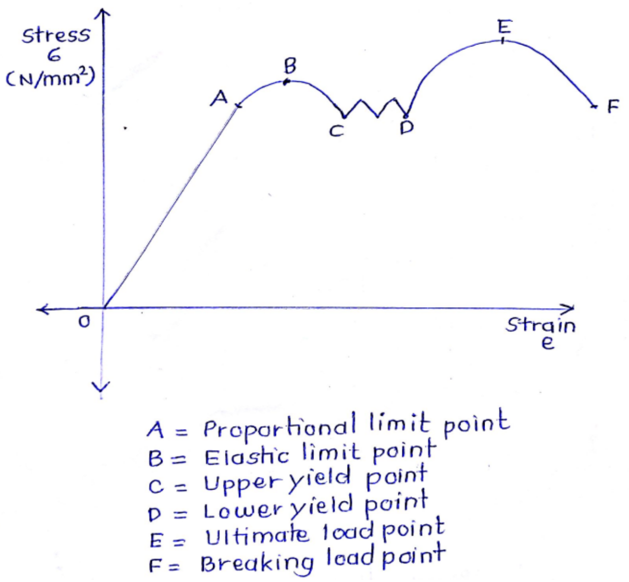
Model Answer: Summer 2017

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

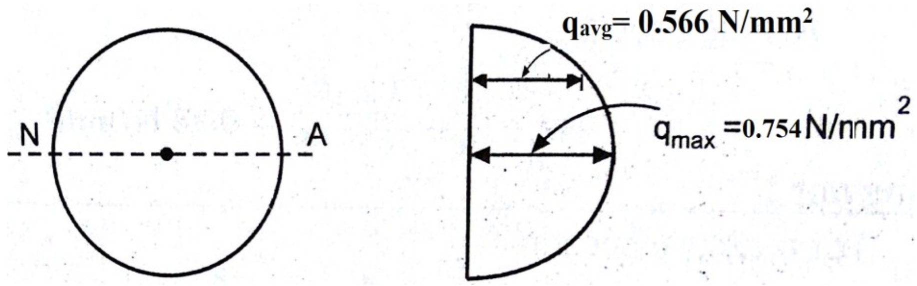
Important Instructions to examiners:

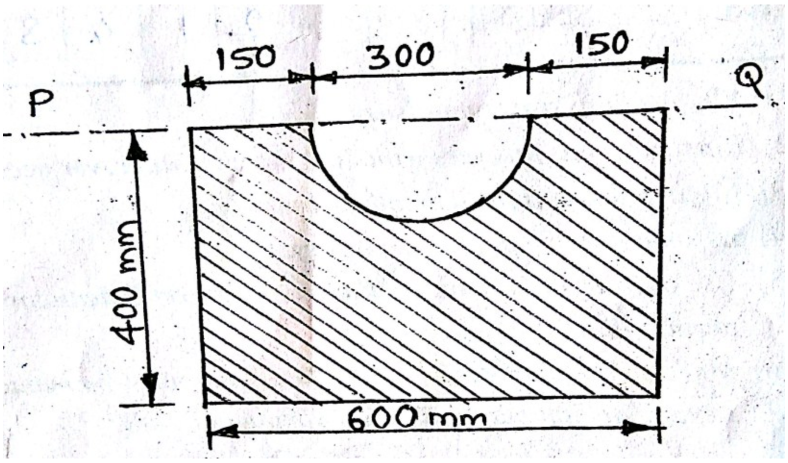
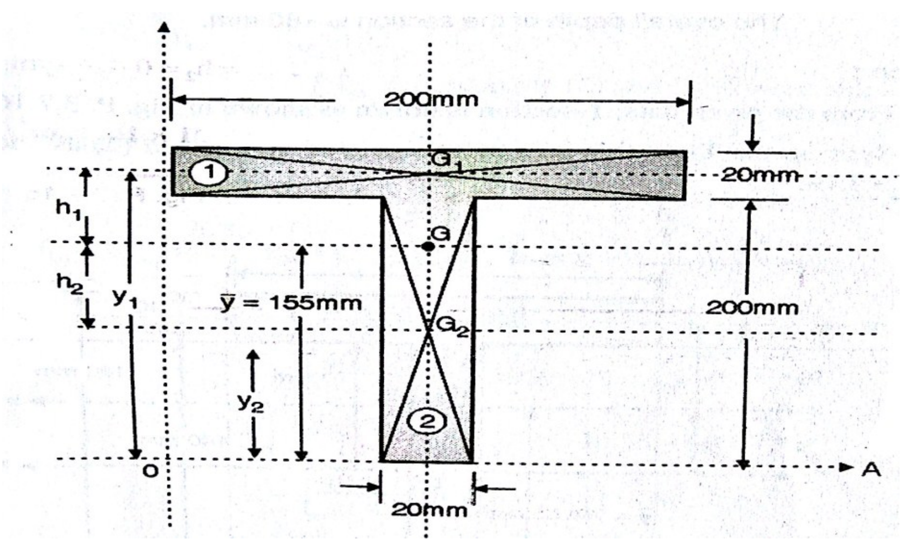
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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 Answers	Marks	Total Marks
1		**Attempt *any six* of the following :**		12
	i)	**Define moment of inertia. State MI of triangular section about its base.**		
	Ans.	**Moment of Inertia: -** It is the second moment of area which is equal to product of area of the body and square of the distance of its centroid from that axis, is called as moment of Inertia.	01	
		OR Moment of inertia of a body about any axis is defined as the sum of second moment of all elementary areas about that axis.		02
		MI of triangular section about base $I_{base} = \frac{bh^3}{12}$ Where, b = Base of triangle and h = Height of triangle	01	
	ii)	**Calculate polar MI of solid circular shaft section having Dia. 'D'**		
	Ans.	$I_{xx} = I_{yy} = \frac{\pi}{64} \times D^4$ for soild circular section.	01	
		Polar moment of inertia , $I_p = I_{xx} + I_{yy}$		02
		$I_p = \frac{\pi}{64} D^4 + \frac{\pi}{64} D^4$ $\boxed{I_p = \frac{\pi}{32} D^4}$ Or $\boxed{I_p = 0.098170D^4}$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1	iii)	**Define 'Modulus of rigidity'. State its SI unit.**		
	Ans.	**Modulus of rigidity** : - It is ratio of shear stress to shear strain, is called as Modulus of Rigidity. **Unit: -** N/m^2 Or Pascal Or N/mm^2	01 01	02
	iv)	**Draw stress-strain curve for a ductile material showing important points.**		
	Ans.	 *(Note: One mark for curve and one mark for important point shown in curve)*	02	02
	v)	**State the relationship between linear strain and lateral strain.**		
	Ans.	Lateral strain is directly proportional to linear strain. When a homogeneous material is loaded within its elastic limit, the ratio of lateral strain to linear strain is called as Poisson's ratio. Lateral strain produced in any material is equal to product of Poission's ratio and linear strain of same material.	02	02
	vi)	**Define slenderness ratio.**		
	Ans.	It is the ratio of effective length of column to minimum radius of gyration, is called as slenderness ratio.	02	02
	vii)	**Give an example of suddenly applied load. Also write equation for stress developed due to suddenly applied load.**		
	Ans.	**Example: -**		

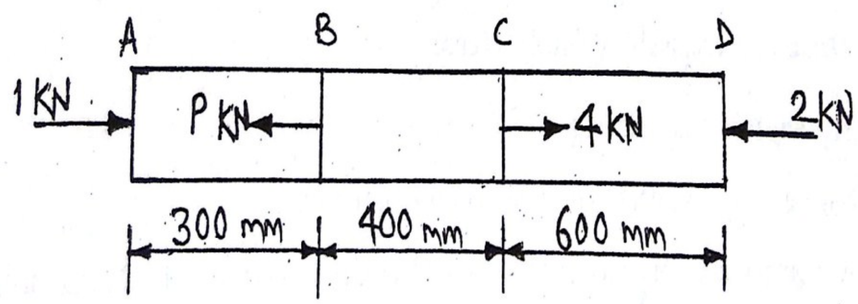
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1.		1. Weight on balance. 2. Load in truck. 3. Person standing on weighing balance. 4. Load lifted by a small height and dropped on platform.	½ **mark each (any two)**	**02**
		Equation for stress developed due to suddenly applied load, $\sigma = \dfrac{2P}{A}$ Where, P = Load, A= Cross section area	**01**	
	viii)	**Define resilience and modulus of resilience.**		
	Ans.	**Resilience: -** It is the energy stored in the body or material, when loaded within elastic limit is called as strain energy or resilience.	**01**	**02**
		Modulus of Resilience: - It is the proof resilience per unit volume, called as modulus of resilience is called as modulus of resilience. **OR** It is the maximum strain energy stored in body per unit volume is called modulus of resilience.	**01**	
	B)	**Attempt *any two* of the following :**		**08**
	i)	**State any four assumptions made in theory of pure bending.**		
	Ans.	1. The material of the beam is homogeneous and isotropic i.e. the beam made of the same material throughout and it has the same elastic properties in all the directions. 2. The beam is subjected to pure bending that is shear stress is totally neglected. 3. The beam material is stressed within its elastic limit and thus obeys Hooke's law. 4. The transverse sections which where plane before bending remains plane after bending. 5. Each layer of the beam is free to expand or contact independently of the layer above or below it. 6. Young's modulus (E) for the material has the same value in tension and compression.	**01 mark each (any four)**	**04**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1		7. The radius of curvature is large as compared to the dimensions of the cross section		
	ii)	**A circular section diameter 150 mm is subjected to shear force 10kN when used as a beam. Calculate average and maximum shear stress and draw shear stress distribution diagram.**		
	Ans.	A= $\frac{\pi}{4}(D^2)=\frac{\pi}{4}(150)^2=17671.45868 mm^2$	01	
		$q_{avg}=\frac{S}{A}=\frac{10\times10^3}{17671.458}=0.566 N/mm^2$	01	04
		$q_{max}=\frac{4}{3}q_{avg}=\frac{4}{3}\times0.566=0.754 N/mm^2$	01	
			01	
	iii)	**A column having diameter 300mm is 5 m long. Determine Euler's crippling load, if both end of column are fixed. Take E = 2x10^{5}N/mm^2.**		
	Ans.	$Le=\frac{L}{2}=\frac{5000}{2}=2500 mm$	01	
		$I_{min}=\frac{\pi}{64}(D)^4=\frac{\pi}{64}(300)^4$ $\boxed{I_{min}=397607820.2 mm^4}$	01	
		$P=\frac{\pi^2 EI_{min}}{(Le)^2}$	01	04
		$P=\frac{\pi^2\times2\times10^5\times397607820.2}{(2500)^2}$ $P=125575420.6 N$ $\boxed{P=125.575\times10^6 N}$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2.		**Solve *any two* of the following :**		**16**
	a)	**A column having diameter 300 mm is 5 m long. Determine Euler's crippling load, if both ends of column are fixed. Take E=2x10[5] N/mm[2].**		
	Ans.			
		I_{PQ} = MI of reactangle about PQ - MI of semicircle about PQ		
		$I_{PQ} = \left[\frac{1}{12}bd^3 + A_1 h_1^2\right] - \left[\frac{\pi}{128}D^4\right]$	**02**	
		$= \left[\frac{1}{12}\times 600 \times 400^3 + \left((600\times 400)\times 200^2\right)\right] - \left[\frac{\pi}{128}(300)^4\right]$	**03**	**08**
		$I_{PQ} = 128\times 10^8 - 1.99\times 10^8$	**02**	
		$\boxed{I_{PQ} = 1.26\times 10^{10}\, mm^4}$	**01**	
	b)	**Calculate I_{xx} for the T section having flange 200 x 20 mm and web 20 x 200 mm overall depth is 220 mm.**		
	Ans.			

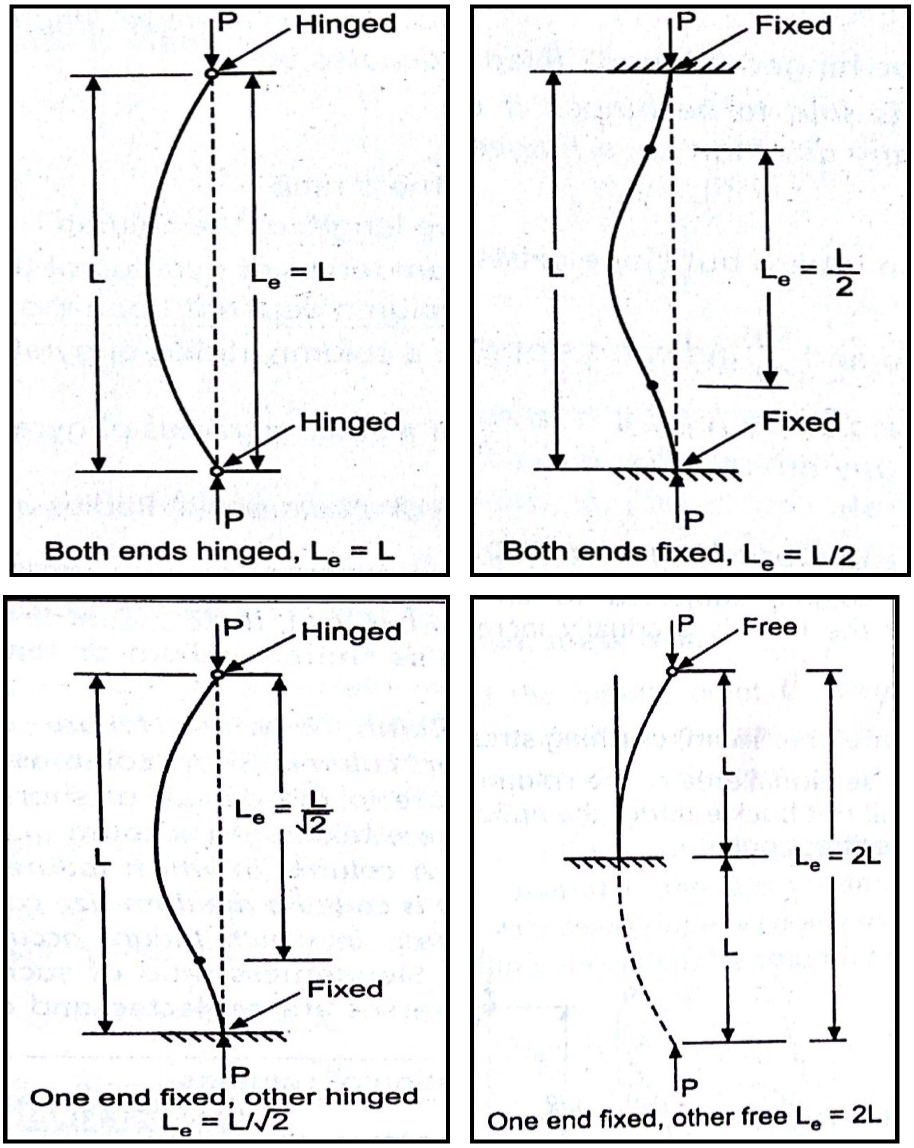
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2		$\overline{Y} = \dfrac{a_1x_1 + a_2x_2}{a_1 + a_2}$	02	
		$\overline{Y} = \dfrac{(200\times 20)10 + (200\times 20)\times 120}{(200\times 20)+(200\times 20)}$	02	
		$\boxed{\overline{Y} = 65mm}$ from top		
		$I_{xx} = \left[\dfrac{1}{12}b_1d_1^{\,3} + A_1h_1^{\,2}\right] - \left[\dfrac{1}{12}b_2d_2^{\,2} + A_2h_2^{\,2}\right]$	02	08
		$I_{xx} = \left[\dfrac{1}{12}\times 200\times 20^3 + \left((200\times 20)\times 55^2\right)\right] + \left[\dfrac{1}{12}\times 20\times 200^3 + \left((20\times 200)\times 55^2\right)\right]$		
		$I_{xx} = 12.233\times 10^6 + 25.433\times 10^6$		
		$\boxed{I_{xx} = 37.67\times 10^6\ mm^4}$	02	
	c)	**i) Calculate the radius of gyration of steel pipe having external diameter 22 mm and internal diameter 16 mm.** **ii) Find the diameter of circular rod 2.4 m long when subjected to an axial pull 15 kN, shows an elongation of 1 mm. Take E= 205 kN/mm^2.**		
	Ans.	*i)*		
		$K_{xx} = \sqrt{\dfrac{I_{xx}}{A}}$	01	
		$K_{yy} = \sqrt{\dfrac{I_{yy}}{A}}$		
		$I_{xx} = I_{yy} = \dfrac{\pi}{64}(D^4 - d^4)$		
		$= \dfrac{\pi}{64}(22^4 - 16^4)$		
		$\boxed{I_{xx} = I_{yy} = 8282.024mm^4}$	01	
		Area,		
		$A = \dfrac{\pi}{4}(D^2 - d^2)$		08
		$= \dfrac{\pi}{4}(22^2 - 16^2)$		
		$\boxed{A = 179.07\ \text{mm}^2}$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2		$K_{xx} = K_{yy} = \sqrt{\dfrac{8282.024}{179.07}}$		
		$\boxed{K_{xx} = K_{yy} = 6.80\text{mm}}$	01	
		ii)		
		$P = 15kN = 15\times10^3 N$		
		$t = 2.4 = 2400mm$		
		$\delta l = 1mm$		
		$E = 205kN/mm^2 = 205\times10^3 N/mm^2$		
		$d = ?$		
		$\delta L = \dfrac{PL}{AE}$	01	
		$A = \dfrac{PL}{E\delta L}$		
		$\dfrac{\pi}{4}(d)^2 = \dfrac{PL}{E\delta L}$		
		$d^2 = \dfrac{4PL}{\pi E\delta L}$		
		$d = \sqrt{\dfrac{4PL}{\pi E\delta L}}$	01	
		$d = \sqrt{\dfrac{4\times15\times10^3\times2400}{\pi\times205\times10^3\times1}}$		
		$d = \sqrt{223.5932859}$	02	
		$\boxed{d = 14.953mm}$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3		**Solve *any two* of the following:**		**16**
	a)	**A bar of uniform cross section area 100 mm^2 is subjected to axial forces as shown in fig 2. Calculate the net change in length of the bar. Take E = 25 x 10^5 N/mm^2.**		
	Ans.			
		$A = 100mm^2 \quad E = 2\times10^5\ N/mm^2 \quad \delta L = ?$		
		To calculate, P		
		$1 + 4 = P - 2$		
		$P = 5 - 2$	01	
		$P = 3kN$		
		$\delta L = -\delta L_{AB} + \delta L_{BC} - \delta L_{CD}$	01	
		$\delta L = -\left(\frac{PL}{AE}\right)_{AB} + \left(\frac{PL}{AE}\right)_{BC} - \left(\frac{PL}{AE}\right)_{CD}$	02	
		$\delta L = -\left(\frac{1\times10^3\times300}{100\times200\times10^3}\right)_{AB} + \left(\frac{2\times10^3\times400}{100\times200\times10^3}\right)_{BC} - \left(\frac{2\times10^3\times600}{100\times200\times10^3}\right)_{CD}$	03	08
		$\delta L = -0.015 + 0.04 - 0.06$		
		$\boxed{\delta L = -0.035mm}$	01	

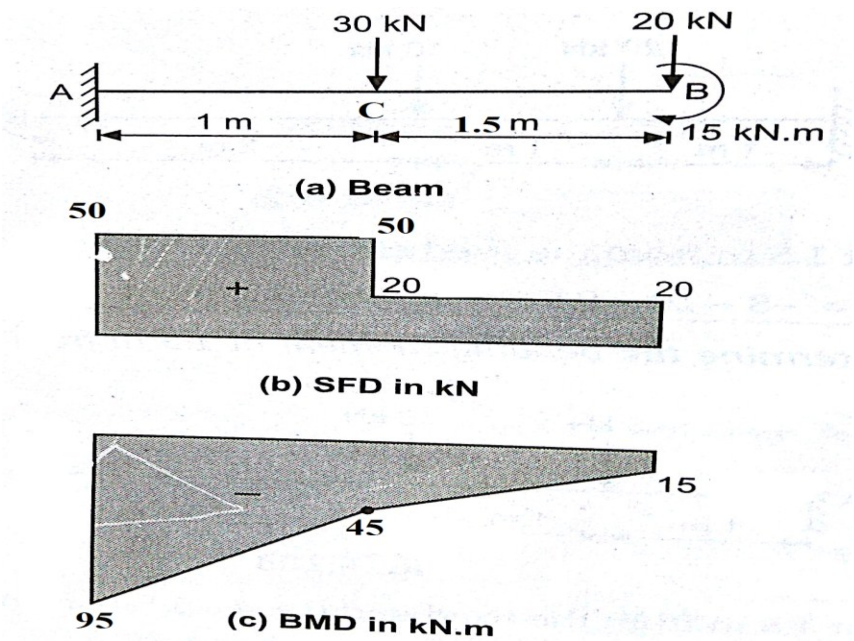
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3	b)	**A steel tube with 40 mm inside diameter and 4 mm thickness is filled with concrete. Determine load shared by each material due to axial thrust of 60 kN.**		
		Take $E_{steel} = 210\ N/mm^2$		
		$E_{concrete} = 14 \times 10^3\ N/mm^2$		
	Ans.	*Given :*		
		$d = 40mm$		
		$t = 4mm$		
		$P = 60KN$		
		$E_S = 210\times10^3\ N/mm^2$		
		$E_C = 14\times10^3\ N/mm^2$		
		$D = d + 2t = 40 + (2\times4)$		
		$\boxed{D = 48mm}$	01	
		$A_S = \frac{\pi}{4}\times(D^2 - d^2)$		
		$A_S = \frac{\pi}{4}\times(48^2 - 40^2)$		
		$\boxed{A_S = 552.92mm^2}$	01	
		$A_C = \frac{\pi}{4}\times(d^2)$		
		$A_C = \frac{\pi}{4}\times(40^2)$		
		$\boxed{A_C = 1256.637mm^2}$	01	
		$m = \frac{E_S}{E_C} = \frac{210\times10^3}{14\times10^3} = 15$		
		$e_s = e_c$		
		$\frac{\sigma_s}{E_S} = \frac{\sigma_c}{E_C} \qquad ....(i)$		
		$\sigma_s = \left(\frac{E_S}{E_C}\right)\sigma_c$		
		$\boxed{\sigma_s = 15\sigma_c}$	01	
		$P = P_S + P_C \qquad ....(ii)$		
		$P = \sigma_s A_S + \sigma_c A_C$		08
		$60\times10^3 = 15\sigma_c\times552.92 + \sigma_c\times1256.637$		

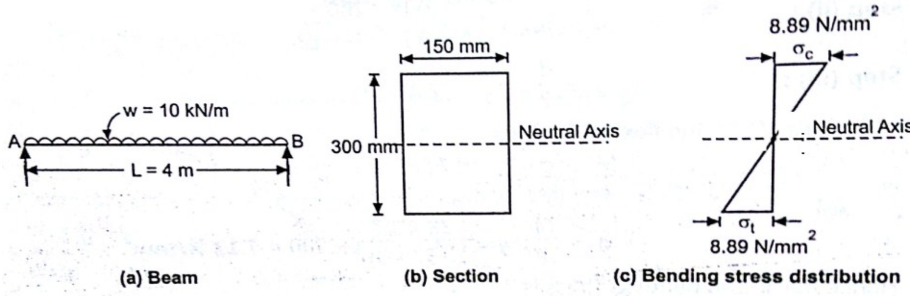
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3		$60\times10^3=\sigma_c\times8293.8+\sigma_c\times1256.637$		
		$\sigma_c=\dfrac{60\times10^3}{9550.437}$		
		$\boxed{\sigma_c=6.2824\,N/mm^2}$	01	
		$P_c=\sigma_c A_C$		
		$P_c=6.2824\times1256.637$		
		$P_c=7894.74N$		
		$\boxed{P_c=7.89kN}$	01	
		$\sigma_s=15\sigma_c$		
		$\sigma_s=15\times6.2824$	01	
		$\boxed{\sigma_s=94.236\,N/mm^2}$		
		$P_s=\sigma_s A_S$		
		$P_s=94.236\times552.92$		
		$P_s=52104.96N$		
		$\boxed{P_s=52.104kN}$	01	
	c)	**i) A square rod 10 mm x 10 mm in cross section and 1 m long is at 20^0 C. Find free expansion of rod, if temperature to70^0 C. If this expansion is prevented, find temperature stress developed in the bar. Take E = 2 x 10^5N/mm^2 and α = 12 x 12^{-6} per ^{0}C**		
		ii) With a neat sketch show effective length of Column for various end conditions. (min. four)		
	Ans.	**i)**		
		$L=1m=1\times10^3mm$		
		$t_1=20^0C$		
		$t_2=70^0C$		
		$E=2\times10^5\,N/mm^2$		
		$\alpha=12\times10^{-6}/{}^0C$		
		$\Delta t=t_2-t_1=70-20=50^0C$	01	
		$i)$ *Free Expansion,*		
		$(\delta L)=L\alpha T$		
		$=1\times10^3\times12\times10^{-6}\times50$		
		$\boxed{(\delta L)=0.6mm}$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3		*ii)Temp. stress*		**08**
		$(\sigma) = E\alpha T$	**01**	
		$= 2\times10^5 \times 12\times10^{-6} \times 50$		
		$(\sigma) = 120\, N/mm^2$	**01**	
		ii)		
			**01 mark each**	

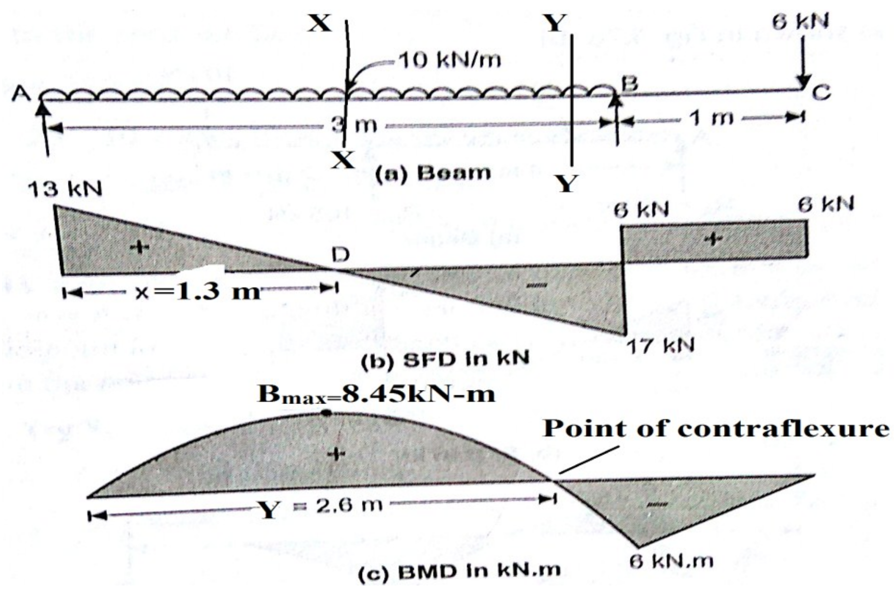
Both ends hinged, $L_e = L$
Both ends fixed, $L_e = L/2$
One end fixed, other hinged $L_e = L/\sqrt{2}$
One end fixed, other free $L_e = 2L$

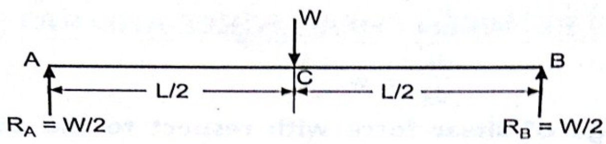
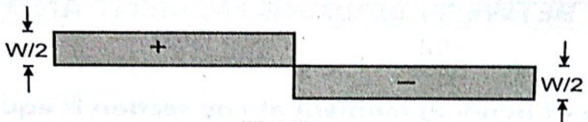
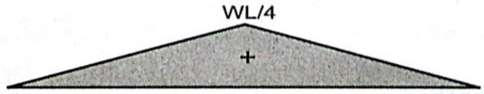
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4		**Solve *any two* of the following**		16
	a)	**A metal rod 20 mm diameter and 2 m long when subjected to tensile force of 60 kN shows an elongation of 2 mm and reduction in diameter 0.006 mm. Calculate the modulus of elasticity and modulus of rigidity.**		
	Ans.	$E = \frac{PL}{A\delta L}$	01	
		$E=\frac{60\times10^3\times2\times10^5}{\frac{\pi}{4}\times20^2\times2}$	01	
		$\boxed{E=1.91\times10^5 \text{ N/mm}^2}$	01	
		$\mu = \frac{\text{Lateral Strain}}{\text{linear Strain}}$	01	08
		$\mu = \frac{\left(\frac{\delta d}{d}\right)}{\left(\frac{\delta L}{L}\right)} = \frac{\left(\frac{0.006}{20}\right)}{\left(\frac{2}{2000}\right)}$	01	
		$\boxed{\mu = 0.3}$	01	
		$E = 2G(1+\mu)$	01	
		$= 2G(1+0.3)$		
		$1.91\times10^5 = 2G(1+0.3)$		
		$G=\frac{1.91\times10^5}{2\times1.3}$	01	
		$\boxed{G=7.345\times10^4 \text{N/mm}^2}$		
	b)	**A cube of 200 mm side is subjected to a compressive force of 3600 kN on all its faces. The change in the volume of cube is found to be 5000 mm^3. Calculate the Bulk modules. If the μ = 0.28, Find the Young's modulus.**	02	
	Ans.	$\sigma = \frac{P}{A} = \frac{3600\times10^3}{200\times200}$		
		$\boxed{\sigma = 90\text{N/mm}^2}$	01	
		$V = L^3 = (200)^3$		
		$\boxed{V = 8\times10^6 mm^3}$		

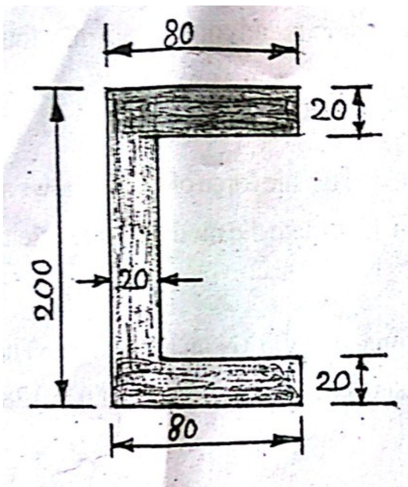
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4		$\frac{\delta V}{V} = \frac{\sigma_x + \sigma_y + \sigma_z}{E}(1-2\mu)$	01	08
		$E = \frac{3\sigma}{\left(\frac{\delta V}{V}\right)}(1-2\mu)$	01	
		$E = \frac{3\times 90}{\left(\frac{5000}{8\times 10^6}\right)}(1-2\times 0.28)$	02	
		$\boxed{E = 1.9\times 10^5 N/mm^2}$	01	
	c)	**Draw SFD and BMD for the cantilever beam loaded as shown in Fig. 3**		
	Ans.	SF Calculations: SF at A = +50kN C_L = +50kN C_R = +50-30 =20 kN B_L = +20kN B = +20-20 = 0	02	
		BM Calculations: BM at B = -15 kN-m BM at C = -15-20×1.5 = - 45kN-m BM at A = -15-20×2.5-30×1 = - 95kN-m	03	08
			01 02	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		**Solve _any two_ of the following.**		16
	a)	**A timber beam 15mm wide and 300mm deep is simply supported over a span of 4m. It carries udl 10kN/m over entire span. Find the maximum bending stress induced in the section. Draw bending stress distribution diagram. Also find radius of curvature if E=1.4 kN/mm^2.**		
	Ans.	 (a) Beam (b) Section (c) Bending stress distribution	01	
		E =1.4 kN/mm^2 $=1.4\times10^3 N/mm^2$ $b=150mm, d=300mm, L=4m, w=10kN/m$ $Find:-\quad \sigma_{b(\max)}; R$		
		$I_{xx}=I_{NA}=\frac{1}{12}bd^3$ $I_{xx}=I_{NA}=\frac{1}{12}\times150\times300^3$	½	
		$\boxed{I_{xx}=I_{NA}=337.5\times10^6 mm^4}$	01	
		$Y=\frac{d}{2}=\frac{300}{2}$ $\boxed{Y=150mm}$	½	
		$M_{\max}=\frac{wl^2}{8}=\frac{10\times4^2}{8}=20kN-m$ $\boxed{M_{\max}=20\times10^6 N-mm}$	1 ½	08
		Using relation, $\frac{M}{I}=\frac{\sigma_b}{Y}$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		$\sigma_{b(\max)} = \frac{M}{I} \times Y$ $\sigma_{b(\max)} = \frac{(20 \times 10^6)}{337.5 \times 10^6} \times 150$ $\boxed{\sigma_{b(\max)} = 8.89 N/mm^2}$	01	
		$\frac{M}{I} = \frac{\sigma_b}{Y} = \frac{E}{R}$ $R = \frac{E}{\sigma_b} \times Y$ OR $R = \frac{E}{M} \times I$	½	
		$R = \frac{(1.4 \times 10^3)}{8.89} \times 150$ OR $R = \frac{(1.4 \times 10^3)}{(20 \times 10^6)} \times 337.5 \times 10^6$ $\boxed{R = 23625mm}$ $\boxed{R = 23.625m}$	01	
	b)	**A beam ABC supported at A and B such that BC as overhang. AB = 3m, BC = 1m, span AB carried udl 10 kN/m and point load of 6 kN acts at point C. Draw shear force and bending moment diagrams. Also locate point of contra flexure, if any.**		
	Ans.	Step1 Calculation of Reaction, $\sum F_y = 0$ $R_A + R_B = (10 \times 3 + 6)$ $R_A + R_B = 36$ $\sum M_A = 0$ $R_B \times 3 = \left(10 \times 3 \times \frac{3}{2}\right) + 6 \times 4$ $R_B = 23kN$ $R_A = 36 - 23 = 13kN$	01	
		Step 2 Shear force calculation , SF at A= +13kN $B_L = +13 - 10 \times 3 = -17kN$ $B_R = -17 + 23 = 6kN$ $C_L = 6kN$ $C = 6 - 6 = 0$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		Step 3 Calculation of zero SF from A, $\frac{13}{X}=\frac{17}{(3-X)}$ $\boxed{X=1.3m}$ *From* point *A*	**01**	**08**
		$SF\ at\ \text{sec}tion\ XX=0$ $13-10x=0$ $x=1.3m$ *from* support *A*		
		Step 4	**01**	
		Bending Moment calculation, $M_A=M_C=0$ $M_B=-6\times1=-6kN\text{-}m$ $M_{max}=13\times1.3-10\times\frac{1.3^2}{2}=8.45kN\text{-}m$ $\boxed{M_{max}=8.45kN\text{-}m}$	**01**	
		Step 5 To locate point of contraflexure at section Y-Y, $BM=0$ $13Y-10\times\frac{Y^2}{2}=0$ $13-5Y=0$ $\boxed{Y=2.6m}$ from support A.	**01**	
			**01** **01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5	**C**	**i) A simply supported beam of span 'L' carries central point load 'W'. Draw SFD and BMD.** **ii) Define shear force and bending moment. Write unit of each. Also state relation between them.**		
	Ans.	**i)** Step 1 Calculation of Reaction, As, the load is at centre so, support reaction are equal, $R_A = R_B = \frac{W}{2}$ Step 2 Shear force calculation a) S.F. at any section between A and C is, $F_x = +R_A = \frac{W}{2}$ b) S.F. at any section between B and C is, $F_x = -R_B = -\frac{W}{2}$	**01**	
		Step-3 Bending Moment Calculation, Beam is simply supported at the end A and B, $\therefore M_A = M_B = 0$ $\therefore M_{max} = Mc = +\frac{W}{2} \times \frac{L}{2}$ $\therefore Mc = \frac{WL}{4}$	**01**	**04**
		 (I) Simply supported beam		
		 (II) SFD	**01**	
		 (III) BMD	**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		**ii)**		
		Shear force: - Shear force at any cross section of the beam is the algebraic sum of 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.	**01**	
		Unit :- kN or N	½	**04**
		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.	**01**	
		Unit: - kN-m or N-m	½	
		Relation between shear force and bending moment $\frac{dM}{dx} = F$	½	
		The rate of change of bending moment at any section is equal to the shear force at that section.	½	
6		**Solve *any two* of the following**		**16**
	a)	**A channel section as shown in Fig. carries shear force of 100kN at a particular section. Calculate the ratio of average shear stress to maximum shear stress.**		
	Ans.	*Given* :		
		$SF = 100kN, Find = \frac{q_{avg}}{q_{max}}$		
		$A = (2\times80\times20)+(160\times20)$		
		$\boxed{A = 6400\ mm^2}$ 	½	
		$q_{avg} = \frac{S}{A} = \frac{100\times10^3}{6400}$		
		$\boxed{q_{avg} = 15.625 N/mm^2}$	**02**	
		$I_{xx} = I_{NA} = \frac{1}{12}(BD^3 - bd^3)$		
		$I_{xx} = I_{NA} = \frac{1}{12}(80\times200^3 - 60\times160^3)$		
		$\boxed{I_{xx} = I_{NA} = 3.285\times10^7 mm^4}$	**02**	**08**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6		$A\bar{Y} = a_1 y_1 + a_2 y_2$	½	
		$A\bar{Y} = (80\times20)\times90 + (20\times80)\times40$		
		$A\bar{Y} = 144000 + 64000$		
		$A\bar{Y} = 208000$	½	
		$q_{\max} = \dfrac{SA\bar{Y}}{bI}$	01	
		$q_{\max} = \dfrac{100\times10^3\times208000}{20\times3.285\times10^7}$		
		$\boxed{q_{\max} = 31.656 N/mm^2}$		
		$Ratio = \dfrac{q_{avg}}{q_{\max}} = \dfrac{15.625}{31.656} = 0.493$	01	
		$\boxed{\dfrac{q_{avg}}{q_{\max}} = 0.493}$	½	
	b)	**A cast iron column 100 mm external diameter is an 80 mm internal diameter 2m long. It is fixed at one end and hinged at other end. Calculate the safe axial load by Rankine's formula taking factor of safety 3. Assume σ_c = 550 N/mm^2 and Rankine's constant α= 1/1600.**		
	Ans.	*Given*		
		$D = 100mm, d = 80mm, L = 2m = 2000mm,$		
		$FOS = 3, \sigma_c = 550N/mm^2, \alpha = \dfrac{1}{1600}$		
		As, the column is fixed at one end and hinged at other end.		
		Efeective length, $(Le) = \dfrac{L}{\sqrt{2}} = \dfrac{2000}{\sqrt{2}}$		
		$\boxed{Le = 1414.2mm}$	01	
		For hollow circular column,		
		$I_{min.} = I_{xx.} = I_{yy.} = \dfrac{\pi}{64}(100^4 - 80^4)$		
		$\boxed{I_{min.} = I_{xx.} = I_{yy.} = 2898119.223mm^4}$	01	
		Area,		
		$A = \dfrac{\pi}{4}(100^2 - 80^2)$		
		$\boxed{A = 2827.433mm^2}$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
		$K^2 = \frac{I}{A}$ $K^2 = \frac{2898119.223}{2827.433}$ $\boxed{K = 32.0156mm}$	01	08
		$\therefore 1 + a\frac{(Le)^2}{K^2} = 1 + \left(\frac{1}{1600}\right) \times \left(\frac{(1414.2)^2}{32.0156}\right)$ $\boxed{1 + a\frac{(Le)^2}{K^2} = 2.2195}$	01	
		By using Rankine's formula, $P_R = \frac{\sigma_c.A}{1 + a\frac{(Le)^2}{K^2}}$	01	
		$P_R = \frac{550 \times 2827.433}{2.2195}$ $\boxed{P_R = 707644.2077N}$	01	
		Safe Load= $\frac{\text{Rankine's crippling load}}{\text{Factor of safety}}$ Safe Load= $\frac{707644.2077}{3}$ $\boxed{\text{Safe Load}=233548.0692N}$ $\boxed{\text{Safe Load}=233.548kN}$	01	
	C)	**A weight of 2 kN falls on a collar attached at the lower end of a vertical bar 3 m long and 25 mm in diameter. Calculate the height of drop if the instantaneous stress developed is 120 N/mm^2. Also calculate corresponding elongation and strain energy stored in the bar. Take E=2 X 10^5 N/mm^2.**		
	Ans.	Given: W = 2kN = 2000N L=3m=3000mm d=25mm σ=120N/mm^2 $E = 2 \times 10^5$ N/mm^2 $Find = h = ?, \delta l = ?, U = ?$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
		$\sigma = \frac{W}{A} + \sqrt{\left(\frac{W}{A}\right)^2 + \frac{2WEh}{AL}}$	01	
		$120 = \frac{2000}{\frac{\pi}{4}\times 25^2} + \sqrt{\left(\frac{2000}{\frac{\pi}{4}\times 25^2}\right)^2 + \frac{2\times 2000\times 2\times 10^5\times h}{\frac{\pi}{4}\times 25^2\times 3000}}$		
		$120 = 4.074 + \sqrt{(4.074)^2 + 543.2h}$		
		$120 - 4.074 = \sqrt{(4.074)^2 + 543.2h}$		
		$(115.9256)^2 = 16.597 + 543.2h$	03	
		$\boxed{h = 24.71mm}$		
		$\delta l = \frac{\sigma L}{E} = \frac{120\times 3000}{2\times 10^5}$	02	
		$\boxed{\delta l = 1.8mm}$		
		$U = \frac{\sigma^2}{2E}\times AL$	01	
		$U = \frac{120^2}{2\times 2\times 10^5}\times\left(\frac{\pi}{4}\times 25^2\times 3000\right)$		
		$U = 53014.376N - mm$	01	
		$\boxed{U = 53.014N - m}$		