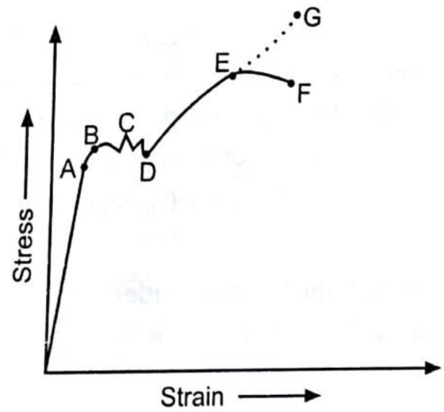
Model Answer: Winter-2017

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

Important Instructions to examiners:

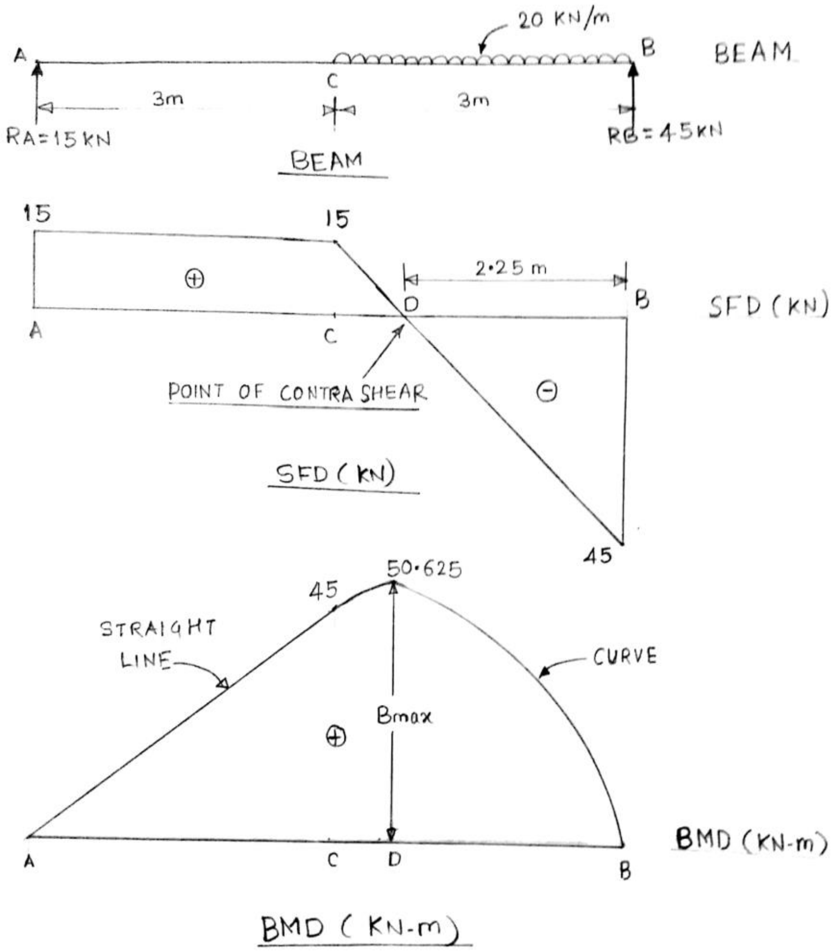
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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 ductility and malleability.**		
	Ans.	**Ductility:** It is the property of material due to which it can be drawn into thin wires on application of tensile force.	**01**	**02**
		Malleability: It is the property of a material by virtue of which it can be beaten up into thin sheets without cracking when hammered.	**01**	
	ii)	**Define Principal plane and Principal stress.**		
	Ans.	**Principal plane:** A plane which carries only normal stress and no shear stress is called Principal plane.	**01**	**02**
		Principal stress: The magnitude of normal stress acting on the principal plane is called Principal stress.	**01**	
	iii)	**Write the equation for M.I. of Hollow shaft section.**		
	Ans.	Hollow Shaft: M.I.= $\frac{\pi}{64}\left(D^4 - d^4\right)$ Where, D = External Daimeter d = Internal Daimeter	**02**	**02**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.1	**iv)**	**Define direct load and eccentric load.**		
	Ans.	**Direct load:** When a load whose line of action coincides with the axis of a member or whose line of action acts at a centroid of a section of member then it is called as a direct load.	**01**	**02**
		Eccentric load: A load acts away from the centroid of the section or a load whose line of action does not coincide with the axis of member is called as eccentric load.	**01**	
	v)	**Write torsion equation along with meaning of each term used in it.**		
	Ans.	$\frac{T}{I_P}=\frac{C.\theta}{L}=\frac{\sigma_s}{R}$ Or $\frac{T}{J}=\frac{G.\theta}{L}=\frac{q_{max}}{R}$	**01**	**02**
		Where, T = Twisting moment Or Torque Or Torsion (N-mm) I_P = J = Polar Moment of Inertia (mm^4) C = G= Modulus of Rigidity for shaft material (N/mm^2) θ = Angle of twist (radians) L= Length of the shaft (mm) $\sigma_s = q_{max}$ = Maximum shear stress (N/mm^2) R= Radius of the shaft (mm)	**01**	
	vi)	**Draw a stress- strain diagram for ductile material in tension.**		
	Ans.		**01**	**02**
		(i) Limit of proportionality (A) (ii) Elastic limit (B) (iii) Upper yield point (C) (iv) Lower yield point (D) (v) Ultimate (maximum) load point (E) (vi) Breaking point (F)	**01**	

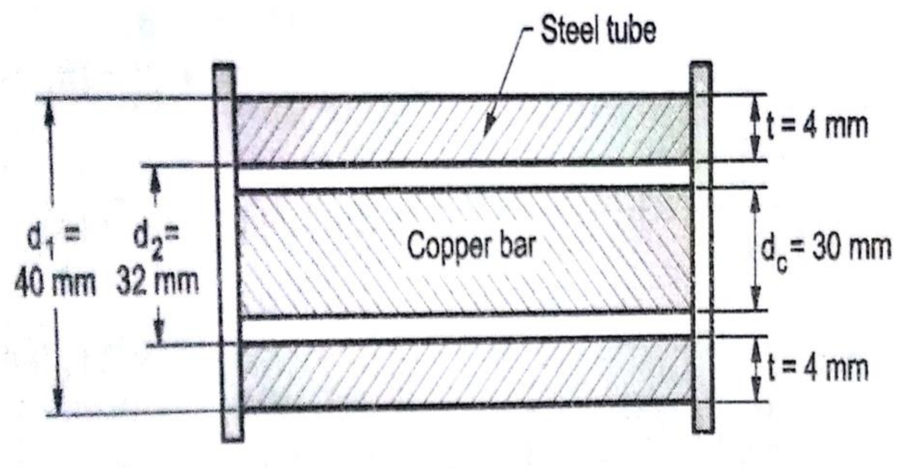
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.1	**vii)**	**State relation between Hoop stress and Longitudinal stress, for thin cylinder.**		
	Ans.	$\sigma_C = 2\sigma_L$ Where, Hoop Stress $(\sigma_C) = \frac{Pd}{2t}$ Longitudinal stress $(\sigma_L) = \frac{Pd}{4t}$	**02**	**02**
	viii)	**Define core of section. Write its value for a circular section.** **Core of section:**		
	Ans.	For no tension condition the load must lie within the middle third shaded area of eccentricity **2e** is called core of section. The stress produced is only compressive stress.	**01**	**02**
		For circular section the core of section is $2\,e = \frac{D}{4}$ Where, e = Eccentricity of circular section D = Diameter of circular section	**01**	
	b)	**Attempt any <u>TWO</u> of the following:**		**(08)**
	(i)	**For a round bar of 50 mm diameter and 2.5 m long of certain material has Young's modulus of 1.1 x 10^5 N/mm^2 and Modulus of rigidity of 0.45 x 10^5 N/mm^2. Find the Bulk modulus and the lateral contraction of the bar when stretched by 3 mm.**		
	Ans.	Given: d = 50mm, L = 2.5m $E = 1.1\times10^5 N/mm^2,\ G = 0.45\times10^5 N/mm^2,$ $\delta L = 3\ mm$ $Find: K,\ \delta d$ $E = 2G(1+\mu)$ $1.1\times10^5 = 2\times0.45\times10^5(1+\mu)$ $\boxed{\mu = 0.22}$	**01**	
		$E = 3K(1-2\mu)$ $1.1\times10^5 = 3\times K(1-2\times0.22)$ $K = 65476.190 N/mm^2$ $\boxed{K = 0.65\times10^5 N/mm^2}$	**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.1	**b)**	$\mu = \dfrac{\text{Lateral Strain}}{\text{linear Strain}}$	**01**	**04**
		Lateral Strain = $\mu \times$ linear Strain		
		$\left(\dfrac{\delta d}{d}\right) = \mu \times \left(\dfrac{\delta L}{L}\right)$		
		$\left(\dfrac{\delta d}{50}\right) = 0.22 \times \left(\dfrac{3}{2500}\right)$	**01**	
		$\boxed{\delta d = 0.0132 mm}$		
	ii)	**A simply supported beam 6 m long is carrying a udl of 20 kN/m over a length of 3 m from the right end. Draw the SFD and BMD for the beam and also calculated the maximum bending moment in the section.**		
	Ans.	Step I		
		Calculation of reactions		
		$\sum M_A = 0$		
		$R_B \times 6 = 20 \times 3 \times (3+1.5)$		
		$\boxed{R_B = 45 \text{ kN}}$	½	
		$\sum F_y = 0$		
		$R_A + R_B = 20 \times 3$		
		$R_A + 45 = 60$		
		$\boxed{R_A = 15 \text{kN}}$		
		Step II		
		SF Calculations		
		SF at A = +15 kN		
		C_L = +15 kN	½	
		B_L = +15 - 60 = - 45 kN		
		B_R = - 45 + 45 = 0 $(\therefore ok)$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.1	b)	Step III BM Calculations BM at A and B = 0 (Supports are simple) BM at C = + 15×3 = + 45 kN-m To calculate B_{max} SF is Zero at B_{max} $\therefore 20x + 45 = 0$ $\therefore x = 2.25$m from support B $B_{max} = +45 \times 2.25 - 20 \times \frac{(2.25)^2}{2} = +50.625$kN-m $B_{max} = 50.625$ kN-m	01	04
			01 01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.1	**iii)**	**A cantilever beam of span 6.5 m is having cross section of 400 mm wide and 700 mm deep. If the bending stress is not allowed to exceed 280 N/mm^2, calculate the magnitude of point load which can be applied at the free end of the cantilever beam.**		
	Ans.	Given: L = 6.5m, b = 400mm, d = 700mm, $\sigma_b = 280 N/mm^2$ Find: 'W' at free end		
		$M = (W \times L)$ N-m $M = (6.5\times10^3)$ W N-mm	½	
		$I = \frac{bd^3}{12} = \frac{400\times700^3}{12}$ $\boxed{I = 1.143\times10^{10} mm^4}$	**01**	
		$y = \frac{d}{2} = \frac{700}{2} = 350mm$	½	**04**
		$\sigma_b = \left(\frac{M}{I}\right)\times y$	**01**	
		$280 = \left(\frac{(6.5\times10^3)W}{1.143\times10^{10}}\right)\times350$ W = 1407179.487 N $\boxed{W = 1407.179 kN}$	**01**	
Q.2		**Attempt any <u>FOUR</u> of the following:**		**(16)**
	a)	**A metal rod, 500 mm long and 20 mm in diameter is subjected to an axial pull of 40 kN. Under this load, elongation of rod is 0.5 mm and decrease in diameter of rod is 0.006 mm. Calculate modulus of elasticity and Poisson's ratio.**		
	Ans.	Given: P = 40kN, L = 500mm, d = 20mm, δL = 0.5mm, δd = 0.006 mm Find: E, μ $A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(20)^2 = 314.16mm^2$		
		$E = \frac{PL}{A\delta L}$	**01**	

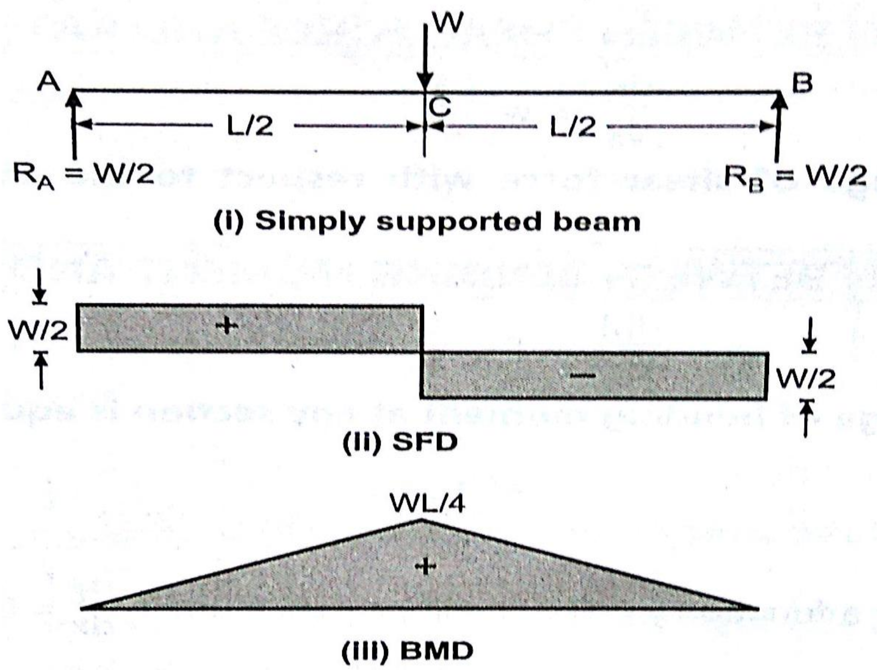
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.2		$E=\dfrac{40\times10^{3}\times500}{314.16\times0.5}=127323.9545 N/mm^{2}$		
		$E = 1.2732\times10^{5}\ N/mm^{2}$	01	
		$\mu=\dfrac{\text{Lateral Strain}}{\text{linear Strain}}$	01	04
		$\mu=\dfrac{\left(\frac{\delta d}{d}\right)}{\left(\frac{\delta L}{L}\right)}=\dfrac{\left(\frac{0.006}{20}\right)}{\left(\frac{0.5}{500}\right)}$		
		$\mu = 0.3$	01	
	b)	**A hollow steel tube 200 mm external diameter and 25 mm thick is 4 m long used as a column. If it's one end is fixed and other end is hinged, find the load the column can carry. Use Euler's formula and FOS = 2, Take E = 2x10^5 N/mm².**		
	Ans.	Given: D = 200mm, t = 25mm, L = 4 m , E = $2\times10^{5}N/mm^{2}$, FOS = 2 Find: P_{safe}		
		$d = (D - 2t)=(200 - 2\times25)=150mm$	½	
		$Le = \dfrac{L}{\sqrt{2}} = \dfrac{4000}{\sqrt{2}} = 2828.427mm$	½	
		$I_{min}= \dfrac{\pi}{64}(D^{4}- d^{4}) =\dfrac{\pi}{64}(200^{4}- 150^{4})$	01	
		$I_{min}= 53689327.58\ mm^{4}$		
		$P =\dfrac{\pi^{2}EI_{min}}{(Le)^{2}}$	01	04
		$P =\dfrac{\pi^{2}\times2\times10^{5}\times53689327.58}{(2828.427)^{2}}$		
		P =13247310.59 N		
		$P_{Safe}=\dfrac{P}{FOS}=\dfrac{13247310.59}{2}$		
		$P_{Safe} = 6623655.3\ N$	01	
		$P_{Safe}= 6.624\times10^{3}kN$		

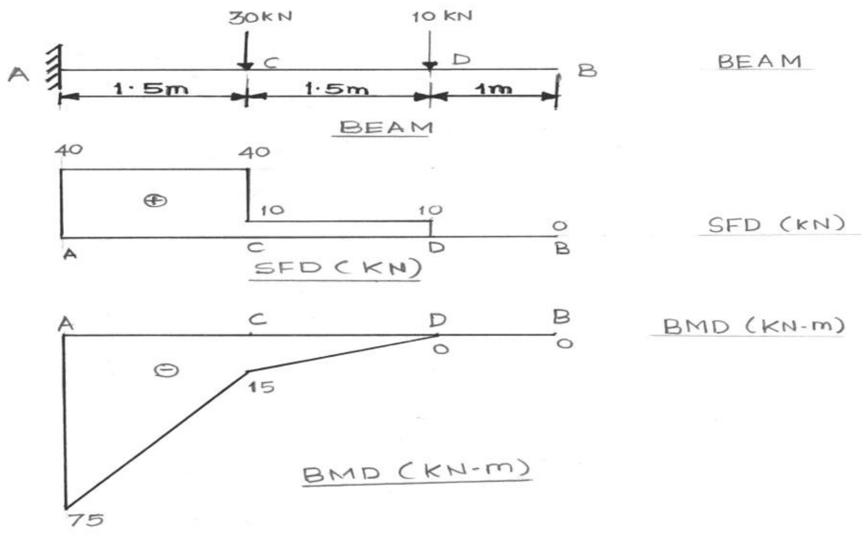
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.2	**c)**	**A steel tube 40 mm external diameter and 4 mm thick encloses centrally a solid copper bar of 30 mm diameter. The bar and the tube are rigidly connected together at the ends at a temperature of 40ºC. Find the stress and its nature in each metal when heated to 180 ºC. Take α_S = 1.08 x 10^{-5}/ºC, α_C = 1.7 x 10^{-5} /ºC, Es = 2.1 x 10^5 N/mm² and Ec = 1.1 x 10^5 N/mm².**		
	Ans.			
		Given:		
		$T_1 = 40^0 C,\quad T_2 = 180^0 C,$		
		$\alpha_S = 1.08\times10^{-5} /^0 C,\quad \alpha_C = 1.7\times10^{-5} /^0 C,$		
		$E_S = 2.1\times10^5 N/mm^2,\ E_C = 1.1\times10^5 N/mm^2$		
		Find : σ_S, σ_C		
		$t = T_2 - T_1$		
		$t = 180 - 40$		
		$\boxed{t = 140^o C}$	½	
		$A_S = \frac{\pi}{4}\left(D^2 - d^2\right)$		
		$A_S = \frac{\pi}{4}\left(40^2 - 32^2\right)$		
		$\boxed{A_S = 452.39 mm^2}$	½	
		$A_C = \frac{\pi}{4}(d)^2$		
		$A_C = \frac{\pi}{4}(30)^2$		
		$\boxed{A_C = 706.86\ mm^2}$	½	

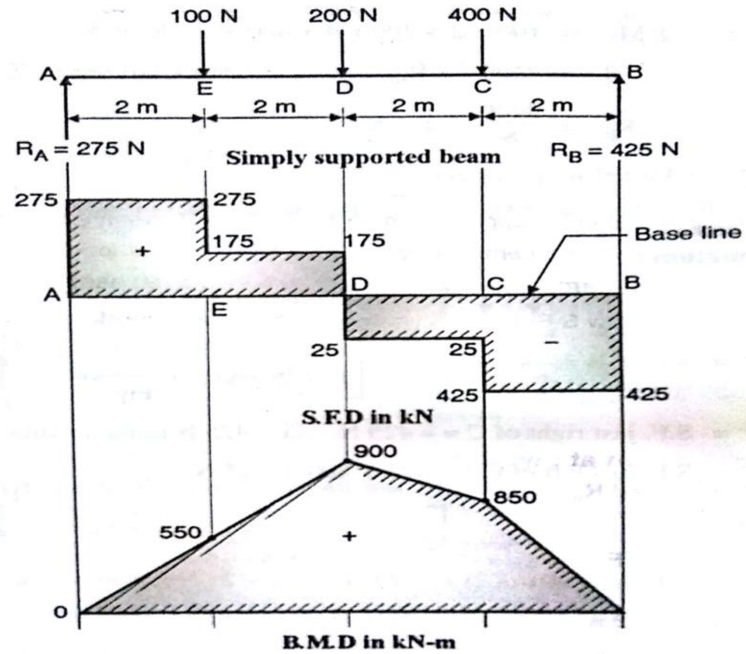
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.2		$P_S = P_C$	½	
		$\sigma_S A_S = \sigma_C A_C$		
		$\sigma_S = \left(\frac{A_C}{A_S}\right)\sigma_C$		**04**
		$\sigma_S = \left(\frac{706.86}{452.39}\right)\sigma_C$		
		$\boxed{\sigma_S = 1.5625\sigma_C}$	½	
		$\frac{\sigma_S}{E_S} + \frac{\sigma_C}{E_C} = (\alpha_C - \alpha_S)t$	½	
		$\frac{1.5625\ \sigma_C}{2.1\times10^5} + \frac{\sigma_C}{1.1\times10^5} = (1.7\times10^{-5} - 1.08\times10^{-5})\times140$		
		$\boxed{\sigma_C = 52.51\text{N/mm}^2\text{(C)}}$	½	
		$\sigma_S = (1.5625)\sigma_C$		
		$\sigma_S = 1.5625\times52.51$		
		$\boxed{\sigma_S = 82.046\text{N/mm}^2\text{(T)}}$	½	
	d)	**A steel tube of 40 mm inside diameter and 4 mm metal thickness is filled with concrete. Determine the stress in each material due to an axial thrust of 60 kN. Take E_{steel} = 2.1 x 10^5 N/mm² and E_{con} = 0.14 x 10^5 N/mm²**		
	Ans.	Given:		
		P = 60kN, d = 40mm		
		t = 4 mm, $E_S = 2.1\times10^5\text{N/mm}^2$		
		$E_C = 0.14\times10^5\text{N/mm}^2$		
		Find: σ_C, σ_S		
		External diameter,		
		D = d + 2 t		
		D = 40 + (2 ×4)		
		$\boxed{D = 48\text{mm}}$	½	
		$A_S = \frac{\pi}{4}(D^2 - d^2)$		
		$A_S = \frac{\pi}{4}(48^2 - 40^2)$		
		$\boxed{A_S = 552.92\text{mm}^2}$	½	

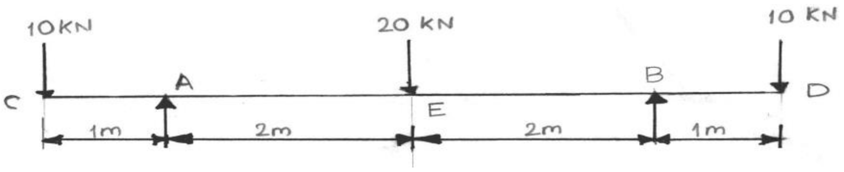
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.2		$A_C = \frac{\pi}{4} d^2$		
		$A_C = \frac{\pi}{4}(40)^2$	½	
		$\boxed{A_C = 1256.637 mm^2}$		**04**
		$\frac{\sigma_S}{E_S} = \frac{\sigma_C}{E_C}$	½	
		$\sigma_S = \left(\frac{E_S}{E_C}\right) \times \sigma_C$		
		$\sigma_S = \left(\frac{2.1\times10^5}{0.14\times10^5}\right) \times \sigma_C$	½	
		$\boxed{\sigma_S = 15\sigma_C}$		
		$P = P_S + P_C$		
		$P = \sigma_S A_S + \sigma_C A_C$	½	
		$60\times10^3 = (15\sigma_C)\times552.92 + \sigma_C\times1256.637$		
		$\boxed{\sigma_C = 6.28 N/mm^2}$	½	
		$\sigma_S = 15\sigma_C$		
		$\sigma_S = 15\times6.28$	½	
		$\boxed{\sigma_S = 94.236 N/mm^2}$		
	e)	**A bar is subjected to a tensile stress of 100 N/mm². Determine the normal and tangential stresses on a plane making an angle of 60º with the axis of tensile stress.**		
	Ans.	Given:		
		$\sigma_x = 100 N/mm^2 \quad \theta = 90^0 - 60^0 = 30^0$		
		Find: σ_n, σ_t		
		$\sigma_n = \sigma_x \cos^2\theta$	**01**	
		$\sigma_n = 100\times\cos^2 30$		
		$\boxed{\sigma_n = 75 N/mm^2 (T)}$	**01**	
		$\sigma_t = \frac{\sigma_x}{2}\sin 2\theta$		**04**
		$\sigma_t = \frac{100}{2}\times\sin(2\times30)$	**01**	
		$\boxed{\sigma_t = 43.30 N/mm^2}$	**01**	

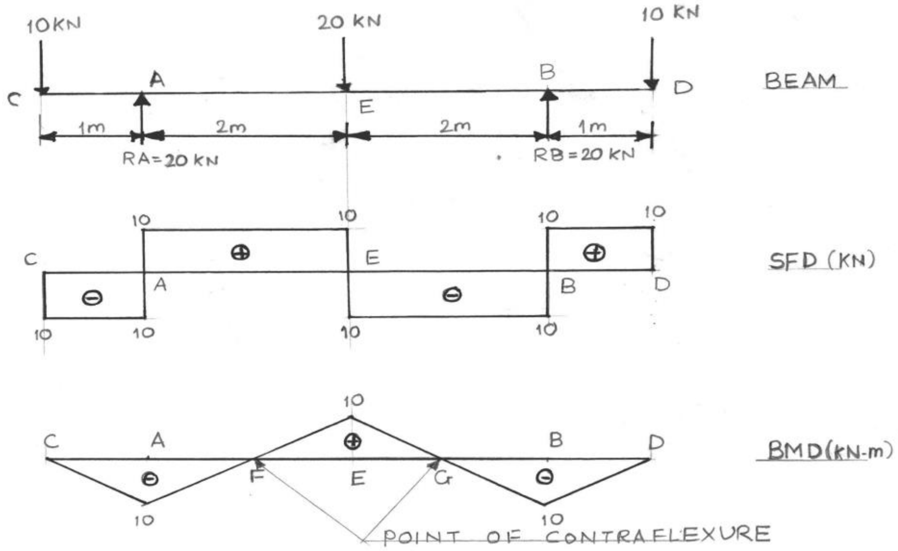
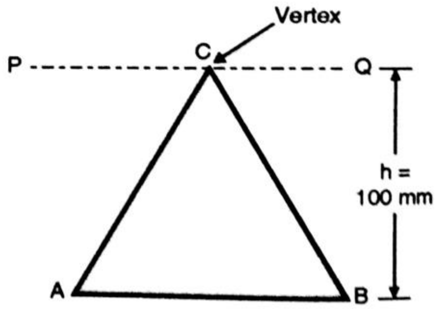
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.2	**f)**	**A cylindrical compressed air drum is 2 m in diameter with plate thickness of 12 mm. If the tensile stress is not to exceed 100 N/mm². Find the maximum safe air pressure.**		
	Ans.	Given: d =2m, t = 12 mm, Tensile stress = $100 N/mm^2$ Find: P_{safe} $\sigma_C = \frac{Pd}{2t}$ $100 = \frac{P \times 2000}{2 \times 12}$ $P = 1.2 N/mm^2$	**1 ½**	**04**
		$\sigma_L = \frac{Pd}{4t}$ $100 = \frac{P \times 2000}{4 \times 12}$ $P = 2.4 N/mm^2$	**1 ½**	
		$\therefore$ Maximum safe air pressure is $1.2 N/mm^2$	**01**	

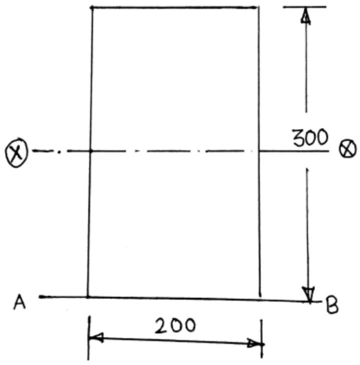
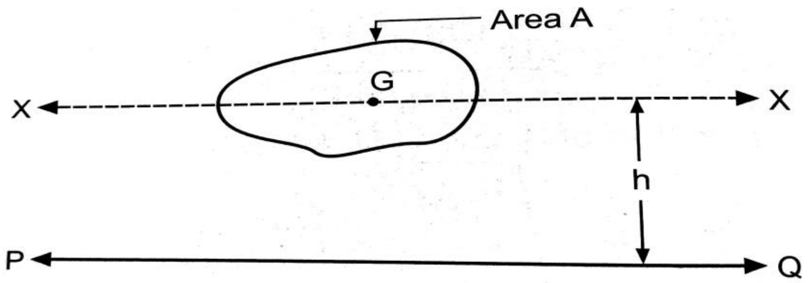
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.3		**Attempt any <u>FOUR</u> of the following:**		**(16)**
	a)	**Define shear force and bending moment.**		
	Ans.	**Shear force:** Shear force at any cross section of the beam is the algebraic sum of vertical forces on the beam acting on right side 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.	**02**	**04**
		Bending Moment: Bending moment at any section of a beam is the algebraic sum of the moment of all forces acting on the right or left side of section is called as bending moment.	**02**	
	b)	**Draw shear force and bending moment diagram for a simply supported beam of span 'L' carrying a central point load 'W'. State the maximum SF and BM values.**		
	Ans.	 	**01** **01**	**04**
		Maximum SF = $\frac{W}{2}$	**01**	
		Maximum BM = $+\frac{WL}{4}$	**01**	
	c)	**A cantilever beam of span 4 m carrying two point loads of 10 kN and 30 kN at 1 m and 2.5 m from free end respectively. Draw SFD and BMD.**		

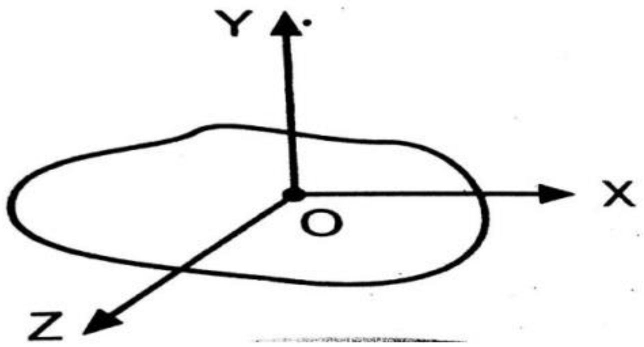
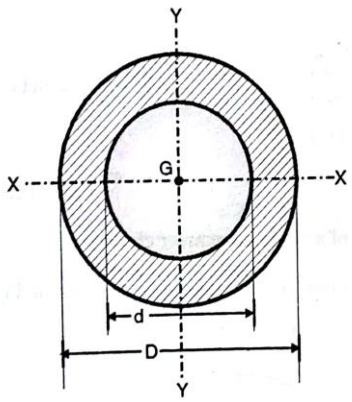
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.3	**Ans.**	Step I Calculate Support reaction $R_A = 30 + 10 = 40$ kN Step II SF Calculations: SF at A = + 40kN C_L = + 40kN C_R = + 40 - 30 =10 kN D_L = +10 kN D_R = +10 - 10 = 0 kN B = 0 kN	01	
		Step III BM Calculations BM at B = 0 (Free end) D = 0 kN-m C = - 10×1.5 = - 15 kN-m A = - 10×3 - 30×1.5 = - 75 kN-m	01	04
			01 01	
	d)	**A simply supported beam of 8 m span carries three point loads of 100 N, 200 N and 400 N at 2 m, 4m and 6 m from left hand support. Draw SF and BM diagrams.**		
	Ans.	Step I Calculate support reactions $\Sigma M_A = 0$ $(R_B \times 8) - (100\times2) - (200\times4) - (400\times6) = 0$ $\boxed{R_B = 425\ N \uparrow}$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.3		$\Sigma F_Y = 0$ $R_A + R_B - 100 - 200 - 400 = 0$ $R_A + 425 - 100 - 200 - 400 = 0$ $R_A = 275$ N ↑	**01**	
		Step II S. F. Calculations SF at A = + 275 N E_L = + 275 N E_R = + 275 - 100 = + 175 N D_L = + 175 N D_R = + 175 - 200 = - 25N C_L = - 25 N C_R = - 25 - 400= - 425 N B_L = - 425 N B= - 425 + 425 = 0 ($\therefore$ ok)	**01**	
		Step III B. M. Calculations BM at A and B = 0 ($\because$ Supports are simple) BM at E = 275×2 = + 550 kN-m BM at D = + 275×4 -100×2 = + 900 kN-m BM at C = + 425×2 = + 850 kN-m		**04**
			**01** **01**	

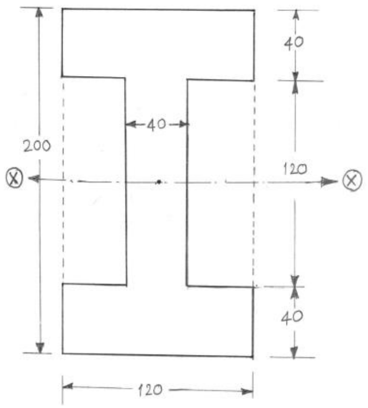
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.3	e)	**A simply supported beam having equal overhangs on both sides and carrying point loads is shown in Fig. No. 1. Draw SF and BM diagrams.**  **Fig. No. 1**		
	Ans.	Step I Calculate support reactions, Due to symmetrical loading, $R_A = R_B$ $R_A = R_B = \left(\frac{10 + 20 + 10}{2}\right) = 20\ kN$ Or $\Sigma M_A = 0$ $(R_B \times 4) + (10\times1) = (20\times2) + (10\times5)$ $\boxed{R_B = 20\ kN}$ $\Sigma F_Y = 0$ $R_A + R_B = 40$ $R_A + 20 = 40$ $\boxed{R_A = 20\ kN}$ Step II S. F. Calculations SF at C_R = - 10 kN A_L = - 10 kN A_R = + 10 + 20 = +10 kN E_L = +10 kN E_R = +10 - 20= -10 kN B_L = - 10 kN B_R = - 10+ 20 = +10 kN D_L = +10 kN D_R = - 10 - 10 = 0 ($\therefore$ ok)	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.3		Step III		
		B. M. Calculations		**04**
		BM at C and D = 0 $(\because \text{ free } end)$	**01**	
		BM at A = -10×1 = - 10 kN-m		
		BM at E = $-10\times3+20\times2$ = +10 kN-m		
		BM at B = -10×1 = -10 kN-m		
			**01** **01**	
	f)	**Calculate M.I. for a triangle of height 100 mm about axis passing through vertex and parallel to base. If M.I. about the base of same triangle is 10^7 mm^4.**		
	Ans.	Given:		
		$I_{base} = 10^7\ mm^4$,		
		Height of Triangle (h) = 100 mm		
		Find: I_{vertex}		
		Step I		
		Calculate base width (b) of Triangle		
		$I_{base} = \frac{bh^3}{12}$	**01**	
		$10^7 = \frac{b\times100^3}{12}$		
				
		$b = \frac{10^7\times12}{100^3} = 120mm$		**04**
		$\boxed{b = 120mm}$	**01**	
		Step II : Calculate I_{vertex}		
		$I_{vertex} = \frac{bh^3}{4} = \frac{120\times100^3}{4} = 3\times10^7 mm^4$	**01**	
		$\boxed{I_{vertex} = 3\times10^7 mm^4}$	**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.4		**Attempt any FOUR of the following:**		**(16)**
	a)	**A rectangular beam section has width 200 mm depth of 300 mm. Using parallel axis theorem. Calculate M.I. about its base.**		
	Ans.	M.I. of rectangle about its base (I_{AB}) Using parallel axis theorem, $I_{AB} = I_G + Ah^2$ $= I_{XX} + Ah^2$ $= \frac{bd^3}{12} + bd \times \left(\frac{d}{2}\right)^2$ 	**02**	**04**
		$= \frac{200 \times 300^3}{12} + \left(200 \times 300 \times (150)^2\right)$ $\boxed{I_{AB} = 1.8 \times 10^9 mm^4}$	**02**	
	b)	**State parallel axis theorem and perpendicular axis theorem of moment of inertia with neat sketches.**		
	Ans.	a) **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 square of the distance between the two axes.	**01**	
		 $\boxed{I_{PQ} = I_G + Ah^2}$	**01**	**04**
		b) Perpendicular axis theorem: It state, if I_{XX} and I_{YY} are the moments inertia of a plane section about the two mutually perpendicular axes meeting at O, then the moment of inertia about the third axis Z-Z i.e. I_{ZZ} is equal to addition of moment of inertia about X-X and Y-Y axes.	**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.4			**01**	
		$I_P = I_{ZZ} = I_{XX} + I_{YY}$		
	c)	**A hollow C.I. pipe, with external diameter 100 mm and thickness of metal 10 mm is used as a strut. Calculate the moment of inertia and radius of gyration about its diameter.**		
	Ans.	Given: D = 100 mm, t = 10mm , 1) D = 100 mm,		
		$d = D\text{-}2t = 100\text{-}(2\times10) = 80mm$	½	
		2) Area of strut $A = \frac{\pi}{4}(D^2\text{-}d^2)$ $= \frac{\pi}{4}(100^2\text{-}80^2)$		
		$A = 2827.43mm^2$	½	
		3) M.I. about diameter $(I_{XX} or I_{YY})$ 		
		$I_{XX} or I_{YY} = \frac{\pi}{64}(D^4 - d^4)$	½	
		$= \frac{\pi}{64}(100^4 - 80^4)$		
		$I_{XX} or\ I_{YY} = 2898119.223mm^4$	**01**	
		4)Radious of gyration,	½	
		$K_{XX}\ or\ K_{YY} = \sqrt{\frac{I_{XX}}{A}} = \sqrt{\frac{2898119.223}{2827.43}}$		
		$K_{XX}\ or\ K_{YY} = 32.015mm$	**01**	
		$K_{XX}\ or\ K_{YY} = 32.015mm$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.4	**d)**	**Find the M.I. of an I-section having equal flanges 120 mm x 40 mm and web 120 mm x 40 mm about XX- axis overall depth 200 mm.**		
	Ans.			



02

M.I. at x-x axis,

$$I_{XX} = \frac{BD^3}{12} - \frac{bd^3}{12}$$

04

$$= \frac{120 \times 200^3}{12} - \frac{80 \times 120^3}{12}$$

02

$$\boxed{I_{XX} = 68.48 \times 10^6 mm^4}$$

OR

OR

Due to symmetry of section ,

$$\bar{x} = \frac{120}{2} = 60mm,$$

01

$$\bar{y} = \frac{200}{2} = 100mm,$$

01

$M.I.$ at x-x axis

$$I_{xx} = I_{XX_1} + I_{XX_2} + I_{XX_3}$$

$$I_{xx} = \left(I_{G_1} + A_1 h_1^{\ 2}\right) + \left(I_{G_2} + A_2 h_2^{\ 2}\right) + \left(I_{G_3} + A_3 h_3^{\ 2}\right)$$

$$I_{G_1} = \frac{b_1 d_1^{\ 3}}{12} = \frac{120 \times 40^3}{12} = 640000 mm^4$$

04

$$I_{G_2} = \frac{b_2 d_2^{\ 3}}{12} = \frac{40 \times 120^3}{12} = 5760000 mm^4$$

$$I_{G_3} = \frac{b_3 d_3^{\ 3}}{12} = \frac{120 \times 40^3}{12} = 640000 mm^4$$

$$A_1 = 120 \times 40 = 4800 mm^2$$

$$A_2 = 40 \times 120 = 4800 mm^2$$

01

$$A_3 = 120 \times 40 = 4800 mm^2$$

$$h_1 = \bar{y} - y_1 = 100 - 20 = 80 mm$$

$$h_2 = \bar{y} - y_2 = 100 - 100 = 0$$

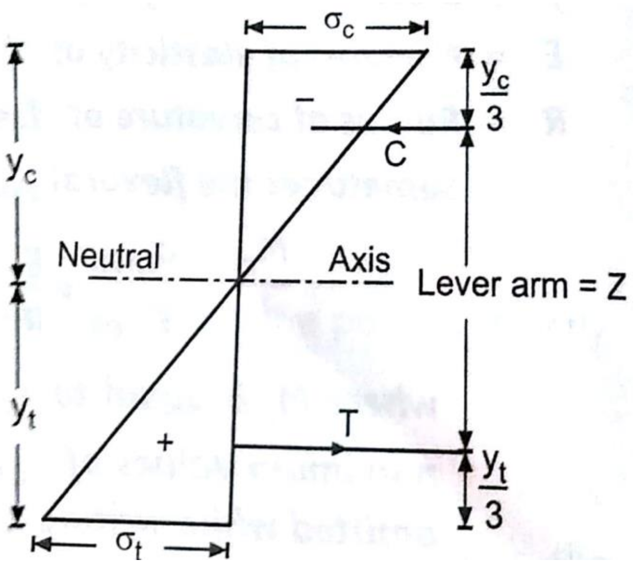
01

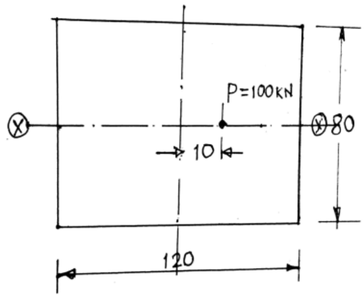
$$h_3 = y_3 - \bar{y} = 180 - 100 = 80 mm$$

$$I_{xx} = \left(I_{G_1} + A_1 h_1^{\ 2}\right) + \left(I_{G_2} + A_2 h_2^{\ 2}\right) + \left(I_{G_3} + A_3 h_3^{\ 2}\right)$$

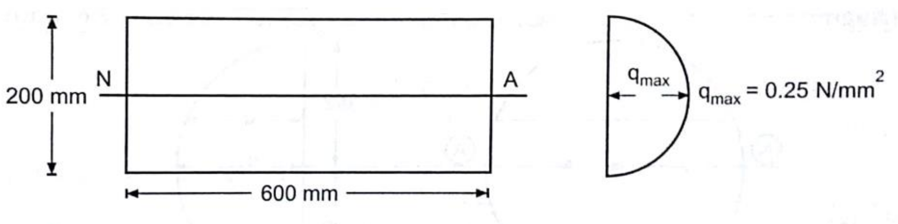
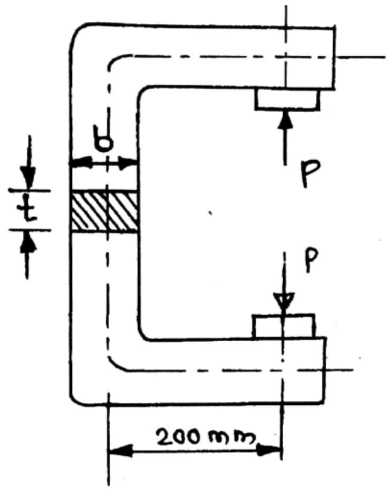
$$I_{xx} = \left(640000 + 4800 \times 80^2\right) + \left(5760000 + 4800 \times 0^2\right) + \left(640000 + 4800 \times 80^2\right)$$

$$\boxed{I_{xx} = 68.48 \times 10^6 mm^4}$$

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.4	e) Ans.	**Explain the meaning of moment of resistance and neutral axis in the theory of simple bending.** **Moment of resistance:** Moment of resistance of the beam is the moment of couple formed by the total compressive force acting at the Centre of gravity of the compressive stress diagram and the total tensile force acting at the Centre of gravity of the tensile stress diagram. Moment of couple = C x Z or T x Z. This moment is called the moment of resistance of the beam and is denoted by M_r.	01	
			01	04
		Neutral Axis: The fibers in the lower part of the beam undergo elongation while those in the upper part are shortened. These changes in the lengths of the fibers set up tensile and compressive stresses in the fibers. The fibers in the centroidal layer are neither shortened nor elongated. These centroidal layers which do not undergo any extension or compression is called neutral layer or neutral surface. When the beam is subjected to pure bending there will always be one layer which will not be subjected to either compression or tension. This layer is called as neutral layer and axis of this layer is called Neutral Axis.	01	
			01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.4	**f)**	**The cross section of beam is symmetrical I- section having flange width 100 mm, overall depth 180 mm and thickness 10 mm. If the permissible bending stress is 120 N/mm², find the moment of resistance of the beam section.**		
	Ans.	Given: $\sigma_b = 120 N/mm^2$ $Find : M_r$ $I = \left[\frac{BD^3}{12} - \frac{bd^3}{12}\right]$	½	
		$I = \left[\frac{100 \times 180^3}{12} - \frac{90 \times 160^3}{12}\right]$ $\boxed{I = 17.88 \times 10^6 mm^4}$	01	
		$y = \frac{180}{2} = 90mm$	½	
		Using flexural formula, $\frac{M}{I} = \frac{\sigma_b}{y}$	01	04
		Momoent of resistance, $M_r = \left(\frac{\sigma_b}{y}\right) \times I$ $= \left(\frac{120}{90}\right) \times 17.88 \times 10^6$ $\boxed{M_r = 23.84 \times 10^6 N-mm}$	01	
Q.5		**Attempt any <u>FOUR</u> of the following:**		**(16)**
	a)	**A rectangular strut is 120 mm x 80 mm thick. It carries a load of 100 kN at an eccentricity of 10 mm in a plane bisecting the thickness. Find the maximum and minimum intensities of stress in the strut section.**		
	Ans.	Given: b = 120mm, d = 80mm, e = 10mm P = 100kN = 100× 10^3 N Find: σ_{max} , σ_{min} Direct Stress, $\sigma_o = \frac{P}{A}$ $\sigma_o = \frac{100 \times 10^3}{120 \times 80}$ $\boxed{\sigma_o = 10.417 N/mm^2}$ 	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.5	a)	Bending Stress, $\sigma_b = \frac{P.e}{I} \times Y$		
		$\sigma_b = \frac{P.e}{\left(\frac{db^3}{12}\right)} \times \frac{b}{2}$	01	
		$\sigma_b = \frac{100 \times 10^3 \times 10}{\left(\frac{80 \times 120^3}{12}\right)} \times \frac{120}{2}$		04
		$\boxed{\sigma_b = 5.208 \text{ N/mm}^2}$	01	
		Maximum stress, $\sigma_{max} = \sigma_o + \sigma_b$		
		$\sigma_{max} = 10.417 + 5.208$	½	
		$\boxed{\sigma_{max} = 15.625 \text{ N/mm}^2 (C)}$		
		Minimum stress, $\sigma_{min} = \sigma_o - \sigma_b$		
		$\sigma_{max} = 10.417 - 5.208$	½	
		$\boxed{\sigma_{min} = 5.209 \text{ N/mm}^2 \ (C)}$		
	b)	**Sketch the shear stress distribution diagram for a rectangular beam of 600 mm x 200 mm deep subjected to shear force of 20 kN.**		
	Ans.	Given: b = 600mm, d = 200mm, S.F.= S = 20kN = 20×10^3N		
		Find: q_{max}	01	
		$I_{xx} = \frac{bd^3}{12} = \frac{600 \times 200^3}{12} = 4 \times 10^8 \text{mm}^4$	½	
		$\bar{y} = \frac{d}{4} = \frac{200}{4} = 50\text{mm}$		04
		Area under consideration	½	
		$A = b \times \frac{d}{2} = 600 \times \frac{200}{2} = 6 \times 10^4 \text{mm}^2$		
		$q_{max} = \frac{SA\bar{Y}}{bI} = \frac{20 \times 10^3 \times 6 \times 10^4 \times 50}{600 \times 4 \times 10^8}$	01	
		$\boxed{q_{max} = 0.25 N/mm^2}$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.5	**b)**	*OR*		
		For rectangular cross section ,		
		$q_{max} = \frac{3}{2} \times q_{avg}$	**1 ½**	**04**
		$q_{max} = \frac{3}{2} \times \frac{s}{b.d}$		
		$q_{max} = \frac{3}{2} \times \frac{20 \times 10^3}{600 \times 200}$	**1 ½**	
		$q_{max} = 0.25 N/mm^2$		
		(a) Section (b) Shear stress distribution	**01**	
	c) **Ans.**	**Fig. No. 2 shows the frame of a screw clamp carrying a load of 4 kN. The cross section of frame is rectangular having width 60 mm and thickness 20 mm. Determine to resultant stresses for the frame material.**		
		**Fig. No. 2**		
		Given:		
		$P = 4 kN = 4 \times 10^3 N$		
		b = 60 mm,		
		d = t = 20 mm		
		e = 200 mm		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.5	**c)**	$\sigma_o = \frac{P}{A}$		
		$\sigma_o = \frac{4\times10^3}{60\times 20}$		
		$\boxed{\sigma_o = 3.334 N/mm^2}$	**01**	
		Bending stress,		
		$\sigma_b = \frac{M}{I}\times Y$	**01**	
		$\sigma_b = \frac{P.e}{\frac{db^3}{12}}\times\frac{b}{2}$		
		$\sigma_b = \frac{4\times10^3\times200}{\frac{20\times60^3}{12}}\times\frac{60}{2}$		**04**
		$\boxed{\sigma_b = 66.667\ N/mm^2}$	**01**	
		Maximum stress,		
		$\sigma_{max} = \sigma_o + \sigma_b$		
		$\sigma_{max} = 3.334 + 66.667$		
		$\boxed{\sigma_{max} = 70.001\ N/mm^2 (T)}$	½	
		Minimum stress,		
		$\sigma_{min} = \sigma_o - \sigma_b$		
		$\sigma_{min} = 3.334 - 66.667$		
		$\sigma_{min} = - 63.333\ N/mm^2$		
		$\boxed{\sigma_{min} = 63.333\ N/mm^2\ (C)}$	½	
	d)	**A M.S. link as shown in Fig. No. 3 transmits a pull of 80 kN. Find the cross sectional dimensions (band t) if b = 3t. Assume the permissible tensile stress as 70 MPa.**		
	Ans.	Given:		
		$P = 80kN = 80\times10^3N$		
		$\sigma = 70MPa = 70N/mm^2$		
		$e = \frac{b}{2}$, $b = 3t$		
		Find: b, t		
		$\sigma = \sigma_o + \sigma_b$		
		$\sigma = \frac{P}{A} + \frac{P.e}{I}\times Y$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.5		$\sigma = \frac{P}{A} + \frac{P.e}{\left(\frac{t\times b^3}{12}\right)}\times\frac{b}{2}$	01	
		$70 = \frac{80\times10^3}{b\times t} + \frac{80\times10^3\times\frac{b}{2}\times b\times6}{t\times b^3}$		
		Put b = 3t		
		$70 = \frac{80\times10^3}{3t\times t} + \frac{80\times10^3\times\frac{3t}{2}\times3t\times6}{t\times3t}$	01	04
		$t^2 = \frac{320\times10^3}{70\times3}$		
		$\boxed{t = 39.036\text{ mm}}$	01	
		b = 3×39.036		
		$\boxed{b=117.108\text{ mm}}$	01	
	e)	**A circular section of diameter 'd' is subjected to load 'P' eccentric to the axis-YY. The eccentricity of loads is 'e'. Obtain the limit of eccentricity such that no tension is induced at the section.**		
	Ans.	$A=\frac{\pi}{4}d^2,\ I=\frac{\pi}{64}d^4,\ Y=\frac{d}{2}$	01	
		For no tension condition,		
		$\sigma_0 = \sigma_b$		
		$\frac{P}{A}=\frac{M}{Z}$	01	
		$\frac{P}{A}=\frac{P\times e}{\left(\frac{I}{Y}\right)}$		
		$e = \left(\frac{1}{A}\right)\times\left(\frac{I}{Y}\right) = \left(\frac{1}{\frac{\pi}{4}d^2}\right)\times\left(\frac{\frac{\pi}{64}d^4}{\frac{d}{2}}\right)$	01	04
		$e = \frac{d}{8}$		
		$2e = \frac{d}{4}$		
		Limit of eccentricity $\boxed{2e = \frac{d}{4}}$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.5	f)	**A short MS column of external diameter 200 mm and internal diameter 150 mm carries an eccentric load. Find the greatest eccentricity which the load can have without producing tension in the section of a column.**		
	Ans.	Given: External Diameter, D = 200 mm Internal Diameter, d = 150 mm Find: P, e For no tension condition,		
		$\sigma_0 = \sigma_b$	01	
		$\frac{P}{A} = \frac{M}{Z}$		
		$\frac{P}{A} = \frac{P.e.Y}{I}$	01	
		$e = \frac{I}{A.Y}$		04
		$e = \frac{\left(\frac{\pi}{64}\times\left(D^4 - d^4\right)\right)}{\left(\frac{\pi}{4}\times\left(D^2 - d^2\right)\times\frac{D}{2}\right)} = \frac{\left(\frac{\pi}{64}\times\left(200^4 - 150^4\right)\right)}{\left(\frac{\pi}{4}\times\left(200^2 - 150^2\right)\times\frac{200}{2}\right)}$	01	
		e = 39.0625 mm		
		Greatest eccentricity e = 39.0625 mm	01	
Q.6		**Attempt any FOUR of the following:**		(16)
	a)	**State assumptions in theory of pure torsion.**		
	Ans.	**Assumptions:** 1. The shaft is straight having uniform circular cross section. 2. The shaft is homogeneous and isotropic. 3. Circular section remains circular even after twisting. 4. Plain section before twisting remains plain after twisting and do not twist or wrap. 5. A diameter in the section before deformation remains a diameter or straight line after deformation. 6. Stresses do not exceed the proportional limit. 7. Shaft is loaded by twisting couples in the planes that are perpendicular to the axis of the shaft. 8. Twist along the shaft is uniform.	½ mark each	04

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.6	b) Ans.	**Find the torque that can be applied to a shaft of 100 mm in diameter, if the permissible angle of twist is 2.75º in a length of a 6 m. Take C = 80 kN/mm².** Given data: $\theta = 2.75^0 = 2.75 \times \frac{\pi}{180} = 0.048$ rad. d =100 mm L = 6 m = 6000 mm $C = G = 80\ kN/mm^2 = 80 \times 10^3 N/mm^2$ Find: T From rigidity eqution, $\frac{T}{J} = \frac{G.\theta}{L}$ $\frac{T}{\frac{\pi}{32} \times d^4} = \frac{G.\theta}{L}$ $T = \frac{\pi \times d^4 \times G \times \theta}{32 \times L}$ $T = \frac{\pi \times 100^4 \times 80 \times 10^3 \times 0.048}{32 \times 6000}$ T = 6282734.283 N-mm $\boxed{T = 6.282\ kN\text{-}m}$	½ ½ 01 02	04
	c) Ans.	**Find the power transmitted by a solid shaft of diameter 60 mm running at 220 rpm; if the permissible shear stress is 68 MPa. The maximum torque is likely to exceed the mean torque by 25%.** Given: d = 60mm, N = 220rpm, $\tau = 68 N/mm^2$ $T_{\max} = 1.25 T_{mean}$ Find: P = ? $\frac{T_{\max}}{J} = \frac{\tau}{R}$ $T_{\max} = \left(\frac{\tau}{R}\right) J = \left(\frac{\tau}{\frac{d}{2}}\right) \frac{\pi}{32} d^4$	 01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.6		$T_{max} = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 68 \times 60^3$	**01**	
		$T_{max} = 2883.982 \times 10^3$ N-mm		
		$T_{max} = 1.25 T_{mean}$		**04**
		$T_{mean} = \frac{T_{max}}{1.25}$		
		$T_{mean} = \frac{2883.982 \times 10^3}{1.25} = 2307.1856 \times 10^3$ N-mm		
		$T_{mean} = 2307.1856$ N-m		
		Power transmitted by shaft	**01**	
		$P = \frac{2\pi N T_{mean}}{60} = \frac{2\pi \times 220 \times 2307.1856}{60}$		
		$P = 53.153 \times 10^3$ W		
		$\boxed{P = 53.153 kW}$	**01**	
	d)	**Calculate the suitable diameter of the solid shaft to transmit 220 kW power at 150 rpm; if the permissible shear stress is 68 MPa.**		
	Ans.	Given:		
		Power = 220 kW = 220×10^3 W		
		Speed N = 150 rpm		
		Shear stress,		
		f_S = 68 MPa = 68 N/mm^2		
		Find: D		
		i) Using the relation,		
		$P = \frac{2\pi NT}{60}$ watts	**01**	
		$220 \times 10^3 = \frac{2 \times \pi \times 150 \times T}{60}$		
		T = 14005.63499 N.m		
		$\boxed{T = 14005.63499 \times 10^3 \text{ N-mm}}$	**01**	**04**
		ii)Using the relation,		
		$T = \frac{\pi}{16} \times f_S \times D^3$	**01**	
		$14005.63499 \times 10^3 = \frac{\pi}{16} \times 68 \times D^3$		
		D = 101.604 mm		
		$\boxed{\text{Diameter of Shaft} = 101.604 \text{ mm}}$	**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.6.	**e)**	**Find the torsional moment of resistance for a hollow circular shaft of 225 mm external diameter and 220 mm internal diameter, if the permissible shear is 60 MPa.**		
	Ans.	Given: External Diameter D = 225 mm Internal Diameter d = 220 mm τ = 60 MPa , Find: Torsional Moment or Resistance. $\frac{T}{J}=\frac{\tau}{R}$ $T_R=\left(\frac{\tau}{R}\right)J=\left(\frac{\tau}{\frac{d}{2}}\right)\frac{\pi}{32}\left(D^4-d^4\right)$	02	
		$T_R=\left(\frac{60}{\frac{225}{2}}\right)\frac{\pi}{32}\left(225^4-220^4\right)$ $T_R=11.536\times10^6$N-mm $\boxed{T_R=11.536\times10^3\text{N-m}}$	02	04
	f)	**(i) Define - Section modulus.** **(ii) Define – Torsional stiffness.**		
	Ans.	**Section Modulus(Z):** Section modulus is the ratio of M.I of the section about the Neutral Axis and the distance of the most extreme fiber from the Neutral axis. Z=I/Y	02	04
		Torsional Stiffness: It is defined as the torque required per unit angle of twist. Torsional Stiffness=T/θ	02	