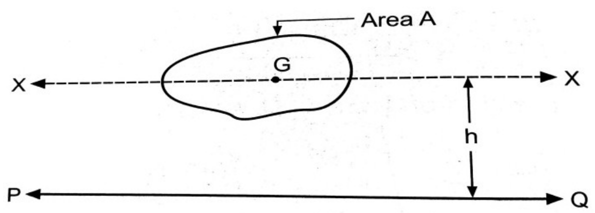
Model Answer: Summer 2018

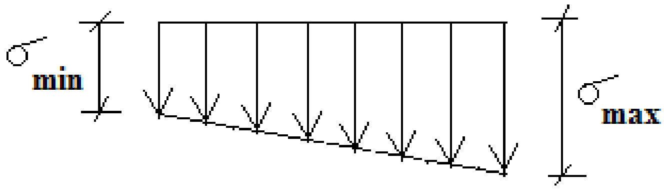
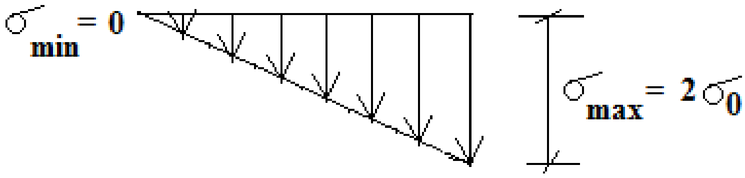
Subject: Strength of Materials **Sub. Code: 17304**

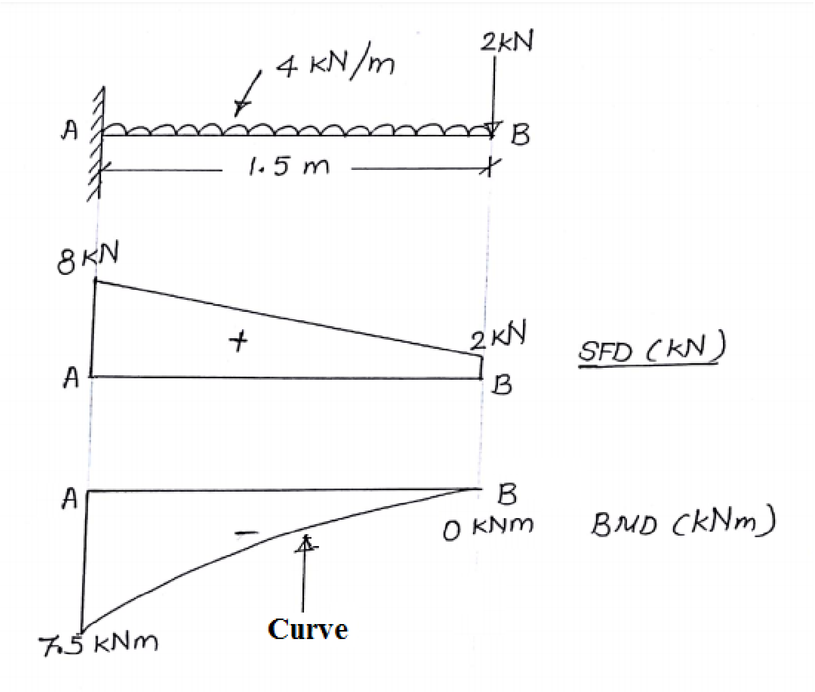
Important Instructions to examiners:

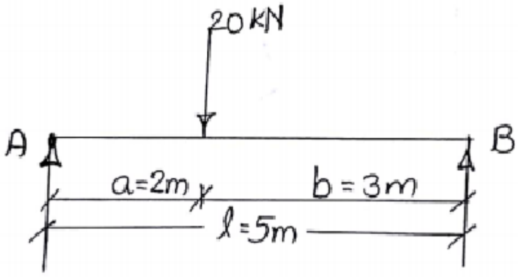
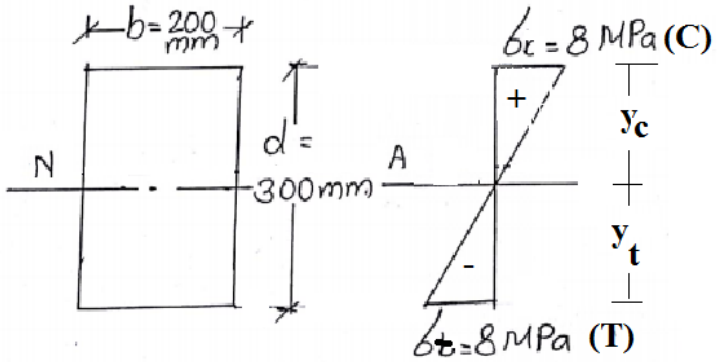
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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) Ans.	**Define ductility and state names of two ductile metals.** **Ductility:** It is the property of material to undergo a considerable deformation under tension before rapture.. **Ductile Metals** – Steel, Aluminum, Copper.	1 1(any two)	2
	(ii) Ans.	**Define principal plane and principal stress.** **Principal Plane:** A plane which carries only normal stress and no shear stress is called a principal plane. **Principal Stress:** The magnitude of normal stress acting on the principal plane is called principal stress.	1 1	2
	(iii) Ans.	**State theorem of parallel axis for moment of inertia along with a diagram.** 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.  MI about PQ = $I_{PQ} = I_G + Ah^2$	1 1	2

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1	(iv) Ans.	**Define axial load and eccentric load.**		
		Axial 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 axial load.	1	
		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.	1	2
	(v) Ans.	**State an expression for power transmitted by a shaft giving meaning of each term used in it.**		
		$P=\left(\frac{2\pi NT}{60}\right)$ Watt	1	
		Where, P = Power transmitted by shaft (Watt) N = Number of revolutions of shaft per minute (r.p.m) T = Average or mean torque (N-m)	1	2
		OR		
		$P=\left(\frac{2\pi NT}{4500}\right)$ H.P.	1	
		Where, P = Power transmitted by shaft (H.P) N = Number of revolutions of shaft per minute (r.p.m) T = Average or mean torque (kg-m)	1	2
	(vi) Ans.	**Define Poison's ratio. Also state common value of Poison's ratio for C.I.**		
		Poison's ratio (μ or 1/m) : When a homogeneous material is loaded within its elastic limit, the ratio of the lateral strain to the linear strain is constant is known as 'Poison's ratio.'	1	
		Common value of Poison's ratio for C.I. = 0.21 to 0.26	1	2
	(vii) Ans.	**Define hoop stress and longitudinal stress.**		
		Hoop Stress (σ_c): The stresses which act in the tangential direction to the perimeter (circumference) of the cylinder are called as hoop stress or circumferential stress.	1	
		Longitudinal Stress (σ_L): The stresses which act parallel to the longitudinal axis of cylinder are called as longitudinal Stress.	1	2

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1	(viii)	**In relation with eccentric load, draw stress distribution diagram for** **1) Direct stress > bending stress and** **2) Direct stress = bending stress**		
	Ans.	**1) Direct stress > bending stress i.e. $\sigma_0 > \sigma_b$**  	1	
		2) Direct stress = bending stress i.e. $\sigma_0 = \sigma_b$  	1	2
	(b)	**Attempt any TWO of the following :**		8
	(i)	**Calculate minimum diameter of steel wire to lift a load of 8.2 kN, if the permissible stress in wire is 120 MPa.**		
	Ans.	Given : P = 8.2 kN, σ = 120 MPa = 120 N/mm^2 To find : d_{min} Solution :		
		$\sigma = \frac{P}{A}$	1	
		$= \frac{P}{\frac{\pi}{4}(d^2)}$	1	
		$(d^2) = \frac{P}{\frac{\pi}{4}(\sigma)} = \frac{8.2\times10^3}{\frac{\pi}{4}(120)}$ $d = \sqrt{\frac{8.2\times10^3}{\frac{\pi}{4}(120)}} = \sqrt{87.004}$	1	
		$d_{min.} = 9.327\ \text{mm}$	1	4

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1	(ii)	**A cantilever beam, fixed at 'A' has span of 1.5 m. Beam is loaded with uniformly distributed load of 4 kN/m over entire span and downward point load of 2 kN at free end 'B'. Draw shear force and bending moment diagrams for the beam.**		
	Ans.	Reaction at A = RA = (4 x 1.5) + 2 = 8 kN		
		SF calculations -		
		SF at A = + 8 kN		
		SF at B_L = +8 - 6 = + 2 kN		
		SF at B = + 2 - 2 = 0 (∴ ok)	1	
		BM calculations -		
		BM at B = 0 (∵ d)		
		BM at A $= -(2\times1.5)-\left(4\times1.5\times\frac{1.5}{2}\right) = -7.5\,\text{kNm}$	1	
			1 1	4
	(iii)	**A simply supported beam of span 5 m is subjected to downward point load of 20 kN at 2m from left end. Cross section of beam is 200 mm wide and 300 mm deep. Calculate maximum bending stress developed in beam material. Also draw bending stress distribution across the section of beam.**		

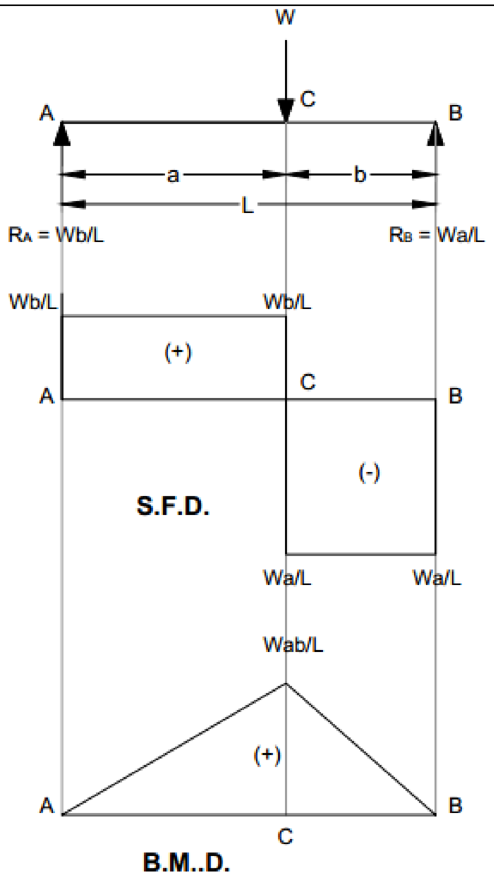
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1	**Ans.**			
			½	
		Given : l = 5 m, W = 20 kN at 2 m from left, b = 200 mm, d = 300 mm		
		To find : $(\sigma_b)_{max}$		
		Solution :		
		$BM_{max} = M_{max} = \frac{Wab}{L} = \frac{20\times2\times3}{5} = 24\ kNm = 24\times10^6\ Nmm$	½	
		$I = \frac{bd^3}{12} = \frac{200\times300^3}{12} = 450\times10^6\ mm^4$	1	
		$y = \frac{d}{2} = \frac{300}{2} = 150\ mm$	½	
		By using flexural equation		
		$\frac{M}{I} = \frac{\sigma}{y}$	½	
		$\sigma = \frac{M\times y}{I} = \frac{24\times10^6\times150}{450\times10^6} = 8\ N/mm^2$		
		$(\sigma_b)_{max} = 8\ MPa$	1	4

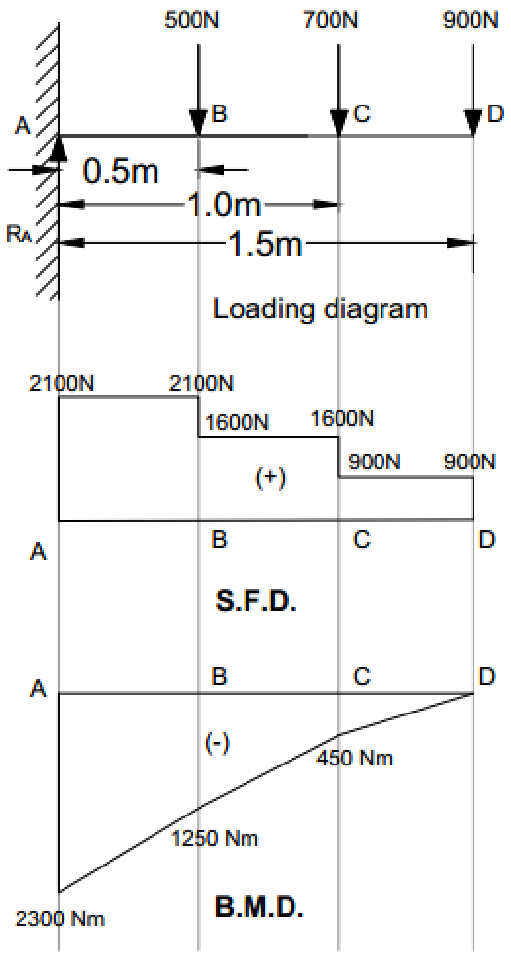
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2		**Attempt any FOUR of the following :**		16
	(a) Ans.	**(i) Define composite section and modular ratio.** **Composite Section:** If two or more members of different materials are connected together and are subjected to loads, then such section is called composite section.	1	
		Modular Ratio (m): It is defined as the ratio of modulii of the two different materials. $m=\frac{E_1}{E_2}$ Where, E_1 = Modulus of elasticity of material 1 E_2 = Modulus of elasticity of material 2	1	
		(ii) State equivalent length for column which is fixed at one end and hinged at other. Equivalent length for column which is fixed at one end and hinged at other is given by $l_e = \frac{L}{\sqrt{2}}$	2	4
	(b) Ans.	**A column fixed at one end and free at other has effective length of 6 m. Calculate its actual length.** Given : Column is fixed at one end and free at other end, l_e = 6m To find : L Solution : $l_e = 2 \times L$	2	
		$6 = 2 \times L$ $L = \frac{6}{2} = 3\,m$ $\text{Actual length} = 3\,m$	2	4
	(c) Ans.	**A steel rod 12 mm dia and 2.2 m in length is at 40° C. Find expansion of rod if the temperature is raised to 110° C. If this expansion is fully prevented, find the magnitude and nature of the stress induced in the rod.** **Take E= 2.1 x 10^5 N/mm^2 and α = 12 x 10^{-6} / ° C.** Given : d =12 mm, L = 2.2 m, T_1= 40° C, T_2= 110° C, E= 2.1 x 10^5 N/mm^2 and α = 12 x 10^{-6} / ° C To find : δL, σ, Nature of stress		

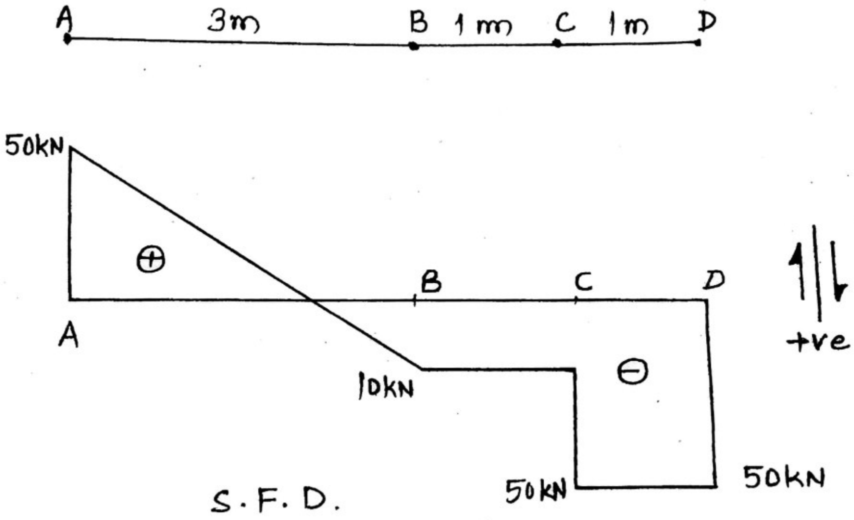
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2		Solution : Free expansion $\delta L = L \times \alpha \times T = L \times \alpha \times (T_2 - T_1)$ $= 2.2 \times 10^3 \times 12 \times 10^{-6} \times (110-40)$ $= 1.848\,mm$	1 1	
		If the expansion is prevented, compressive stress is developed in the steel rod. Compressive stress (σ) $\sigma = \alpha \times T \times E$ $= \alpha \times (T_2 - T_1) \times E$ $= 12 \times 10^{-6} \times \times (110-40) \times 2.1 \times 10^5$ $= 176.40\,N/mm^2$ (Compressive)	1 1	4
	(d)	**A metal rod of 20 mm diameter and 1.8 m long when subjected to an axial tensile force of 58 kN showed an elongation of 2.2 mm and reduction in diameter was 0.006 mm. Calculate Poisson's ratio and modulus of Elasticity.**		
	Ans.	Given : d =20 mm, L = 1.8 m, P = 58 kN, δ_L=2.2 mm, δ_d = 0.006mm To find : μ, E Solution : $E = \frac{P \times L}{A \times \delta L} = \frac{58 \times 10^3 \times 1.8 \times 10^3}{\left(\frac{\pi}{4} \times (20)^2\right) \times 2.2}$ $= 151052.51\,N/mm^2$ $E = 1.51 \times 10^5\,N/mm^2$	1 1	
		$\mu = \frac{\text{Lateral Strain}}{\text{Linear Strain}} = \left(\frac{\left(\frac{\delta_d}{d}\right)}{\left(\frac{\delta_L}{L}\right)}\right) = \left(\frac{\left(\frac{0.006}{20}\right)}{\left(\frac{2.2}{1800}\right)}\right)$ $\mu = 0.245$	1 1	4

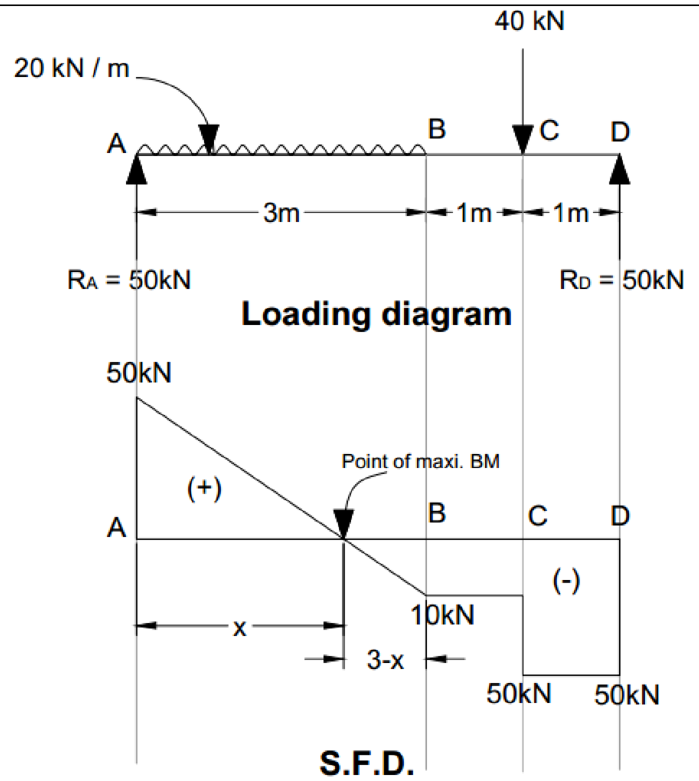
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2	(e)	**At a point, the normal stress 'σ' is associated with a shearing stress 'q'. If the principal stresses at the point are 80 MPa (tensile) and 30 MPa (compressive), determine values of 'σ' and 'q'.**		
	Ans.	$\sigma_{n_1}=\frac{\sigma_x}{2}+\sqrt{\left(\frac{\sigma_x}{2}\right)^2+q^2}$		
		$80=\frac{\sigma_x}{2}+\sqrt{\left(\frac{\sigma_x}{2}\right)^2+q^2}$ -----(i)	1	
		$\sigma_{n_2}=\frac{\sigma_x}{2}-\sqrt{\left(\frac{\sigma_x}{2}\right)^2+q^2}$		
		$-30=\frac{\sigma_x}{2}-\sqrt{\left(\frac{\sigma_x}{2}\right)^2+q^2}$ -----(ii)	1	
		Adding equation (i) and (ii)		
		$80-30=\left[\frac{\sigma_x}{2}+\sqrt{\left(\frac{\sigma_x}{2}\right)^2+q^2}\right]+\left[\frac{\sigma_x}{2}-\sqrt{\left(\frac{\sigma_x}{2}\right)^2+q^2}\right]$		
		$50=2\times\left(\frac{\sigma_x}{2}\right)=\sigma_x$		
		$\sigma_x=50\ N/mm^2$	1	
		Substituting the value of σ_x in equation (i)		
		$80=\frac{50}{2}+\sqrt{\left(\frac{50}{2}\right)^2+q^2}$		
		$80-25=\sqrt{(25)^2+q^2}$		
		$(55)^2=(25)^2+q^2$		
		$q^2=(55)^2-(25)^2=2400$		
		$q=48.99\ N/mm^2$	1	4

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2	(f)	**A cylindrical shell is 4 m long with internal diameter 900 mm and thickness 10 mm. If the tensile stress in the material is not to exceed 54 MPa, determine the maximum fluid pressure which can be allowed in shell.**		
	Ans.	Given : L = 4 m, d = 900 mm, t = 10 mm, σ = 54 MPa To find : P_{max} Solution :		
		$\sigma_c = \frac{P\times d}{2\times t}$	2	
		$54 = \frac{P\times 900}{2\times 10}$ $P = 1.2 N/mm^2$ Allowable maximum fluid pressure $= 1.2 N/mm^2$	2	4
Q. 3		**Attempt any FOUR of the following :**		16
	(a)	**A simply supported beam of span 'L' is subjected to downward point load of 'w' at a distance of 'a' from left support and 'b' from right support. Draw S.F. and B.M. diagrams. Take a > b.**		
	Ans.	i) Support reactions $R_A = \frac{Wb}{L}$ $R_B = \frac{Wa}{L}$ ii) Shear force reactions S.F. at A = + $\frac{Wb}{L}$ $C_L = + \frac{Wb}{L}$ $C_R = + \frac{Wb}{L} - W = - \frac{Wa}{L}$ $B_L = - \frac{Wa}{L}$ $B = - \frac{Wa}{L} + \frac{Wa}{L} = 0$ (∴ OK)	1	
		iii) Bending Moment calculations BM at A and B is equal to zero (Supports are simple) BM at C = $+\frac{Wb}{L} \times a = \frac{Wab}{L}$	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3			1 1	4
	(b) Ans.	**State relation between rate of loading, shear force and bending moment.** a) Relation between rate of loading and shear force $$\frac{dF}{dx} = W$$ The rate of change of shear force with respect to the distance is equal to the intensity of loading. b) Relation between shear force and bending moment. $$\frac{dM}{dx} = F$$ The rate of change of bending moment at any section is equal to the shear force at that section with respect to the distance.	2 2	4
	(c)	**A cantilever AD, 1.5 m long, carries point loads of 500 N, 700 N and 900 N at 0.5 m, 1.0 m and 1.5 m from fixed end 'A' respectively. Draw S.F. and B. M. diagrams for cantilever. Neglect self weight of the beam.**		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3	Ans.	i) Support Reaction calculations $\Sigma Fy = 0$ $\therefore$ RA – 500 – 700 – 900 = 0 $\therefore$ RA = 2100 N ii) Shear Force calculations SF at A = +2100 N B_L = +2100 N B_R = +2100 – 500 = +1600 N C_L = +1600 N C_R = +1600 – 700 = +900 N D_L = +900 N D = +900 – 900 = 0 ($\therefore$ OK)	1	
		iii) Bending Moment calculations BM at free end (i.e. at 'D') = 0 BM at C = - (900 x 0.5) = - 450 Nm B = - (900 x 1) – (700 x 0.5) = - 1250 Nm A = - (900 x 1.5) – (700 x 1) – (500 x 0.5) = -2300 Nm	1	
			1 1	4

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3	(d)	**Figure No. 1 shows a shear force diagram for a simply supported beam ABCD of span 5m. Draw loading diagram and locate the position from support 'A' where bending moment will be maximum. (There is no couple acting on the beam)**		
	Ans.	 **Fig. No. 1**		
		(i) At A : The SF increases from 0 to 50 kN therefore R_A = 50 kN. (ii) Between A to B : The SF diagram is an inclined straight line in 3 m length, indicating that the beam carries udl between A to B. AB having intensity = $\left[\frac{50-(-10)}{3}\right]$=20kN/m	2	
		(iii) Between BC, the SF remains constant therefore there is no load. (iv) At C : There is sudden drop from (-10 kN) to (-50kN). Therefore there is a point load of $\left[(-10)-(-50)\right]$=40kN	1	
		(v) Position of maximum bending moment from support 'A' Let 'x' be the distance of point of maximum bending moment from support 'A'. Maximum bending moment occurs at point of contrashear. SF equation at point of contrashear is $50 = 20\times x$ $x = 2.5$ m Maximum Bending Moment at 2.5m from support 'A'.		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3			1	4

(e) **A simply supported beam ABC is supported at 'A' and 'B' 5 m apart with an overhang BC 1.5 m long, carries uniformly distributed load of 10 kN/m over AB and downward point load of 20 kN at 'C'. Draw S.F. and B.M. diagrams. State the value of maximum positive B.M. Calculations for point of contraflexure not expected.**

Ans.

i) Support Reaction calculations

ΣMA = 0

∴ (RA x 0) + (50x2.5) – (RBx5) + (20x6.5) = 0

∴ 0 + 125 - 5 RB + 130 = 0

∴ 255 - 5 RB = 0

∴ RB = 51 kN

ΣFy = 0

∴ RA – 50 + RB – 20 = 0

∴ RA – 50 + 51 – 20 = 0

∴ RA = 19 kN

ii) Shear Force calculations

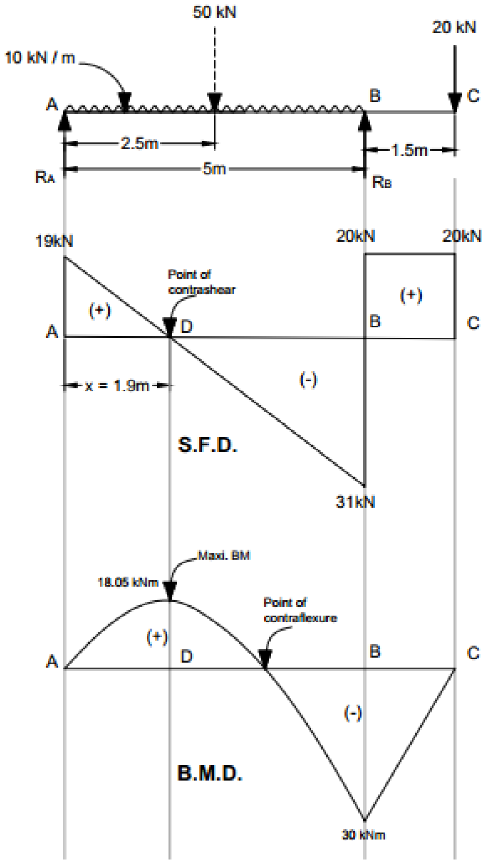
SF at A = +19 kN

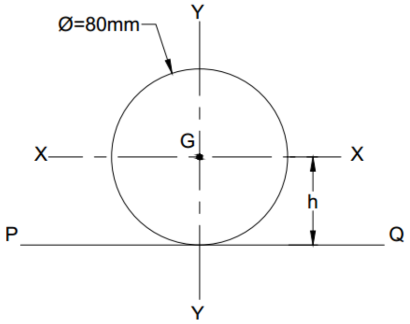
B_L = +19 – 50 = - 31 kN

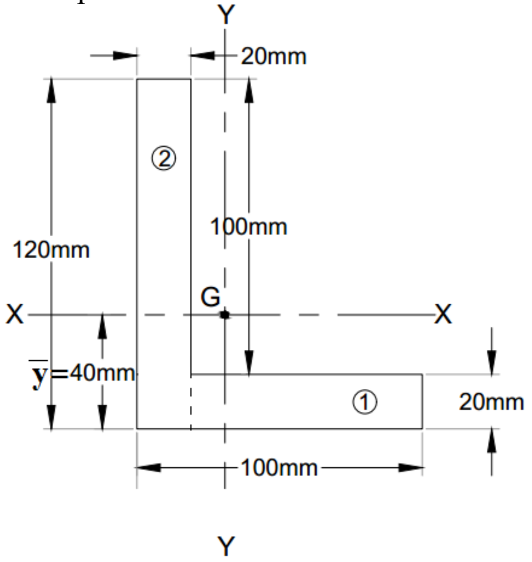
B_R = -31 + 51 = + 20 kN

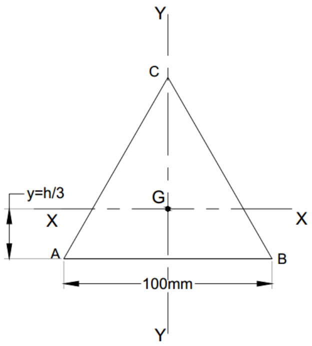
C_L = +20 kN

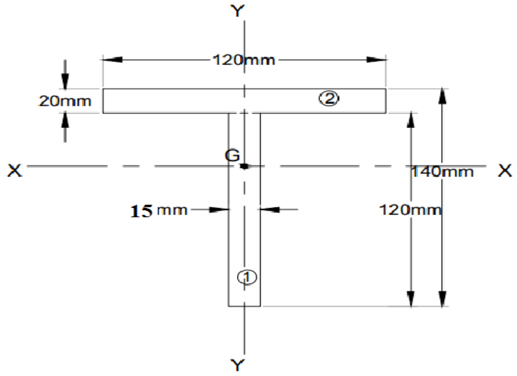
C = +20-20 = 0 (∴ OK) — **1**

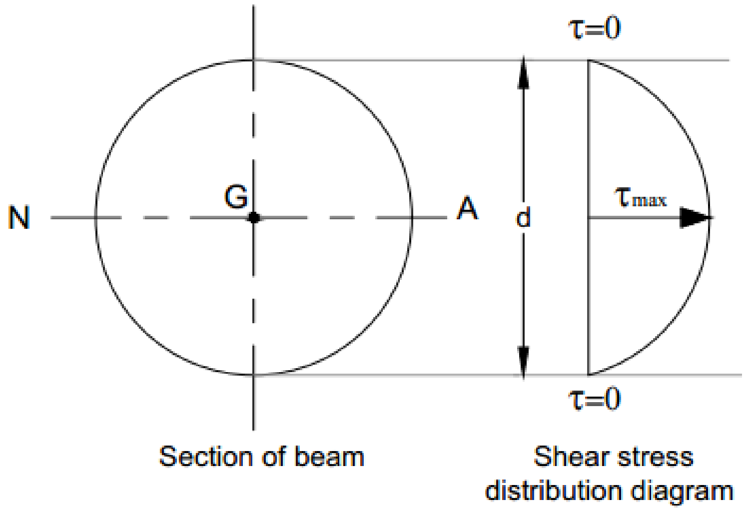
		iii) Bending Moment calculations BM at 'A' and 'C' = 0 ($\because A$ is simple support and C is free end) BM at B = - (20x1.5) = - 30 kNm iv) Maximum Bending Moment Maximum bending moment occurs at point of contrashear. Let AD = x , where 'D' is point of contrashear at which maximum positive bending moment occurs. SF equation at D is 19 = 10x x = 1.9m from support 'A' $M_D = M_{max} = +(19x1.9) – (10x1.9x1.9/2)$ $= 36.1 – 18.05$ $= 18.05$ kNm	1	
			1 1	4

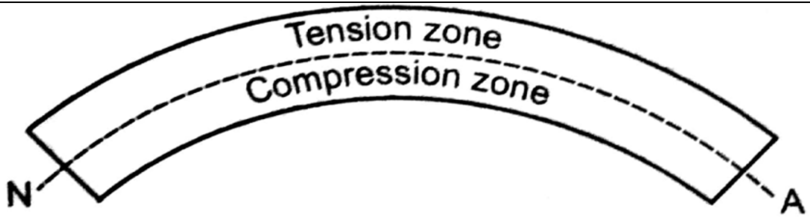
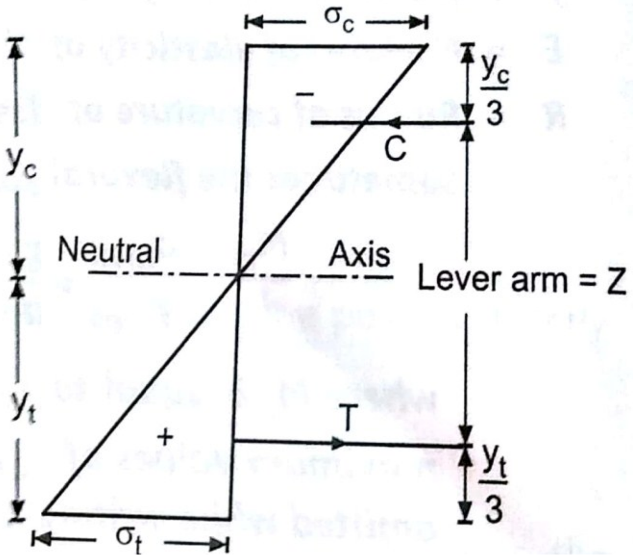
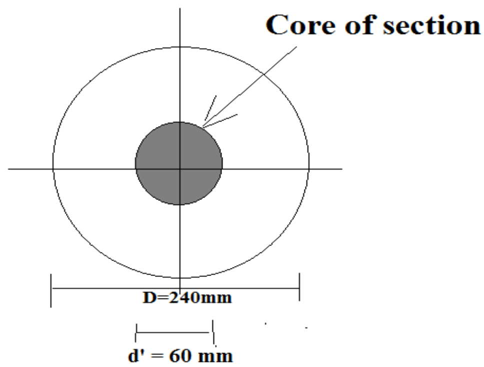
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3	(f) Ans.	**A circular disc has diameter of 80 mm. Calculate moment of inertia about its any one tangent.** Let tangent PQ parallel to centroidal x-x axis  According to parallel axis theorem $I_{PQ} = I_G + Ah^2$	1	
		$I_{PQ} = I_{xx} + Ah^2$		
		$= \frac{\pi}{64}d^4 + \left(\frac{\pi}{4}d^2\right)\left(\frac{d}{2}\right)^2$	1	
		$= \frac{\pi}{64}80^4 + \left(\frac{\pi}{4}80^2\right)\left(\frac{80}{2}\right)^2$	1	
		$= 10.049 \times 10^6\ mm^4$	1	4

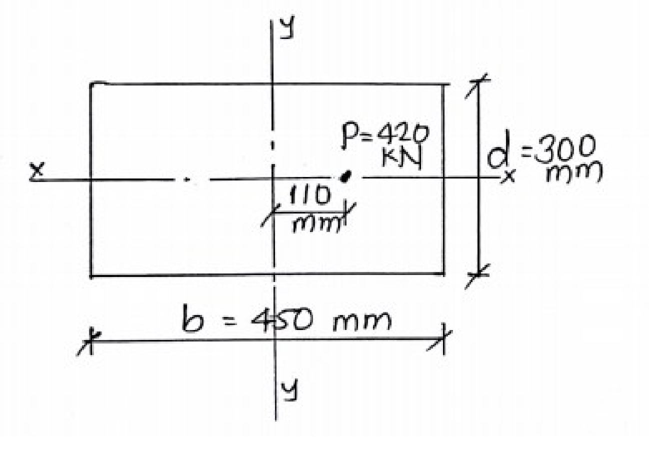
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4		**Attempt any FOUR of the following :**		**16**
	(a)	**An angle section 120 mm x 100 mm x 20 mm is placed such as its longer leg is vertical. Calculate M.I. about centroidal horizontal axis only (i.e. I_{xx} only).**		
	Ans.	i) To find the position of Centroid 		
		$A_1 = 80 \times 20 = 1600\ mm^2$ $y_1 = 10\ mm$		
		$A_2 = 20 \times 120 = 2400\ mm^2$ $y_2 = 120/2 = 60\ mm$		
		$\overline{Y} = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2} = \frac{1600\times10 + 2400\times60}{1600+2400} = 40\ mm$	1	
		ii) Moment of Inertia $I_{XX} = (I_{XX})_1 + (I_{XX})_2$		
		$I_{XX} = \left[\frac{bd^3}{12} + Ah^2\right]_1 + \left[\frac{bd^3}{12} + Ah^2\right]_2$	1	
		$I_{XX} = \left[\frac{80\times20^3}{12} + 1600\times(40-10)^2\right]_1 + \left[\frac{20\times120^3}{12} + 2400\times(60-40)^2\right]_2$	1	
		$I_{XX} = [1493333.333]_1 + [3840000]_2$ $I_{XX} = 5.33\times10^6\ mm^4$	1	4

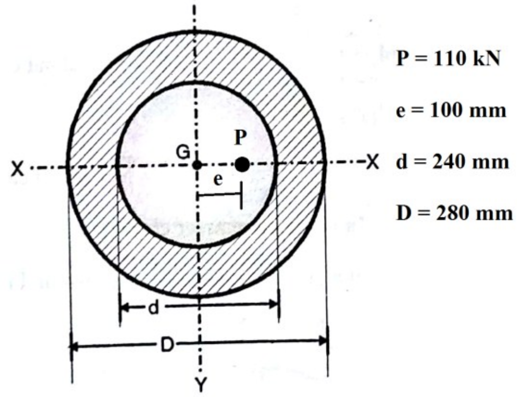
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4	(b)	**Define polar moment of inertia. Also state perpendicular axis theorem of M.I.**		
	Ans.	**Polar Moment of Inertia:** The moment of inertia of a plane area about an axis perpendicular to the plane of the figure is called polar moment of inertia with respect to the point, where the axis intersects the plane. $I_P = I_{zz}$ $I_P = I_{xx} + I_{yy}$	2	
		Perpendicular axis theorem: It states that "if I_{xx} and I_{yy} are the moments of inertia of a plane section about the two mutually perpendicular axes, then moment of inertia of I_{zz} about the third axis z-z perpendicular to the plane and passing through the intersection of x-x and y-y axes. $I_{zz} = I_{xx} + I_{yy}$	2	4
	(c) Ans.	**An equilateral triangle has base of 100 mm. Using parallel axis theorem, calculate its M.I. about base.**		
		 		
		Height of triangle (h) h = 100 sin60° = 86.60mm y = h/3 = 86.60 / 3 = 28.87mm	½ ½	
		According to the parallel axis theorem $I_{base} = I_G + Ay^2$ $= \frac{bh^3}{36} + \left(\frac{1}{2}bh\right)y^2$	1	
		$= \frac{100 \times 86.60^3}{36} + \left(\frac{1}{2} \times 100 \times 86.60\right) \times 28.87^2$	1	4
		$= 5.42 \times 10^6 \text{ mm}^4$	1	

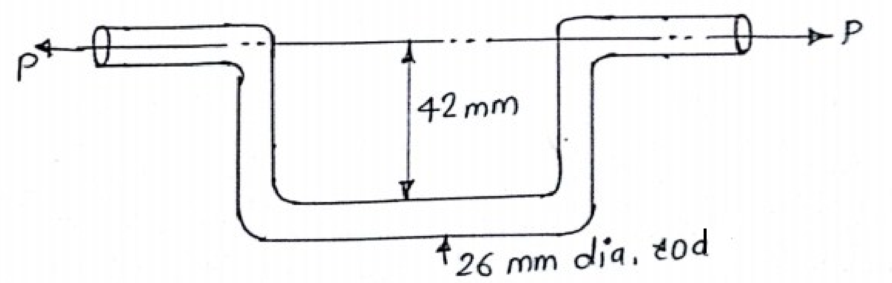
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4	(d)	**A T-section has flange 120 mm x 20 mm and web 15 mm x 120 mm, overall depth 140 mm. Calculate M.I. about its vertical centroidal yy axis. (i.e. I_{yy} only).**		
	Ans.			
		As the given composite section is symmetrical about y-y axis Moment of Inertia about yy axis $I_{YY} = (I_{yy})_1 + (I_{yy})_2$		
		$= \left(\frac{db^3}{12}\right)_1 + \left(\frac{db^3}{12}\right)_2$	1	
		$= \left(\frac{120\times15^3}{12}\right)_1 + \left(\frac{20\times120^3}{12}\right)_2$	1	
		$= (2880000)_1 + (33750)_2$	1	
		$I_{YY} = 2.913 \times 10^6 \text{ mm}^4$	1	4
	(e) Ans.	**State four assumptions made in theory of simple bending.** 1. The martial of the beam homogeneous and isotropic i.e. the beam made of the same material throughout and it has the elastic properties in all the directions. 2. The beam is straight before loading and is of uniform cross section throughout. 3. The beam material is stressed within its elastic limit and this obeys Hooke's law . 4. The transverse sections which where plane before bending remain plane after bending. 5. The beam is subjected to pure bending i.e. the effect of shear stress is totally neglected. 6. Each layer of the beam is free to expand or contact independently of the layer above or below it. 7. Young's modulus E for the material has the same value in tension and compression.	1 each (any four)	4

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4	(f)	**Draw shear stress distribution diagram for circular beam section. State the formula to calculate average shear stress for circular section having diameter 'd'.**		
	Ans.		2	
		Average shear stress for circular section – $\tau_{avg} = \frac{S}{A} = \frac{S}{\frac{\pi}{4}d^2}$	2	4
		OR $\tau_{max} = \frac{4}{3}\tau_{avg}$ $\tau_{avg} = \frac{3}{4}\tau_{max}$	2	
Q. 5		**Attempt any FOUR of the following :**		16
	(a)	**With reference to theory of simple bending, explain neutral axis and moment of resistance.**		
	Ans.	**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.	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5			1	
		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.	1	
			1	4
	(b)	**Calculate diameter of core of section for circular column section having diameter of 240 mm. Using basic principles draw neat sketch for the same with dimensions. (Do not use direct formula)**		
	Ans.	Given : Diameter of circular column = 240 mm To find: Diameter of core of section.		
			½	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5		Solution :		
		$A=\frac{\pi}{4}\times d^2=\frac{\pi}{4}\times(240)^2=45238.9342\,mm^2$	½	
		$I=\frac{\pi}{64}\times d^4=\frac{\pi}{64}\times(240)^4=162860163.20\,mm^4$	½	
		$y=\frac{d}{2}=\frac{240}{2}=120\,mm$		
		$Z=\frac{I}{y}=\frac{162860163.20}{120}=1357168.026\,mm^3$	½	
		For no tension condition		
		Direct stress = Bending stress	1	
		$\sigma_0=\sigma_b$		
		$\frac{P}{A}=\frac{M}{Z}$		
		$\frac{P}{A}=\frac{P\times e}{Z}$		
		$e=\frac{Z}{A}$		
		$e=\frac{1357168.026}{45238.9342}$		
		$e=30\,mm$		
		Diameter of core of section is		
		$d'=2\times e=2\times 30$	1	4
		$d'=60\,mm$		
	(c)	**A rectangular column 450 mm wide and 300 mm thick carries a load of 420 kN at an eccentricity of 110 mm in the plane bisecting the thickness. Calculate maximum and minimum stress intensities at the base along with their nature.**		
	Ans.			

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5	Ans.	Given: P = 420 kN, b = 450 mm, d = 300 mm, e = 110 mm To find : σ_{max} and σ_{min} at base along with their nature Solution :		
		Direct stress $(\sigma_0) = \frac{P}{A} = \frac{P}{b \times d}$	½	
		$= \frac{420 \times 10^3}{450 \times 300}$ $= 3.111 \text{ N/mm}^2$	½	
		$M = P \times e = 420 \times 10^3 \times 110 = 46.20 \times 10^6$ Nmm	½	
		$I_{yy} = \frac{d \times b^3}{12} = \frac{300 \times 450^3}{12} = 2278125000 \text{ mm}^4$	½	
		$y = \frac{b}{2} = \frac{450}{2} = 225 \text{ mm}$ $Z = \frac{I}{y} = \frac{2278125000}{225} = 10125000 \text{ mm}^3$	½	
		Bending stress $(\sigma_b) = \pm \frac{M}{Z} = \pm \frac{46.20 \times 10^6}{10125000} = \pm 4.563 \text{ N/mm}^2$	½	
		$\sigma_{max} = \sigma_0 + \sigma_b = 3.111 + 4.563$ $\sigma_{max} = 7.674 \text{ N/mm}^2$ (C)	½	
		$\sigma_{min} = \sigma_0 - \sigma_b = 3.111 - 4.563$ $\sigma_{min} = 1.4519 \text{ N/mm}^2$ (T)	½	4
	(d)	**A hollow circular column having external and internal diameters 280 mm and 240 mm respectively is subjected to an eccentric vertical load of 110 kN at an eccentricity of 100 mm. Calculate maximum and minimum intensities of stress across the section.**		
	Ans.			

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5	Ans.	Given : D = 280 mm, d = 240 mm, e = 100 mm, P = 110 kN To find : σ_{max} and σ_{min} across the section Solution : Direct stress $(\sigma_0) = \frac{P}{A} = \frac{P}{\frac{\pi}{4}\left(D^2 - d^2\right)}$	½	
		$= \frac{110\times10^3}{\frac{\pi}{4}\left(280^2 - 240^2\right)}$ $= 6.733\ \text{N/mm}^2$	½	
		Bending stress $(\sigma_b) = \pm\frac{M}{Z}$		
		$M = P\times e = 110\times10^3\times100 = 11\times10^6$ Nmm	½	
		$I = \frac{\pi}{64}\left(D^4 - d^4\right) = = \frac{\pi}{64}\left(280^4 - 240^4\right) = 138858395.3\ \text{mm}^4$	½	
		$y = \frac{D}{2} = \frac{280}{2} = 140\ \text{mm}$		
		$Z = \frac{I}{y} = \frac{138858395.3}{140} = 991845.6806\ \text{mm}^3$	½	
		$(\sigma_b) = \pm\frac{M}{Z} = \pm\frac{11\times10^6}{991845.6806} = \pm11.09\ \text{N/mm}^2$	½	
		$\sigma_{max} = \sigma_0 + \sigma_b = 6.733 + 11.09$ $\sigma_{max} = 17.823\ \text{N/mm}^2$ (C)	½	
		$\sigma_{min} = \sigma_0 - \sigma_b = 6.733 - 11.09$ $\sigma_{min} = 4.357\ \text{N/mm}^2$ (T)	½	4
	(e)	**A 26 mm diameter rod is bentup to form as offset link as shown in Figure No. 2. If permissible tensile stress is 90 N / mm², calculate maximum value of 'P'.**		
	Ans.	Figure No. 2.		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5	Ans.	Given : d = 26 mm, σ_{max} = 90 N/mm^2 To find : P_{max} Solution : $\text{C/S area of section (A)} = \frac{\pi}{4}\times d^2 = \frac{\pi}{4}\times 26^2 = 530.929\ mm^2$	½	
		$\text{M.I. of section (I)} = \frac{\pi}{64}\times d^4 = \frac{\pi}{64}\times 26^4 = 22431.756\ mm^4$	½	
		$\text{Eccentricity (e)} = 42 + \frac{d}{2} = 42 + \frac{26}{2} = 55\ mm$ $\text{Maximum distance from neutral axis (y)} = \frac{d}{2} = \frac{26}{2} = 13\ mm$	½	
		$\text{Section Modulus (Z)} = \frac{I}{y} = \frac{22431.756}{13} = 1725.52\ mm^3$	½	
		$\text{Direct stress } (\sigma_0) = \frac{P}{A} = \frac{P}{530.929} = \left(1.8835\times 10^{-3}\right)P$	½	
		$\text{Bending stress } (\sigma_b) = \pm\frac{M}{Z} = \pm\frac{P\times e}{Z} = \pm\frac{P\times 55}{1725.52} = \pm(0.03187)P$	½	
		$\sigma_{max} = \sigma_0 + \sigma_b$ $90 = \left(1.8835\times 10^{-3}\right)P + (0.03187)P$ $90 = (0.03375)P$	½	
		$P = 2666.39\ N$ $P_{max} = 2.66\ kN$	½	4
	(f)	**Calculate maximum eccentricity for a hollow circular section having external diameter and internal diameter equal to 250 mm and 120 mm respectively, so that stress distribution is of same nature.**		
	Ans.	Given : D = 250 mm, d = 120 mm To find : e_{max} Solution : $A = \frac{\pi}{4}\left(D^2 - d^2\right) = \frac{\pi}{4}\left(250^2 - 120^2\right) = 37777.65\ mm^2$	½	
		$I = \frac{\pi}{64}\left(D^4 - d^4\right) = \frac{\pi}{64}\left(250^4 - 120^4\right) = 181568838.3\ mm^4$	½	
		$y = \frac{D}{2} = \frac{250}{2} = 125\ mm$	½	
		$Z = \frac{I}{y} = \frac{181568838.3}{125} = 1452550.706\ mm^3$ For stress distribution of same nature i.e. for no tension condition	½	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5		Direct stress = Bending stress	½	
		$\sigma_0 = \sigma_b$		
		i.e. $e \le \frac{Z}{A}$	½	
		$e = \frac{1452550.706}{37777.65}$	½	
		$e = 38.45\,mm$		
		$e_{max} = 38.45\,mm$	½	4
Q. 6		**Attempt any FOUR of the following :**		16
	(a)	**State torsional equation with meaning of each term.**		
	Ans.	**Torsion Equation: -**		
		$\frac{T}{I_P} = \frac{C\,\theta}{L} = \frac{f_s}{R}$	2	
		Where,		
		T = Torque Or Turning moment (N.mm)		
		I_P = Polar momet of inertia of the shaft section = $I_{xx} + I_{yy}$		
		C= Modulus of rigidity of the shaft material (N/mm^2)		
		θ = Angle through which the shaft is twisted due to torque i.e. angle of twist (radians)		
		L= Lenght of the shaft (mm)	2	4
		f_s = Maximum shear stress induced at the outermost layer of the shaft (N/mm^2)		
		R= Radius of the shaft (mm)		
	(b)	**A shaft required to transmit 25 kW power at 180 r.p.m. The maximum torque may exceed the mean torque by 30%. If shear stress is not to exceed 60 N/mm², determine the minimum diameter of the shaft.**		
	Ans.	Given : P = 25 kW = 25 x 10^3 Watt, N = 180 rpm, T_{max} = 1.3 T_{mean}, $q_{max} = 60\ N/mm^2$		
		To find : Diameter of shaft		
		Solution :		
		$P = \frac{2\times\pi\times N\times T_{mean}}{60}$	½	
		$25\times10^3 = \frac{2\times\pi\times180\times T_{mean}}{60}$		
		$T_{mean} = 1326.29Nm$	½	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6		$T_{max} = 1.3 \times T_{mean}$	½	
		$= 1.3 \times 1326.29$		
		$= 1724.178 Nm$		
		$= 1724178.55 Nmm$	½	
		$T_{max} = \frac{\pi}{16} \times q_{max} \times d^3$	1	
		$1724178.55 = \frac{\pi}{16} \times 60 \times d^3$		
		$d = 52.7 mm$	1	4
	(c)	**A solid circular shaft of 30 mm diameter is subjected to torque of 0.28 kNm, causing angle of twist of 3.50° in a length of 2 m. Calculate modulus of rigidity for the material of shaft.**		
	Ans.	Given : d = 30 mm, T = 0.28 kNm= 0.28 x 10^6 Nmm,		
		L = 2 m = 2000 mm,		
		$\theta = 3.50° = \left(3.5 \times \frac{\pi}{180}\right) rad = 0.06108$		
		To find : G		
		Solution :		
		$I_P = \frac{\pi}{32} \times d^4$	½	
		$= \frac{\pi}{32} \times 30^4$		
		$= 79521.564\, mm^4$	½	
		Using torsional formula,		
		$\frac{T}{I_P} = \frac{G \times \theta}{L}$	1	
		$G = \frac{T \times L}{I_P \times \theta}$		
		$= \frac{0.28 \times 10^6 \times 2 \times 10^3}{79521.564 \times 3.5 \times \frac{\pi}{180}}$	1	
		$= 115281\, N/mm^2$		
		$G = 1.15281 \times 10^5\, N/mm^2$	1	4
	(d)	**Compare the torsional strengths of two shafts A and B, made up of same material having equal weight and length. Shaft A is solid and B is hollow circular with D = 1.6 d.**		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6	Ans.	Given: D = 1.6 d To compare the torsional strength of two shafts A and B Solution : As the material of shaft A and B is same their shear strengths are same. As their lengths and weights are same their cross sectional areas will be same. Let d' be the diameter of solid shaft. D and d be the external and internal diameters of hollow such that D=1.6d. Area of (solid) shaft A = Area of (hollow) shaft B $\frac{\pi}{4}d'^2 = \frac{\pi}{4}\left[D^2 - d^2\right]$ $d'^2 = \left[(1.6d)^2 - d^2\right]$ $d'^2 = \left[2.56 - 1\right]d^2$ $d'^2 = 1.56d^2$ $d' = \sqrt{1.56d^2}$ $\boxed{d' = 1.25d}$	1	
		Torsional strength for solid shaft A, $T_A = \frac{\pi}{16}\times q\times d'^3$ $= \frac{\pi}{16}\times q\times (1.25d)^3$ $T_A = (1.953125)\frac{\pi}{16}\times q\times d^3 ---------(1)$	1	
		Torsional strength for hollow shaft B, $T_B = \frac{\pi}{16}\times q\times\left(\frac{D^4 - d^4}{D}\right)$ $= \frac{\pi}{16}\times q\times\left(\frac{(1.6\times d)^4 - d^4}{(1.6\times d)}\right)$ $= \frac{\pi}{16}\times q\times\left(\frac{(1.6)^4 - (1)^4}{(1.6)}\right)\times\frac{d^4}{d}$ $= \frac{\pi}{16}\times q\times 3.471\times d^3$ $= 3.471\times\left(\frac{\pi}{16}\times q\times d^3\right) ---------(2)$	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.6	(d)	From equation 1 and 2 $\frac{T_B}{T_A}=\frac{(3.471)\times\left(\frac{\pi}{16}\times q\times d^3\right)}{(1.953125)\times\left(\frac{\pi}{16}\times q\times d^3\right)}$ $\frac{T_B}{T_A}=\frac{(3.471)}{(1.953125)}=1.78$ The torsional strength of shaft B (hollow shaft) is 78% greater than that of shaft B (solid shaft) of same material and same cross sectional area.	1	4
	(e)	**A hollow shaft, having external diameter 1.5 times the internal diameter, is to transmit 150 kW at 200 r.p.m. If allowable angle of twist is 2° in a length of 3 m. Calculate diameters of the shaft. Take T_{max} = 1.2 T_{mean}. G = 80 GPa.** Given : D = 1.5 d, P = 150 kW = 150 x 10^3 Watt, N = 200 rpm, L = 3 m = 3000 mm, T_{max} = 1.2 x T_{mean}, G = 80 GPa = 80 x 10^3 N/mm^2, $\theta=2°=\left(2\times\frac{\pi}{180}\right)=0.0349\text{rad}$ To find : d and D Solution :		
		$P=\frac{2\times\pi\times N\times T_{mean}}{60}$	½	
		$150\times10^3=\frac{2\times\pi\times200\times T_{mean}}{60}$ $T_{mean}=7161.972439\text{ Nm}$	½	
		$T_{max}=1.2\times T_{mean}$ $=1.2\times7161.972439$ $=8594.366\text{ Nm}$ $=8594366.927\text{ Nmm}$	½	
		Using relation based on angle of twist $\frac{T}{I_p}=\frac{G\times\theta}{L}$	½	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6				

$$I_P = \frac{\pi}{32} \times (D^4 - d^4)$$

$$= \frac{\pi}{32} \times \left[(1.5d)^4 - d^4)\right]$$

$$= \frac{\pi}{32} \times \left[(1.5)^4 - (1^4)\right] d^4$$

$$I_P = (0.398835) d^4$$ — ½

$$\frac{T}{I_p} = \frac{G \times \theta}{L}$$

$$\frac{8594366.927}{(0.398835)d^4} = \frac{80 \times 10^3 \times 0.0349}{3000}$$ — ½

$$d^4 = \frac{8594366.927 \times 3000}{(0.398835) \times 80 \times 10^3 \times 0.0349}$$

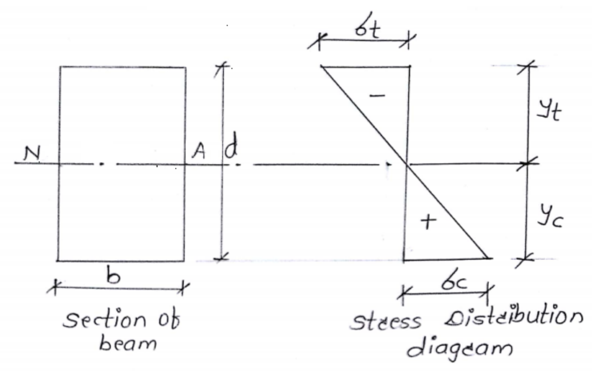
$$d = 69.367\,mm$$ — ½

$$D = 1.5 \times d$$

$$= 1.5 \times 69.367$$

$$= 104.05\,mm$$ — ½ — Total: 4

(f) **(i) Draw bending stress distribution for rectangular beam section which is used for cantilever beam, subjected to downward load.**



— 2

(ii) Define torque and state its S.I. unit.

Torque: When a tangential force is applied to a shaft at the circumference, in the plane of its transverse cross-section, the shaft is said to be subjected to a twisting moment called torque. — 1

Torque = Force x Radius

S. I. Unit - Nm — 1 — Total: 4