{t^2}$	½	
		$75t^2 = 26666.67 + 8 \text{ x } 10^4$		
		$t^2 = 1422.22$		
		$t = 37.71 \ mm$		
		$b = 3t = 3 \times 37.71 = 113.137 mm$	½	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6		**Attempt any <u>FOUR</u> of the following:**		**16**
	a)	**Calculate limit of eccentricity of a rectangular cross section of size 1200 mm x 2400 mm and sketch it.**		
	Ans.	Data: b =1200 mm d =2400 mm Find: e_x and e_y i. Eccentricity about X- axis		
		$e_x \le \frac{Z_{XX}}{A}$	½	
		$e_x \le \frac{\left(\frac{bd^2}{6}\right)}{b \times d}$ $e_x \le \frac{d}{6}$ $e_x = \frac{2400}{6} = 400$ mm	1	
		ii. Eccentricity about Y- axis		
		$e_y \le \frac{Z_{yy}}{A}$	½	4
		$e_y \le \frac{\left(\frac{db^2}{6}\right)}{b \times d}$ $e_y \le \frac{b}{6}$ $e_y = \frac{1200}{6} = 200$ mm	1	
			1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.6	**b)**	**Differentiate between the polar modulus and section modulus. Also define torsional rigidity.**		
	Ans.	**Torsional rigidity:** It is defined as the torque required to produce a twist of one radian per unit length of shaft.	**1**	
		OR		
		It is defined as the product of modulus of rigidity and polar moment of inertia of shaft.		

Sr. No.	Polar modulus	Section modulus
1	The ratio of polar MI to the radius of shaft is called Polar modulus.	The ratio of MI about N.A. to the distance 'y' from N.A. to the extreme layer of the section is called Section modulus.
2	Twisting moment is considered.	Bending moment is considered.
3	It is a measure of strength of shaft.	It is a measure of strength of section.
4	$Z_P = \frac{I_P}{R}$	$Z = \frac{I}{y_{max}}$

Marks: **1 each (any three)** — Total Marks: **4**

c) **Find the power transmitted by a shaft 40 mm diameter rotating at 250 rpm if the maximum permissible shear stress is 80 N/mm^2.**

Ans. Data: D =40 mm N = 250 rpm q_{max} = 80 N/mm^2 Find: P =?

$$T_{max} = \frac{\pi}{16} D^3 \times q_{max}$$ **1**

$$T_{max} = \frac{\pi}{16} \times 40^3 \times 80$$

$$T_{max} = 1005309.649 \text{ N-mm}$$

$$T_{max} = 1005.309 \text{ N-m}$$ **1**

Relation between T_{max} and T_{mean} not given ($\therefore$Assuming T_{max}=T_{mean})

$$P = \frac{2\pi N T_{mean}}{60}$$ **1**

$$P = \frac{2\pi \times 250 \times 1005.309}{60}$$

P = 26318.945 Watt **1**

P = 26.32 KW

Total Marks: **4**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.6	**d)**	**A solid shaft transmits 1000kWt 120 rpm. If the shear stress of the material is not to exceed 80N/mm^2 and maximum torque is likely to exceed 25% over its mean value, find the diameter of the shaft.**		
		Data: P=1000kW N=120rpm q_{max}=80N/mm^2 $T_{max} = 1.25\ T_{mean}$		
		Find: D=?		
	Ans.	$P = \dfrac{2\pi N T_{mean}}{60}$	**1**	
		$T_{mean} = \dfrac{P \times 60}{2\pi N}$		
		$T_{mean} = \dfrac{1000 \times 10^3 \times 60}{2\pi \times 120}$		
		$T_{mean} = 79577.47155$ N-m		
		$T_{mean} = 79577471.55$ N-mm		
		$T_{max} = 1.25 T_{mean}$		
		$T_{max} = 1.25 \times 79577471.55$	**1**	
		$T_{max} = 99471839.43$N-mm		
		$T_{max} = \dfrac{\pi}{16} D^3 q_{max}$	**1**	**4**
		$D^3 = \dfrac{16 T_{max}}{\pi q_{max}}$		
		$D^3 = \dfrac{16 \times 99471839.43}{\pi \times 80}$		
		$D = 185.009$ mm	**1**	
	e)	**A Solid circular shaft of 40 mm diameter is subjected to torque of 0.25 kN-m causing an angle of twist of 4^0 in 2 m length. Determine the modulus of rigidity for the material of shaft.**		
	Ans.	Data: D=40mm, T=0.25 kN-m, $\theta = 4^0$ L=2 m Find: G = ?		
		L=2m=2×10^{3}mm		
		T=0.25 kN-m =0.25×10^{6}N-mm		
		$\theta = 4 \times \dfrac{\pi}{180} = 0.06981317 rad$	**1**	
		$J = \dfrac{\pi}{32} D^4 = \dfrac{\pi}{32}(40)^4 = 251327.4123$ mm^4	**1**	
		$\dfrac{T}{J} = \dfrac{G\theta}{L}$	**1**	**4**
		$\dfrac{0.25 \times 10^6}{251327.4123} = \dfrac{G \times 0.069813170}{2 \times 10^3}$		
		$G = 28496.5829$ N/mm^2		
		$G = 0.285 \times 10^5$ N/mm^2	**1**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6	**f.**	**Find the maximum stress in propeller shaft 400 mm external diameter and 200 mm internal diameter when subjected to a twisting moment of 4.65 x 10^8 N-mm. If the modulus of rigidity is 0.82 x 10^5 N/mm^2. How much will be the twist in a length of 20 times the external diameter.**		
	Ans.	Data: D = 400mm, d = 200 mm, T = 4.65 x 10^8 N.mm,		
		G = 0.82 x 10^5 N/mm^2, L = 20D.		
		Find: q_{max} and θ=?		
		L = 20D = 20 x 400 = 8 x 10^3 mm		
		$T_{\max} = \frac{\pi}{16} \times q_{\max} \left(\frac{D^4 - d^4}{D} \right)$	1	
		$q_{\max} = \frac{T_{\max} \times 16}{\pi \times \left(\frac{D^4 - d^4}{D} \right)}$		
		$q_{\max} = \frac{4.65 \times 10^8 \times 16}{\pi \times \left(\frac{400^4 - 200^4}{400} \right)}$		
		$q_{\max} = 39.47 \text{N/mm}^2$	1	4
		$\frac{T}{J} = \frac{G\theta}{L}$	1	
		$\theta = \frac{T \times L}{J \times G}$		
		$\theta = \frac{4.65 \times 10^8 \times 8 \times 10^3}{\frac{\pi}{32} \left(400^4 - 200^4 \right) \times 0.82 \times 10^5}$		
		$\theta =$ 0.01925 rad		
		$\theta =$ 0.01925 $\times \frac{180}{\pi}$		
		$\theta = 1.103^0$	1	