Model Answer: Winter - 2019

Subject: Mechanics of Structures | **Sub. Code: 22303**

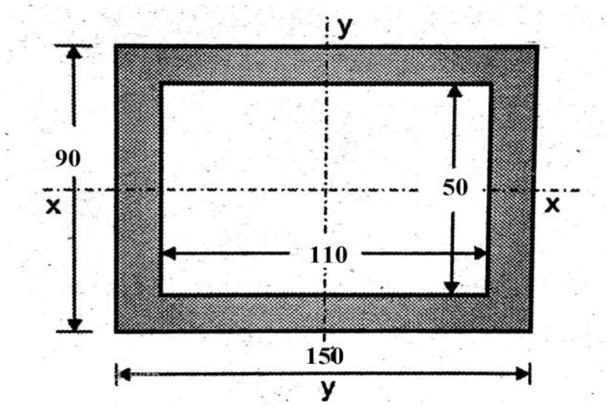
Important Instructions to examiners:

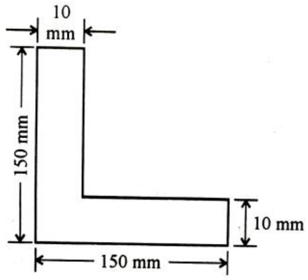
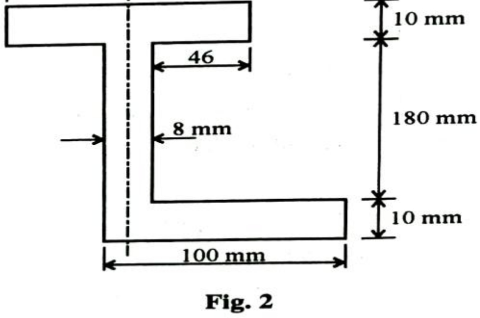
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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		**Attempt any FIVE of the following:**		(10)
	(a)	**Define Hooke's law with expression.**		
	Ans.	**Hook's law.**	1	
		It states that when a material is loaded within its elastic limit, the stress produced is directly proportional to the strain.		
		$\sigma \ \alpha \ e$		
		$\frac{\sigma}{e} = \text{Constant} = E$	1	2
	(b)	**Write down formula of M-I of quarter circle about its centroidal axes.**		
	Ans.	M.I. of quarter circle $(I_{XX}) = 0.055R^4$	1	
		M.I. of quarter circle $(I_{YY}) = 0.055R^4$	1	2
	(c)	**Define modulus of rigidity and bulk Modulus.**		
	Ans.	**Bulk Modulus (K)**:		
		When a body is subjected to three mutually perpendicular like stresses of same intensity then the ratio of direct stress and the corresponding volumetric strain of the body is constant and is known as Bulk Modulus.	1	
		Modulus of rigidity (G):		
		It is ratio of shear stress to shear strain, is called as Modulus of Rigidity.	1	2

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.1	(d) Ans.	**Define stress and strain.** **Stress:** The internal resistance force against the deformation per unit cross sectional area is called stress. **Strain:** When a body of an elastic material is subjected to an axial force it undergoes change in dimensions. The change in dimension per original dimension is called as strain.	1 1	2
	(e) Ans.	**Write Euler's and Rankine's formula with meaning of each term.** *Euler's formula,* $P_E = \frac{\pi^2 E I_{min}}{L_e^2}$ Where, P_E = Euler's buckling load at failure. E = Modulus of elasticity of column material. I_{min} = Minimum moment of inertia of column section. Le = Effective length of the column. *Rankine's Formula,* $P_R = \frac{\sigma_c A}{1 + a\lambda^2}$ Where, P_R = Rankine's buckling load at failure. σ_c= Crushing Stress. A= Cross sectional area of column. a= Rankine's constant. λ= Slenderness ratio.	1 1	2
	(f) Ans.	**Define shear force and bending moment.** **Shear force:** Shear force at any cross section of the beam is the algebraic sum of all vertical forces on the beam acting on right side or left side of the section is called as shear force. **OR** A shear force is the resultant vertical force acting on the either side of a section of a beam. **Bending Moment:** Bending moment at any section at any cross section is the algebraic sum of the moment of all forces acting on the right or left side of section is called as bending moment.	1 1	2

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.1	(g) Ans.	**Give relation between average and maximum shear stress for rectangular and circular cross section.** 1. Rectangular *Section*: $q_{\max} = \frac{3}{2}\, q_{avg}$ 2. *Circular Section*: $q_{\max} = \frac{4}{3}\, q_{avg}$	1 1	2

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.2		**Attempt any THREE of the following:**		(12)
	(a)	**State the parallel axis theorem and perpendicular axis theorem.**		
	Ans.	**Parallel axis theorem:** It states that the M. I. of a plane section about any axis parallel to the centroidal axis is equal to the M. I. of the section about the centroidal axis plus the product of the area of the section and the square of the distance between the two axes.	2	
		Perpendicular axis theorem: It states MI of a plane lamina about an axis perpendicular to the plane of lamina and passing through the centroid of the lamina is equal to the addition of the moments of inertia of the lamina about its centroidal axes.	2	4
	(b)	**Determine M-I about both axes for a Hollow rectangular section having 150 mm width and 90 mm depth.**		
		Note ***The inner dimensions of hollow rectangular section are not given. Therefore assume inner dimensions as follows.*** ***Width (b)=110 mm and Depth (d) = 50 mm*** ***(If students assumed the appropriate dimensions and try to attempt should be considered.)***		
	Ans.	**Data:** B=150mm, D = 90mm, b=110mm, d=50mm. **Calculate:** MI about both axis 		
		$I_{XX} = \left(\frac{BD^3}{12} - \frac{bd^3}{12}\right) = \left(\frac{150\times 90^3}{12} - \frac{110\times 50^3}{12}\right) = 7966666.67 = 7.967\times 10^6 mm^4$	2	
		$I_{YY} = \left(\frac{DB^3}{12} - \frac{db^3}{12}\right) = \left(\frac{90\times 150^3}{12} - \frac{50\times 110^3}{12}\right) = 19766666.67 = 19.77\times 10^6 mm^4$	2	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.2	(c)	**Calculate the moment of inertia of a L- section about the XX axis passing through the center of gravity for a section as shown in fig. No. 1.**		
				
		Fig. 1		
	Ans.	$a_1 = 150 \times 10 = 1500\ mm^2 \quad y_1 = \frac{150}{2} = 5mm$		
		$a_2 = 10 \times 140 = 1400mm^2 \quad y_2 = 10 + \frac{140}{2} = 80mm$		
		$\bar{y} = \frac{a_1 y_1 + a_2 y_2}{a_1 + a_2} = \frac{(1500 \times 5) + (1400 \times 80)}{1500 + 1400} = 41.21mm\ from\ the\ base.$	1	
		$I_{xx} = I_{xx_1} + I_{xx_2} = (I_G + ah^2)_1 + (I_G + ah^2)_2$		
		$I_{xx} = \left(\frac{bd^3}{12} + ah^2\right)_1 + \left(\frac{bd^3}{12} + ah^2\right)_2$	1	
		$I_{xx} = \left(\frac{150 \times 10^3}{12} + \left(1500 \times (41.21 - 5)^2\right)\right)_1 + \left(\frac{10 \times 140^3}{12} + \left(1400 \times (80 - 41.21)^2\right)\right)_2$	1	
		$I_{xx} = (1979246.15)_1 + (4393196.407)_2$		
		$I_{xx} = 6372442.557mm^4$	1	4
	(d)	**Calculate the M-I @ YY axis for following section.**		
				
		Fig. 2		

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.2	(d) Ans.	i) Calculation of $\bar{X}$:		
		$A_1 = 100\times10 = 1000\ mm^2$ $\quad A_2 = 180\times8 = 1440\ mm^2$ $\quad A_3 = 100\times10 = 1000\ mm^2$		
		$X_1 = 46+\frac{100}{2} = 96\ mm,$ $\quad X_2 = 46+\frac{8}{2} = 50\ mm,$ $\quad X_3 = 50\ mm,$		
		$\bar{X} = \frac{A_1X_1 + A_2X_2 + A_3X_3}{A_1+A_2+A_3} = \frac{(1000\times96)+(1440\times50)+(1000\times50)}{1000+1440+1000} = 63.37\ mm$	1	
		ii) Calculation of I_{xx}:		
		Here, $h_1 = X_1 - \bar{X} = 96-63.37 = 32.63\ mm$		
		$h_2 = \bar{X} - X_2 = 63.37-50 = 13.37mm$		
		$h_3 = \bar{X} - X_3 = 63.37-50 = 13.37mm$		
		$I_{yy} = I_{yy1}+I_{yy2}+I_{yy3}$		
		$I_{yy} = (I_G+Ah^2)_1+(I_G+Ah^2)_2+(I_G+Ah^2)_3$	1	
		$I_{yy} = \left(\frac{bd^3}{12}+Ah^2\right)_1+\left(\frac{bd^3}{12}+Ah^2\right)_2+\left(\frac{bd^3}{12}+Ah^2\right)_3$		
		$I_{yy} = \left(\frac{10\times100^3}{12}+1000\times32.63^2\right)+\left(\frac{180\times8^3}{12}+1440\times13.37^2\right)+\left(\frac{10\times100^3}{12}+1000\times13.37^2\right)$	1	
		$\boxed{I_{yy} = 3.175\times10^6\ mm^4}$	1	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.3		**Attempt any <u>THREE</u> of the following :**		(12)
	(a)	**A steel rod 20 mm in diameter 1.2 m long is heated through 120° C at the same time subjected to a pull 'P' if the total extension of the rod is 3 mm calculate the magnitude of 'P'. Take $\alpha = 12 \times 10^{-6} / ° C$ and E= 200GPa.**		
	Ans.	Data : d =20 mm, L = 1.2 m, T= 120°C, , $E = 2 \times 10^5$ N/mm^2 and $\alpha_S = 12 \times 10^{-6} / °C$ Find: P=?		
		$A = \frac{\pi d^2}{4} = \frac{\pi \times 20^2}{4} = 314.16 mm^2$ *i)* δL_1 *due to change in temperature.* $\delta L_1 = L \times \alpha \times T$ $\delta L_1 = 1200 \times 10^3 \times 12 \times 10^{-6} \times 120$ $\delta L_1 = 1.728 mm$	1	
		ii) δL_2 *due to force applied.* $\delta L_2 = \frac{PL}{AE}$ $\delta L_2 = \frac{P \times 1200}{314.16 \times 200 \times 10^3}$ $\delta L_2 = (1.91 \times 10^{-5}) P\ mm$	1	
		iii) Total change in length is δL. $\delta L = \delta L_1 + \delta L_2$ $3 = 1.728 + (1.91 \times 10^{-5}) P$	1	
		$P = 66598.82\ N$ $\boxed{P = 66.60\ kN}$	1	4
	(b) Ans.	**A bar having cross-section as given in fig. No. 3 is subjected to a tensile load of 150 kN. Calculate the change in length of each part along with the total change in length if $E = 2 \times 10^5$ N/m.**		

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.3	(b)			

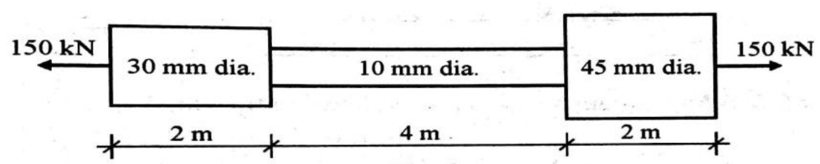


Fig. 3

Data: P = 150 kN, E = 2 x10^5 N/mm^2

Ans.

Find: δL in each part.

$\delta L = \delta L_1 + \delta L_2 + \delta L_3$

$$\delta L = \left(\frac{PL}{AE}\right)_1 + \left(\frac{PL}{AE}\right)_2 + \left(\frac{PL}{AE}\right)_3$$ **1**

$$\delta L = \left(\frac{150\times10^3\times2\times10^3}{\frac{\pi}{4}\times30^2\times2\times10^5}\right)_1 + \left(\frac{150\times10^3\times4\times10^3}{\frac{\pi}{4}\times10^2\times2\times10^5}\right)_2 + \left(\frac{150\times10^3\times2\times10^3}{\frac{\pi}{4}\times45^2\times2\times10^5}\right)_3$$ **2**

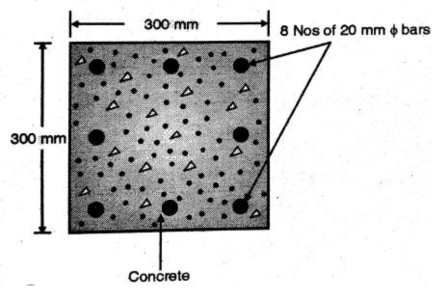
$\delta L = 2.1221+38.1972+0.9431$

$\delta L = 41.262mm$ **1** | Total: **4**

(c) **A reinforced concrete column is 300mm X 300 mm in section, reinforced with 8 steel bars of 20 mm diameter. The column carries a load of 360 kN. Find the stresses in concrete and steel bars.**
Take E_{st} = 2.1x10^5 N/mm^2
E_{con}. = 1.4 x 10^4 N/mm^2

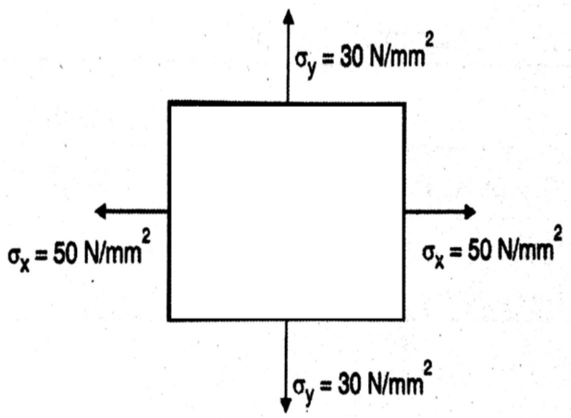
Ans.

Data: A= 300 × 300 mm^2, d = 20 mmφ No. of steel bar = 8,
P = 360 kN, Est = 2.1x10^5 N/mm^2, Econ. = 1.4 x 10^4N/mm^2
Find: σ_c, σ_s,

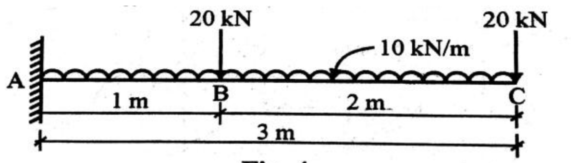


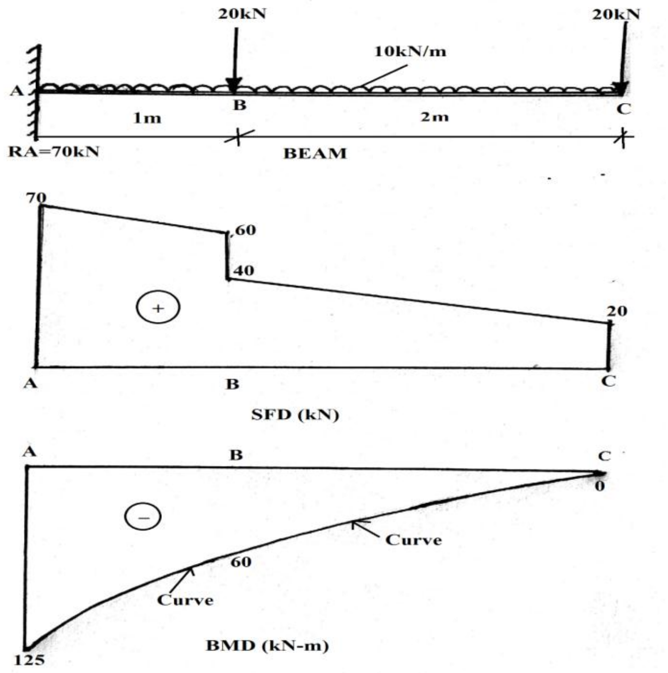
$$A_s = n\left(\frac{\pi d^2}{4}\right) = 8\left(\frac{\pi\times20^2}{4}\right) = 2513.27mm^2$$

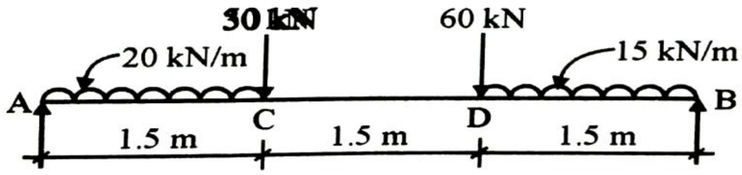
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.3	(c)	$A_c = A_g - A_s$ $A_c = 300\times300 - 2513.27$ $A_c = 87486.72 mm^2$	1	
		$\frac{\sigma_s}{\sigma_c} = m$ $\frac{2.1\times10^5}{1.4\times10^4} = 15$ $\sigma_s = m\times\sigma_c$ $\sigma_s = 15\sigma_c$	1	
		$P = P_s + P_c$ $P = \sigma_s A_s + \sigma_c A_c$ $360\times10^3 = (15\sigma_c)2513.27 + \sigma_c 87486.72$ $360\times10^3 = (37699.11 + 87486.72)\sigma_c$ $\boxed{\sigma_c = 2.876 N/mm^2}$	1	
		$\sigma_s = 15\sigma_c$ $\sigma_s = 15\times2.876$ $\boxed{\sigma_s = 43.136 N/mm^2}$	1	4
	(d)	**A Circular bar of diameter 25 mm and 3.5 m long is subjected to a tensile load of 40 kN. Shows an elongation of 60mm. Determine stress, strain and modulus of elasticity.**		
	Ans.	**Data:** d=25 mm , L=3.5 m, P= 40 kN, δL= 60 mm **Find:** σ, e, E=?		
		$\sigma = \frac{P}{A} = \frac{40\times10^3}{\frac{\pi}{4}\times25^2} = 81.487\ N/mm^2$	1	
		$e = \frac{\delta L}{L} = \frac{60}{3.5\times10^3} = 0.01714$	1	
		$E = \frac{\sigma}{e} = \frac{81.487}{0.01714} = 4753.43\ N/mm^2$	2	4

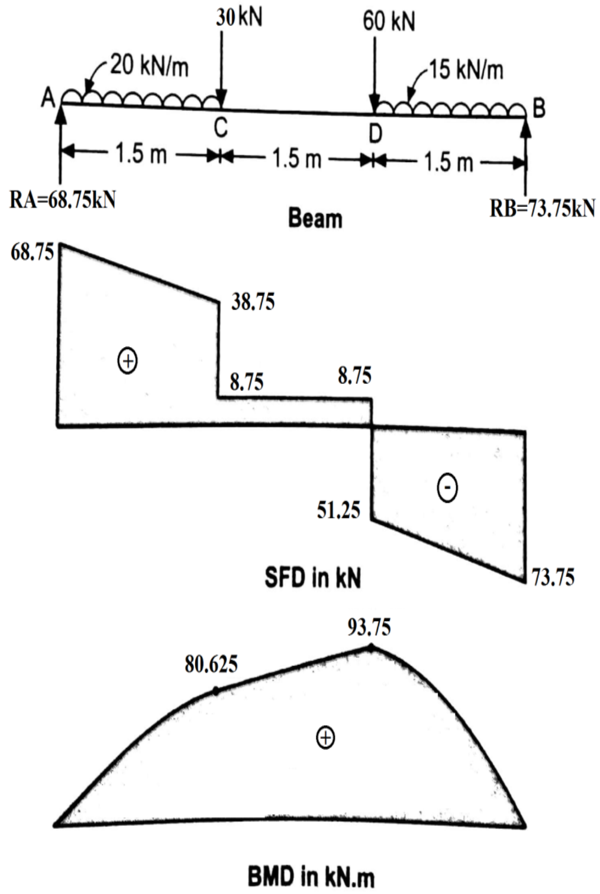
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.4		**Attempt any <u>THREE</u> of the following :**		**(12)**
	(a)	**For a given material E =110 GPa, G = 43 GPa find K and μ.** **Data:** E=110GPa , G= 43GPa **Find:** K=? , μ=?		
	Ans.	$E = 2G(1+\mu)$	**1**	
		$110 = 2\times 43\times(1+\mu)$ $\mu = 0.279$	**1**	
		$E = 2K(1-2\mu)$	**1**	
		$110 = 2K(1-2\times 0.279)$ $K = 82.982\ GPa$	**1**	**4**
	(b)	**In a biaxial stress system, the stresses along the two directions are the σ_x=50 N/mm^2 and σ_y=30 N/mm^2 both tensile. Determine the strains along these two directions. E = 2 x 10^{5}N/mm^2 and Poisson's ratio=0.3.**		
	Ans.	**Data:** σx=50 N/mm^2 , σy=30 N/mm^2 b=30mm, E=2 x 10^{5}N/mm^2, μ=0.3 **Find:** e_x, e_y=? 		

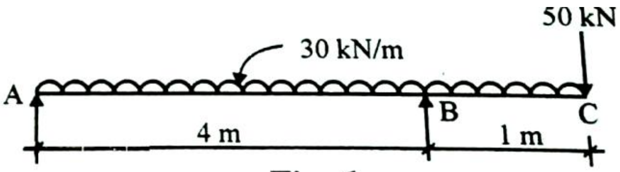
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.4	(b)	$e_x = \frac{\sigma_x}{E} - \mu\frac{\sigma_y}{E} = \frac{1}{E}(\sigma_x - \mu\sigma_y)$	1	
	Ans.	$e_x = \frac{1}{2\times10^5}(50-(0.3\times(30))$		
		$\boxed{e_x = 20.5\times10^{-5}}$	1	
		$e_y = \frac{\sigma_y}{E} - \mu\frac{\sigma_x}{E} = \frac{1}{E}(\sigma_y - \mu\sigma_x)$	1	
		$e_y = \frac{1}{2\times10^5}((30)-(0.3\times50))$		
		$\boxed{e_y = 7.5\times10^{-5}}$	1	4
	c)	**State the relation between E, G and K with expressions.**		
	Ans.	$E = 3K(1 - 2\mu)$	1	
		$E = 2G(1+\mu)$	1	
		Where, E = Young's Modulus G = Modulus of Rigidity K = Bulk Modulus μ = Poisson's Ratio		
		$E = 3K\left[1-2\left(\frac{E}{2G}-1\right)\right]$ $E = 3K\left[1-\left(\frac{E}{G}+2\right)\right]$ $E = 3K\left[3-\frac{E}{G}\right]$ $E = 3K\left(\frac{3G-E}{G}\right)$ $EG = 3K(3G-E)$ $EG = 9KG-3KE$	2	4

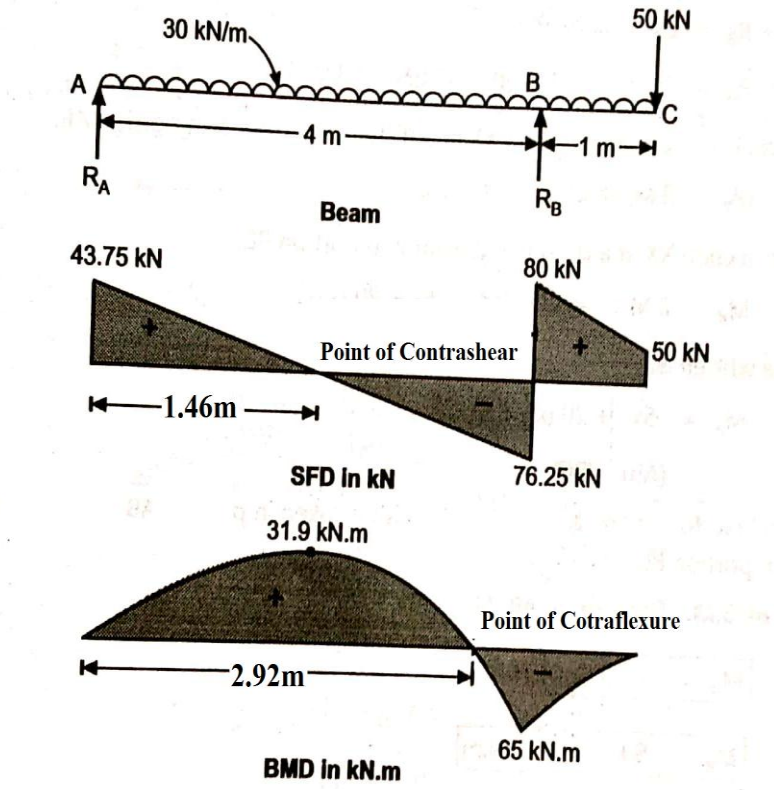
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.4	(d)	**Draw SF and BM diagram for the cantilever beam as shown in fig. No. 4.**  **Fig. 4**		
	Ans.	**I) Reaction Calculation:** $\sum Fy = 0$ RA = 20+20+10×3 = 70kN **II) SF Calculation:** A = +70kN B_L = +70-10×1=60kN B_R = +60-20=+40kN C_L = +40-20=+20kN C = +20-20=0kN (ok)	1	
		III) BM Calculation: C = 0 (B is Free end) B = - 20×2 - (10×2×1) = - 60 kN-m A = - 20×3 - 20×1- (10×3×1.5) = -125 kN-m	1	

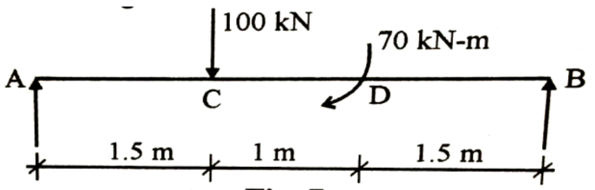
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.4	(d)		1 1	4
	e) Ans.	**State four assumptions made in Euler's theory.** 1. Compressive load on the column is exactly axial. 2. Material of the column is perfectly homogenous and isotropic. 3. Column is initially straight and of uniform lateral dimensions. 4. Self-weight of the column is neglected. 5. Column is long and fails due to buckling only. 6. Shorting of the column due to direct compression is neglected. 7. The stresses do not exceed the limit of proportionality. 8. It obeys Hook's law.	1 each (any four)	4

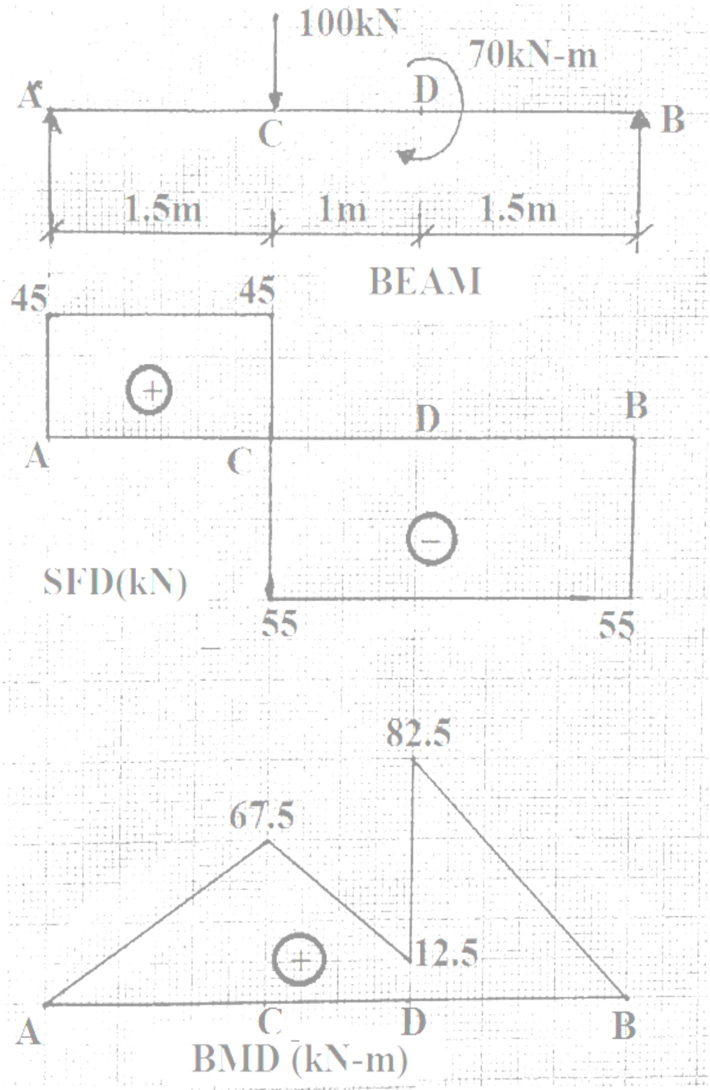
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5		**Attempt any <u>TWO</u> of the following :**		(12)
	(a)	**Draw shear force and bending moment for beam as shown in Fig. No. 5**		
		 **Fig. 5**		
		(Note: If students assume any other value of point load and try to attempt should be considered.)		
	Ans.	**I. Reaction Calculation:** $\sum M_A = 0$ $R_B \times 4.5 = (20\times1.5) \times \frac{1.5}{2} + (30\times1.5) + (60 \times 3) + \left[(15\times1.5) \times \left(3+\frac{1.5}{2}\right)\right]$ $R_B = \frac{22.5 + 45 + 180 + 84.375}{4.5}$ $R_B = 73.75\ kN$	1	
		$\sum F_Y = 0$ $R_A + R_B = (20\times1.5) + 30 + 60 + (15\times1.5)$ $R_A + R_B = 30 + 30 + 60 + 22.5 - 73.75$ $R_A = 68.75\ kN$		
		II. SF Calculation: *SF at A = +68.75kN* C_L = +68.75-(20 x 1.5)= +38.75kN C_R = +38.75-30 = +8.75kN	1	
		D_L = +8.75kN D_R = +8.75-60 = -51.25kN B_L = -51.25-(15x1.5) = -73.75kN B = -73.75-73.75 = 0 (□ ok)		

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5	(a)	**III. BM Calculation:** *BM at A and B = 0 (Supports A and B are simple)* $C = +\ 68.75 \times 1.5 - 20 \times 1.5 \times \frac{1.5}{2} = +\ 80.625\ kN\text{-}m$ $D = 73.75 \times 1.5 - 15 \times 1.5 \times \frac{1.5}{2} = +\ 93.75\ kN\text{-}m$ 	1 1 1 1	6

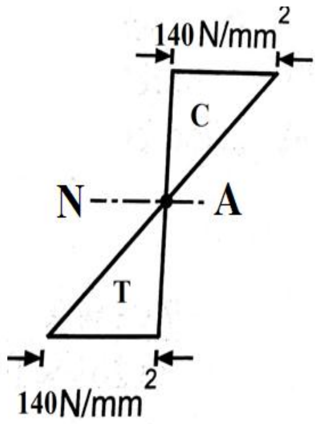
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5	(b)	**Draw S.F. and B.M. diagram for overhanging beam as shown in fig. No. 6.**		
		 **Fig. 6**		
	Ans.	*I. Support Reactions:* $\Sigma M_A = 0$ $R_B \times 4 = (30\times5)\times2.5+50\times5$ $\boxed{R_B = 156.25kN}$ $\Sigma F_Y = 0$ $R_A + R_B = (30\times5)+50$ $R_A + 156.25 = (30\times5)+50$ $\boxed{R_A = 43.75kN}$	1	
		II. SF calculations: $SF\ at\ A = +43.75\ kN$ $B_L = +43.75 - (30\times40) = -76.25\ kN$ $B_R = -76.25 + 156.25 = +80\ kN$ $C_L = +80 - 30\times1 = +50\ kN$ $C = +50 - 50 = 0 \quad (ok)$	1	
		III. BM calculations: $BM\ at\ A\ and\ C = 0.\ (\because\ Supports\ are\ simple)$ $B = -50\times1 - 30\times1\times\frac{1}{2} = -65\ kN\text{-}m$	1	
	·	*IV. To calcuate Maximum Bending Moment* $SF\ at\ x = 0,$ $\therefore 43.75 - 30\times x = 0$ $\therefore x = 1.458m\ from\ A$ $BM_{max} = 43.75\times1.458 - 30\times\frac{1.458^2}{2}$ $\boxed{BM_{max} = 31.90kN-m}$	1	

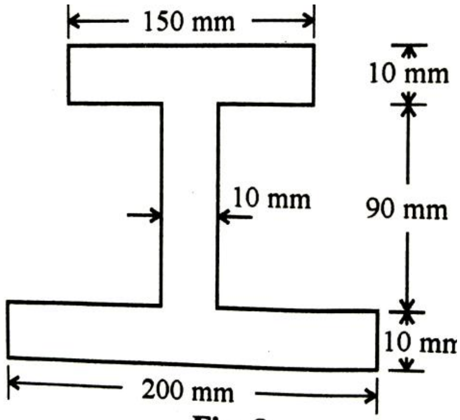
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5	(b)	V. *To calculate point of contraflexure* $At\ distance\ X\ BM = 0$ $43.75x - 30 \times \frac{x^2}{2}$ $x = 2.92\ m\ from\ support\ A$ 	1 1	6

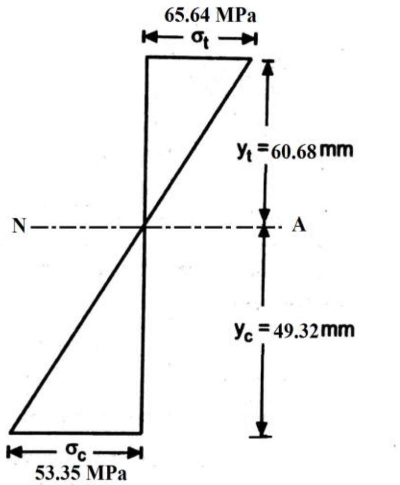
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5	(c)	**Draw S.F. and B.M. diagram for beam as shown in fig. No. 7**		
				
		Fig. 7		
	Ans.	**I) Reaction Calculation:**		
		$\sum M_A = 0$		
		$RB \times 4 = 100 \times 1.5 + 70$		
		$RB = 55$ kN		
		$\sum Fy = 0$	1	
		$RA + RB = 100$		
		$RA = 45$ kN		
		II) SF Calculation:		
		SF at A = + 45kN		
		C_L = + 45kN		
		C_R = + 45 – 100 = - 55kN	1	
		B_L = - 55 kN		
		B_L = - 55 + 55 = 0 (□ ok)		
		III) BM Calculation:		
		BM at A and B = 0 (□ Support A and B is simple)		
		C = + 45 × 1.5= + 67.5 kN-m		
		D_L = + 45 × 2.5 – 100 × 1 = +12.5 kN-m	1	
		D_R = + 45 × 2.5 – 100 × 1 + 70 = + 82.5 kN-m		
		OR		
		D_R = + 55 × 1.5 = + 82.5 kN-m	1	

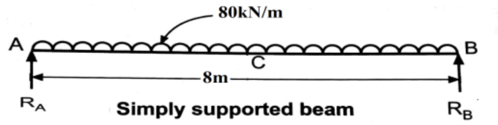
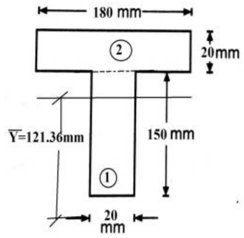
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5	(c) Ans.		½ 1½	6

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6		**Attempt any TWO of the following :**		(12)
	(a)	**Solve the following.**		
	(i)	**Determine by Rankine's formula the safe load on the column of 5.5 m length, with both ends fixed, can carry with a factor of safety 4. The properties of section are A= 1777mm2. Ixx= 11.6x106 mm4. Iyy= 0.84x106 mm4. σc = 3200 N/mm2 and α= 1/1600.**		
	Ans.	*Given* : $L = 5.5m, \; FOS = 4, \; \sigma_c = 320 \; N/mm^2, \; \alpha = \frac{1}{7500},$ $Ixx = 11.6 \times 10^6 \; mm^4, \; Iyy = 0.84 \times 10^6 mm^4$		
		As the column is fixed at both ends, efeective length is $Le = \frac{L}{2} = \frac{5500}{2} = 2750 \; mm$ $K_{\min} = \sqrt{\frac{I_{\min}}{A}} = \sqrt{\frac{0.84 \times 10^6}{1777}} = 21.742 \; mm$	1	
		$\lambda_{\min} = \frac{Le}{K_{\min}} = \frac{2750}{21.742} = 126.484$	1	
		By using Rankine's formula, $P_R = \frac{\sigma_c.A}{1+a\lambda_{\min}^2} = \frac{320 \times 1777}{1+\frac{(126.484)^2}{7500}} = 181494.0678N$		
		$Safe \; Load \; = \frac{P_R}{FOS} = \frac{181494.0678}{4} = 45373.516N \; = \; 45.374kN$	1	3

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6	(a) (ii)	**A simply supported beam has span 7 m carries a point load of 50 kN at the center of the beam. Calculate the modulus of section if bending stress is not to exceed 140 Mpa. With distribution diagram of stress.**		
	Ans.	*Given*: $L = 7m,\ W = 50\ kN,\ \sigma = 140MPa$		
		$M = \frac{WL}{4} = \frac{50\times 7}{4} = 87.5kN\text{-}m = 87.5\times 10^6\ N\text{-}mm$	1	
		Flexural Equation: $\frac{M}{I} = \frac{\sigma}{y}$; $\frac{M}{\sigma} = \left(\frac{I}{y}\right) = Z$; $Z = \frac{M}{\sigma} = \frac{87.5\times 10^6}{140} = 6.25\times 10^5\ mm^3$	1	
		 Bending Stress Distribution Diagram	1	3

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6	(b)	**A cantilever is 2 m long and is subjected to an udl of 5 kN/m. The c/s of a cantilever is a I-section as shown in fig. No. 8. Determine the maximum tensile and compressive stress developed and their position, showing stress distribution diagram.**		
		 **Fig. 8**		
	Ans.	*i*) *Calculation of* $\bar{Y}$: $A_1 = 200 \times 10 = 2000 mm^2$ $A_2 = 10 \times 90 = 900 mm^2$ $A_3 = 150 \times 10 = 1500 mm^2$ $Y_1 = \frac{10}{2} = 5 mm$ $Y_2 = 10 + \frac{90}{2} = 55 mm$ $Y_3 = 10 + 90 + \frac{10}{2} = 105 mm$ $\bar{Y} = \frac{A_1Y_1 + A_2Y_2 + A_3Y_3}{A_1 + A_2 + A_3}$ $\bar{Y} = \frac{(2000 \times 5) + (900 \times 55) + (1500 \times 105)}{2000 + 900 + 1500}$ $\bar{Y} = 49.32 mm$ $Y_C = 49.32 mm$ $Y_T = 110 - 49.32 = 60.68\ mm$	1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6	(b)	ii) Calculation of I_{xx}:		
		Here, $h_1 = \bar{Y} - Y_1 = 49.32 - 5 = 44.32$ mm		
		$h_2 = Y_2 - \bar{Y} = 55 - 49.32 = 5$ mm	1	
		$h_3 = Y_3 - \bar{Y} = 105 - 49.32 = 55.68$ mm		
		$I_{xx} = I_{xx1} + I_{xx2} + I_{xx3}$		
		$I_{xx} = \left(I_G + Ah^2\right)_1 + \left(I_G + Ah^2\right)_2 + \left(I_G + Ah^2\right)_3$		
		$I_{xx} = \left(\frac{bd^3}{12} + Ah^2\right)_1 + \left(\frac{bd^3}{12} + Ah^2\right)_2 + \left(\frac{bd^3}{12} + Ah^2\right)_3$	1	
		$I_{xx} = \left(\frac{200\times10^3}{12} + 2000\times44.32^2\right) + \left(\frac{10\times90^3}{12} + 900\times5.68^2\right) + \left(\frac{150\times10^3}{12} + 1500\times55.68^2\right)$		
		$\boxed{I_{xx} = I_{NA} = 9.245\times10^6 mm^4}$		
		$iii)$ *Bending moment* (M):		
		$M = \frac{wL^2}{2} = \frac{5\times2^2}{2} = 10\ kN\text{-}m = 10\times10^6\ N\text{-}mm$	1	
		$iv)$ *Calculation Maximum Stress*:		
		$\sigma_T = \left(\frac{M}{I_{NA}}\right)\times Y_T = \left(\frac{10\times10^6}{9.245\times10^6}\right)\times 60.68 = 65.64\ N/mm^2$	1	
		$\sigma_C = \left(\frac{M}{I_{NA}}\right)\times Y_C = \left(\frac{10\times10^6}{9.245\times10^6}\right)\times 49.32 = 53.35\ N/mm^2$		
		 Bending stress variation diagram	1	6

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6	**(c)**	**A T-section beam having flange 180mm wide and 20 mm thick and web 150 mm long and 20 mm thick carries a udl of 80 kN/m over an effective span of 8 m. Calculate the maximum bending stress.**   		
	Ans.	$a_1 = 20 \times 150 = 3000 \text{ mm}^2 \quad y_1 = \frac{150}{2} = 75\text{mm}$ $a_2 = 180 \times 20 = 3600\text{mm}^2 \quad y_2 = 150 + \frac{20}{2} = 160\text{mm}$ $\overline{y} = \frac{a_1 y_1 + a_2 y_2}{a_1 + a_2} = \frac{(3000 \times 75) + (3600 \times 160)}{3000 + 3600} = 121.36\text{mm from the base.}$ $y_c = 48.64\ mm,\ \ y_t = 121.36\ mm$	1	
		$I_{xx} = I_{xx_1} + I_{xx_2} = (IG + ah^2)_1 + (IG + ah^2)_2$ $I_{xx} = \left(\frac{bd^3}{12} + ah^2\right)_1 + \left(\frac{bd^3}{12} + ah^2\right)_2$	1	
		$I_{xx} = \left(\frac{20 \times 150^3}{12} + \left(3000 \times (121.75 - 75)^2\right)\right)_1 + \left(\frac{180 \times 20^3}{12} + \left(3600 \times (48.64 - 10)^2\right)\right)_2$ $I_{xx} = (12072748.8)_1 + (5494978.56)_2$ $I_{xx} = 17567727.36\text{mm}^4 = 17.568 \times 10^6 \text{mm}^4$	1	
		Maximum Bending moment: $(M) = \frac{wL^2}{8} = \frac{80 \times 8^2}{8} = 640\ kN\text{-}m\ = 640 \times 10^6\ N\text{-}mm$ *Maximum stress*:	1	
		$\sigma_c = \frac{M}{I} \times y_t = \frac{640 \times 10^6}{17.568 \times 10^6} \times 48.64 = 1771.976 N/mm^2 (C)$ $\sigma_t = \frac{M}{I} \times y_c = \frac{640 \times 10^6}{17.568 \times 10^6} \times 121.36 = 4421.198 N/mm^2 (T)$	1	
		$\boxed{\sigma_t = \sigma_{\max} = 4421.198 N/mm^2 (T)}$ ***(Note- If students assume a cantilever type of beam and try to attempt should be considered).***	1	6