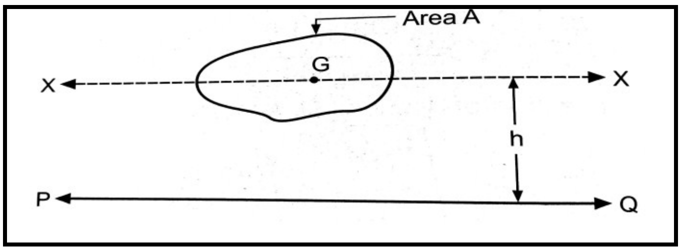
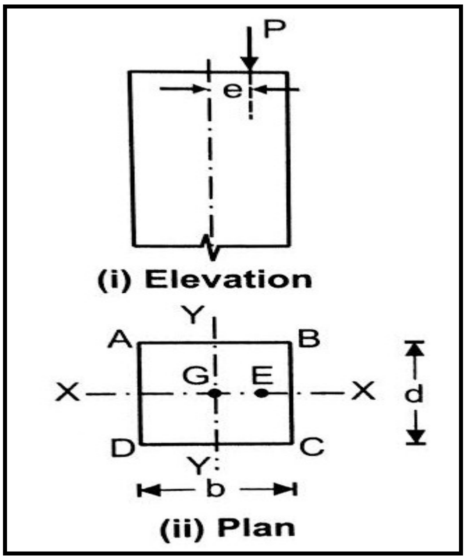
Model Answer: Summer 2017

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.

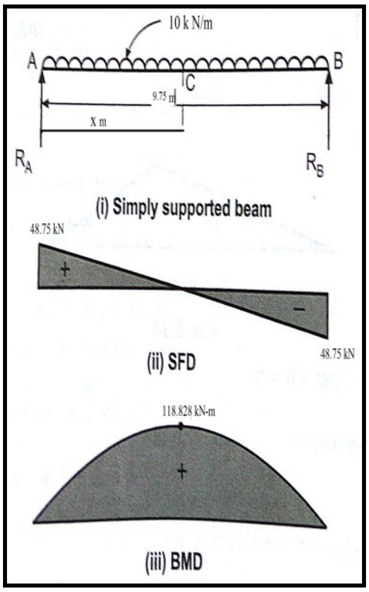
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q 1	a)	**Attempt any SIX of the following:**		12
	i)	**Define elasticity and modulus of elasticity.**		
	Ans.	**Elasticity: -** Elasticity is the property of material by virtue of it can regain its original shape and size after removal of deforming force.	01	02
		Modulus of Elasticity: - It is defined as the ratio of stress to strain within elastic limit.	01	
	ii)	**Define angle of 'obliquity'.**		
	Ans.	**Angle of 'Obliquity' : -** The angle that the line of action of the resultant stress makes with the normal to the plane is called the angle of obliquity	02	02
	iii)	**State the parallel axis theorem.**		
	Ans.	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. 	02	02

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1		MI @ AB $I_{AB} = I_G + Ah^2$		
	iv)	**What do you mean by eccentric load? Show by simple sketch eccentrically applied load.**		
	Ans.	**Eccentric load: -** The load whose line of action does not coincide with the axis of the member is called as eccentric load.	01	02
			01	
	v)	**State any four assumptions made in the theory of pure torsion.**		
	Ans.	**Assumptions in the Theory of Pure Torsion.** 1. The material of the shaft is homogenous and isotropic and follows Hook's law. 2. The twist along the shaft is uniform. 3. The shaft is straight and having uniform circular cross section throughout. 4. Cross sections of the shaft which are plane before twist remain plane after twist. 5. Stresses do not exceed the proportional limit.	**½ mark each (Any four)**	02

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1	**vi)**	**Define bulk modulus.**		
	Ans.	**Bulk Modulus: -**		
		When a body is subjected to three mutually perpendicular like stresses of same intensity then the ratio of direct stress to the corresponding volumetric strain of the body is constant and is called as bulk modulus.	**02**	**02**
	vii)	**Define hoop stress. State the formula.**		
	Ans.	Hoop stress the stress which act in the tangential direction to the circumference of the cylinder called as hoop stress or circumfertial stress	**01**	
		Hoop Stress , $\sigma_c = \frac{Pd}{2t}$		**02**
		Where, σ_c = Hoop stress Or Circumferential stress P = Internal liquid pressure d = Internal daimeter of thin cylinder t = Thickness	**01**	
	viii)	**State middle third rule.**		
	Ans.	In rectangular section for no tension condition the load must lie within the middle third shaded area of size $\frac{b}{3}$ and $\frac{d}{3}$. This is known as middle third rule.	**02**	**02**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1	**b)**	**Attempt any Two of the following:**		**08**
	i)	**A metal rod 24 mm diameter and 2 meter long is subjected to an axial pull of 40 kN. If the elongation of the rod is 0.5mm, find the stress induced and the value of Young's modulus.**		
	Ans.	*Given*: $d = 24mm, \quad L = 2m$ $P = 40kN = 40\times10^3 N$ $\delta l = 0.5mm$ $\sigma = ? \quad E = ?$ *Area*, $A = \frac{\pi}{4}d^2$ $A = \frac{\pi}{4}(24)^2$ $\boxed{A = 452.389mm^2}$	01	
		Stress (σ), $\sigma = \frac{P}{A}$ $\sigma = \frac{40\times10^3}{452.389}$ $\boxed{\sigma = 88.419\, N/mm^2}$	01	
		Young's modulus (E) $E = \frac{PL}{A\delta l}$	01	04
		$E = \frac{40\times10^3\times2000}{452.389\times0.5}$ $\boxed{E = 353.677\times10^3 N/mm^2}$	01	
	ii)	**A simply supported beam of span 9.75m is carrying full span u.d.l. of 10 kN/m. What is the magnitude and position of maximum bending moment developed?**		
	Ans.	*To* find the support recation, $\sum Fy = 0$ $R_A + R_B - (10\times9.75) = 0$ $R_A + R_B = 97.5KN \quad ....(1)$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1		*Taking moment* at *A*, $\sum M_A = 0$ $R_A \times 0 + (10\times 9.75)\times \frac{9.75}{2} - R_B \times 9.75 = 0$ $475.312 = 9.75 \times R_B$ $R_B = \frac{475.312}{9.75}$ $\boxed{R_B = 48.75KN}$	01	
		Put R_B *in* (1) eq^n $R_A + R_B = 97.5$ $R_A + 48.75 = 97.5$ $\boxed{R_A = 48.75KN}$ *SF calculation,* $S.F_{A_L} = 0$ $S.F_{A_R} = 48.75$ $S.F_{B_L} = 48.75 - (10\times 9.75)$ $S.F_{B_L} = -48.75$ $S.F_{B_R} = 0$ *As S.F. is zero at pt. C* *To find pt of contra shear* $S.F_C = 0$ $S.F_C = 48.75 - (10\times \chi) = 0$ $10\chi = 48.75$ $\boxed{\chi = 4.875m}$	BMD 1 Mark	04
		B.M Calculation, $B.M_A = 0$ $B.M_B = 0$ $B.M_C = 48.75\times 4.875 - \left(10\times 4.875\times \frac{4.875}{2}\right)$ $\boxed{B.M_C = 118.828\ kN-m}$ *B.M at C is the* max *B.M. as at C S.F. is zero*	01	



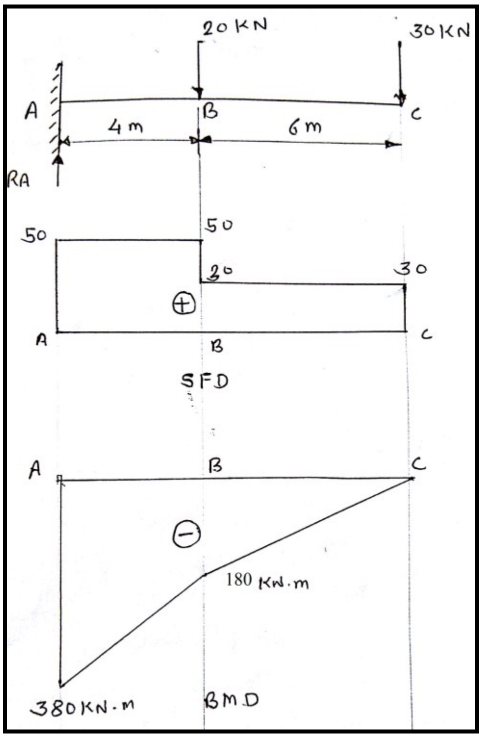
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1	iii)	**A circular beam of 120mm diameter is simply supported over a span of 10m and carries u.d.l of 1000 N/m. find the maximum bending stress produced.**		
	Ans.	*Given data :* $d = 120mm, \quad L = 10m = 10000mm$ $w = 1000\,N/m$ $w = \frac{1000}{1000}\,N/mm = 1\,N/mm$ $\sigma_b = ?$		
		Max. Bending Moment, (M) $M = \frac{wL^2}{8} = \frac{1\times(10000)^2}{8}$ $\boxed{M = 12.5\times10^6\,N-mm}$	01	
		Moment of Inertia, $I = \frac{\pi}{64}d^4 = \frac{\pi}{64}\times(120)^4$ $\boxed{I = 10.178\times10^6\,mm^4}$	01	04
		$y = \frac{d}{2} = \frac{120}{2} = 60mm$ $y = y_c = y_t = 60mm$	01	
		Max. bending stress, $\sigma_b = \frac{M}{I}\times y$ $\sigma_b = \frac{12.5\times10^6}{10.178\times10^6}\times60$ $\boxed{\sigma_b = 73.688\,N/mm^2}$	01	
2		**Attempt any FOUR of the following:**		16
	a)	**i) What is meant by modular ratio?** **ii) State any four assumptions made in Euler's theory.**		
	Ans.	**i) Modular Ratio:** The ratio of modulus of elasticity of two different materials is called as modular ratio. It is denoted by 'm'. $m = \frac{E_1}{E_2} \qquad E_1 > E_2$	02	

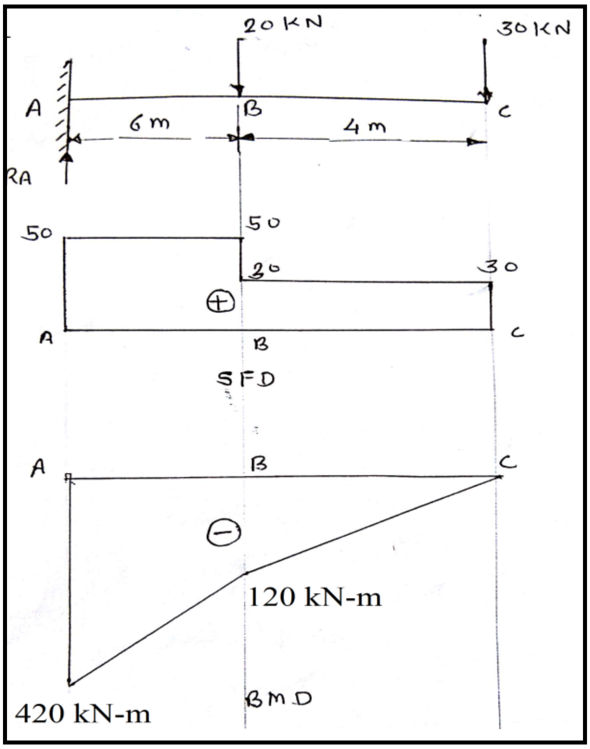
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2		**Following are the assumptions in the Euler's theory.** a) The material of the column is perfectly homogenous and isotropic. b) The column is initially perfectly straight and is axially loaded. c) The cross section of the column is uniform. d) The length of column is very large compared to the lateral dimensions. e) The self-weight of column is neglected. f) The column will fail by buckling only.	**½ marks each (any four)**	**04**
	b)	**A circular steel bar of 10 mm diameter and 1.2m long is subjected to a compressive load in testing machine. Assuming both ends hinged, calculate Euler's crippling load. Also calculate safe load by considering factor of safety as 3. Take E=2x10^5 N/mm^2.**		
	Ans.	*Given data*: $d = 10mm, L = 1.2m = 1200mm,$ $fos = 3, E = 2\times10^5 N/mm^2$ $Pcr = ?$ $safe\ load = ?$ *For column with both ends hinged* $\boxed{Le = l = 1200mm}$	01	
		M.I. for circular section, $I = \frac{\pi}{64} d^4$ $I = \frac{\pi}{64}(10)^4$ $\boxed{I = 490.873\ mm^4}$	01	
		Eulers crippling load, $P_{cr} = \frac{\pi^2 EI}{Le^2}$ $P_{cr} = \frac{\pi^2 \times 2\times10^5 \times 490.873}{(1200)^2}$ $\boxed{P_{cr} = 672.878N}$	01	04

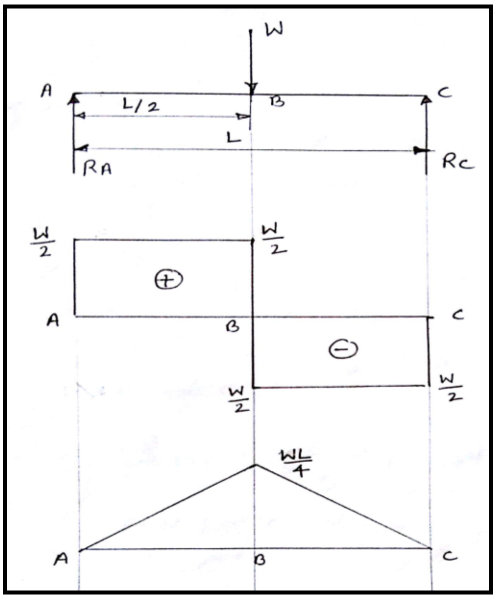
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2		$Safe\ load = \frac{crippling\ load}{F.O.S.}$ $Safe\ load = \frac{672.878}{3}$ $\boxed{Safe\ load = 224.292N}$	01	
	c)	**A steel cube block of 50mm side is subjected to a force of 6 kN (tensile) along X-direction; 8 kN. (compressive) along Y direction and 4 kN (tensile) along Z direction. Determine change in the volume of the block. Take E=200 GPa and $m = \frac{10}{3}$.**		
	Ans.	$Given\ \ data:$ $l = b = t = 50mm$ $Px = 6kN = 6000N \quad (Tensile)$ $Py = 8kN = 8000N \quad (comprtessive)$ $Pz = 4kN = 4000N \quad (Tensile)$ $E = 200Gpa = 200 \times 10^3 N/mm^2$ $m = \frac{10}{3}, \qquad \mu = 0.3$ $Find:\ \delta v = ?$ $Stress\ along\ x\ direction$ $\sigma_x = \frac{Px}{A} = \frac{6000}{50 \times 50} = 2.4N/mm^2$ $Stress\ along\ y\ direction$ $\sigma_y = \frac{Py}{A} = \frac{8000}{50 \times 50} = -3.2N/mm^2 \quad (compressive)$	01	
		$Stress\ \ along\ \ z\ direction$ $\sigma_z = \frac{Pz}{A} = \frac{4000}{50 \times 50}$ $\boxed{\sigma_z = 1.6N/mm^2}$	01	
		$original\ volume\ (V)$ $V = L \times b \times t$ $V = 50 \times 50 \times 50$ $V = 125 \times 10^3 mm^2$		

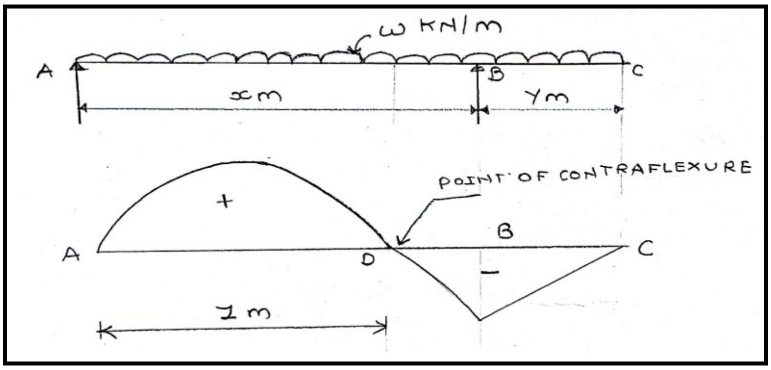
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2		*For triaxial stress system* $e_v = \frac{\sigma_x + \sigma_y + \sigma_z}{E}(1-2\mu)$ $\frac{\delta v}{V} = \frac{\sigma_x + \sigma_y + \sigma_z}{E}(1-2\mu)$ $\frac{\delta v}{125\times10^3} = \frac{2.4-3.2+1.6}{200\times10^3}(1-2\times0.3)$ $\frac{\delta v}{125\times10^3} = 1.6\times10^{-6}$ $\delta v = 1.6\times10^{-6}\times125\times10^3$ $\boxed{\delta v = 0.2mm^3}$ *Change in volume is* $= 0.2mm^3$	01 01	04
	d)	**A concrete column 300mm X 300mm is reinforced with 4 bars of 20mm diameter and carries a compressive load of 400kN. The modular ratio is 15. Calculate the stresses in steel and concrete. Also calculate the load shared by each material.**		
	Ans.	*Given data:* *Area of concrete column,* $A = 300\times300mm$ *Diameter of steel bar,* $d = 20mm$ *No. of steel bar,* $n = 4$ *Load,* $p = 400kN = 400\times10^3 N$ $m = 15$ $\sigma_c = ?$ $\sigma_s = ?$ $P_c = ?$ $P_s = ?$ *Area of steel bar* (A_s) $A_s = n\times\frac{\pi}{4}d^2$ $A_s = 4\times\frac{\pi}{4}20^2$ $\boxed{A_s = 1256.637mm^2}$		

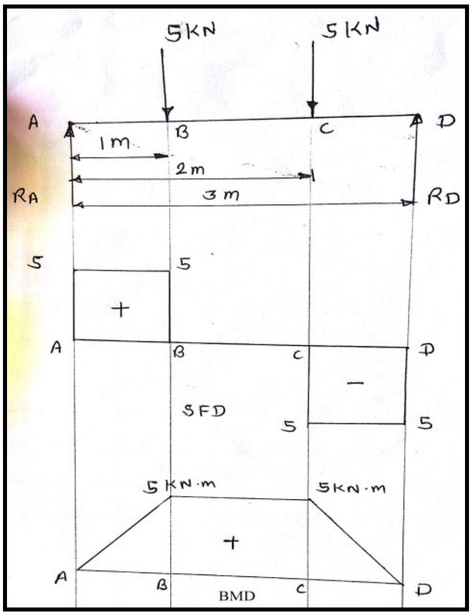
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2		*Area of concrete* (A_c),		
		$A_c = 300\times300 - A_s$		
		$A_c = 90000 - 1256.637$		
		$\boxed{A_c = 88743.363 mm^2}$	01	
		as,		
		$\sigma_s = m\times\sigma_c$		
		$\sigma_s = 15\sigma_c$		
		also,		
		$P = P_s + P_c$		
		$400\times10^3 = \sigma_s A_s + \sigma_c A_c$		
		Put,		
		$\sigma_s = 15\sigma_c$		
		$400\times10^3 = (15\times1256.637\times\sigma_c) + (88743.363\times\sigma_c)$		
		$400\times10^3 = (18849.555 + 88743.363)\sigma_c$		
		$400\times10^3 = 107592.918\times\sigma_c$		
		$\boxed{\sigma_c = 3.717 N/mm^2}$	01	
		As,		
		$\sigma_s = 15\sigma_c$		
		$\sigma_s = 15\times3.717$		
		$\boxed{\sigma_s = 55.755 N/mm^2}$	01	
		Load shared steel		
		$P_s = \sigma_s A_s$		04
		$P_s = 55.755\times1256.637$		
		$P_s = 70063.795 N$		
		$\boxed{P_s = 70.0637 kN}$	½	
		Load shared by econcrete		
		$P_c = \sigma_c A_c$		
		$P_c = 3.717\times88743.363$		
		$P_c = 329859.080 N$		
		$\boxed{P_c = 329.859 kN}$	½	

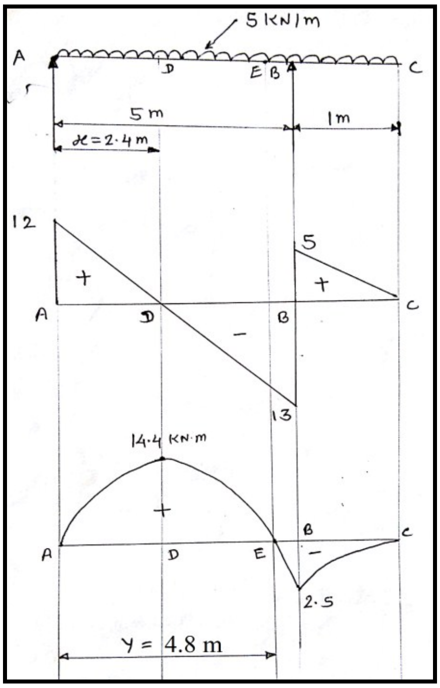
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2	e)	**A cantilever beam of length 10m carries two points load of magnitude 20kN and 30 kN at 4m and free end respectively. Draw the S.F.D and B.M.D.**		
	Ans.	Reaction at fixed end $R_A - 20 - 30 = 0$ $R_A = 50kN$ *S.F. calculation* $S.F._{A_L} = 0$ $S.F._{A_R} = 50\ kN$ $S.F._{B_L} = 50\ kN$ $S.F._{B_R} = 50 - 20 = 30\ kN$ $S.F._{C_L} = 50 - 20 = 30\ kN$ $S.F._{C_R} = 50 - 20 - 30 = 0$	01	
		BM calculation, $B.M._C = 0$ $B.M._B = -30 \times 6$ $B.M._B = -180\ kN - m$ $BM_A = -30 \times 10 - 20 \times 4$ $B.M._A = -380\ kN - m$	01	04
			01 01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
		OR		
		$S.F.\ calculation$ $S.F._{A_L} = 0$ $S.F._{A_R} = 50\ kN$ $S.F._{B_L} = 50\ kN$ $S.F._{B_R} = 50 - 20 = 30\ kN$ $S.F._{C_L} = 50 - 20 = 30\ kN$ $S.F._{C_R} = 50 - 20 - 30 = 0$	01	
		$BM\ \ calculation,$ $B.M._C = 0$ $B.M._B = -30 \times 4$ $B.M._B = -120\ kN - m$ $BM_A = -30 \times 10 - 20 \times 6$ $B.M._A = -420\ kN - m$	01	
			01 01	04
	f)	**A gas cylinder of internal diameter 1.2m and thickness 24mm is subjected to a maximum tensile stress of 90 MPa. Find the allowable pressure of gas inside cylinder.**		

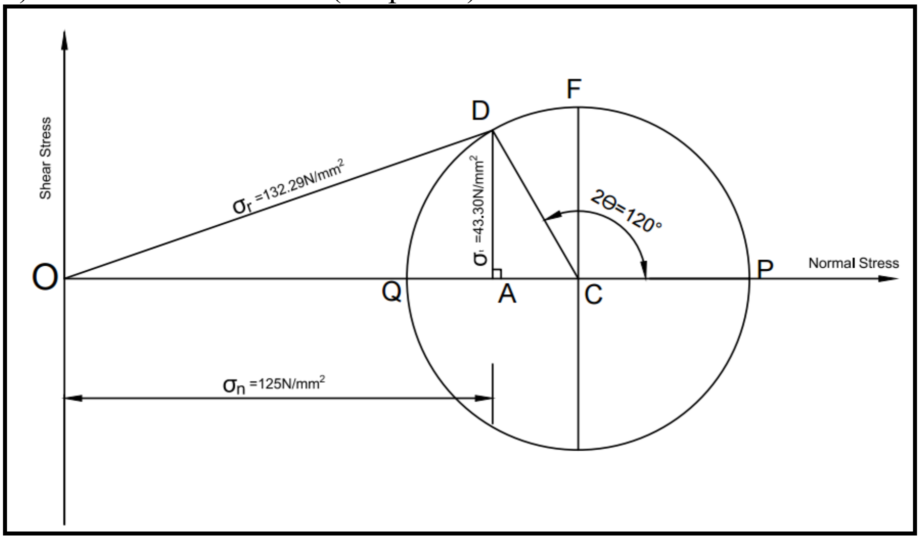
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
	Ans.	*Internal* daimeter d = 1.2 m = 1200mm Thickness, t = 24 mm Tensile stress, $\sigma = 90MPa = 90N/mm^2$ Pr*essure of gas*, p = ? As tensile stress = Hoop Stress = $\sigma_c = 90N/mm^2$ $\sigma_c = \frac{P.d}{2t}$ $P = \frac{90 \times 2 \times 24}{1200}$ $\boxed{P = 3.6N/mm^2}$	02 02	04
3		**Attempt any <u>FOUR</u> of the following:**		16
	a)	**Draw S.F. and B.M. diagram for simply supported beam of span 'L' carrying a central point load 'W'. State the value of maximum shear force and maximum bending moment.**		
	Ans.	 $\boxed{\text{Max. S. F} = \frac{W}{2}}$ $\boxed{\text{Max. B.M} = \frac{WL}{2}}$	01 01 01 01	04

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3	**b)**	**Define point of contra flexure. How is the point of contra flexure located for a beam?**		
	Ans.	**Point of contra-flexure: -**		
		The point at which bending moment diagram changes the sign from positive to negative or vice versa or the point at which BM is zero is called as point of contra-flexure	**02**	
		Location of point of contra-flexure i) At the point of contra-flexure B.M is zero. ii) Take B.M at the point of contra-flexure and equate with zero. iii) The distance (location) of point of contra-flexure will be find from either end of beam.	**01**	**04**
			**01**	
		Point D, B.M. = 0 ∴ Point D is Point of Contraflexure. Point D is at Z m from A		
	c)	**A simply supported beam of 3 m span carries two point loads of 5 kN each at 1 m and 2 m from the left end A. Draw the shear force and bending moment diagram.**		
	Ans.			

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3		*Step* i) *To* find support reactions,		
		∵ ading is symmetical		
		$R_A = R_D = 5kN$	½	
		Step ii) SF calculations		
		$S.F._A = 5$ kN		
		$S.F._{B_L} = 5$ kN		
		$S.F._{B_R} = +5 - 5 = 0$ kN	½	
		$S.F._{C_L} = 0$ kN		
		$S.F._{C_R} = -5$ kN		
		$S.F._{D_L} = -5$ kN		
		$S.F._D = 0$ kN		
		Step iii) $B.M.$ Calculation,		
		∵ ıe supports are simple		
		$B.M._A = 0$	01	
		$B.M._D = 0$		
		$B.M._B = 5 \times 1 = +5$ kN-m		
		$B.M._C = 5 \times 1 = +5$ kN-m		04
			01	
			01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3	d)	**A beam 6 m long rests on two supports 5 m apart. The right end is overhang by 1 m. the beam carries a u.d.l. of 5 kN/m over the entire length of the beam. Draw S.F. and B. M. diagram.**		
	Ans.	*To* find support reactions, $\sum F_Y = 0$ $R_A - (5 \times 6) + R_B = 0$ $R_A + R_B = 30$ ....(i) Taking moment at A $(R_A \times 0) + \left(5 \times 6 \times \frac{6}{2}\right) - R_B \times 5 = 0$ $R_B \times 5 = 90$ $\boxed{R_B = 18\ kN}$ *Put* R_B in equation (i) $R_A + R_B = 30$ $R_A + 18 = 30$ $\boxed{R_A = 12\ kN}$ *S.F. Calculation,* $S.F._{A_L} = 0$ $S.F._{A_R} = 12$ kN $S.F._{B_L} = 12 - (5 \times 5) = -13$ kN $S.F._{B_R} = 12 - (5 \times 5) + 18 = 5$ kN $S.F._{C_L} = 12 - (5 \times 6) + 18 = 0$ $S.F._{C_R} = 0$ Shear force is zero at pt. D and the pt. D is at 'x' m from A $S.F._D = 0$ $S.F._D = 12 - 5 \times x = 0$ $\therefore\ 5 \times x = 12$ x = 2.4 m *B.M.* Calculation, $B.M._A = 0$ $B.M._D = (12 \times 2.4) - \left(5 \times 2.4 \times \frac{2.4}{2}\right)$ $B.M._D = 5\ kN - m$ 	**SF cal. 01** **SFD and BMD (1 mark each)** **BM cal. 01**	**04**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3		$B.M._D = 14.4$ kN-m		
		$B.M._B = (12\times5)$-$\left(5\times5\times\frac{5}{2}\right)$		
		$B.M._B$= - $2.5\ kN-m$		
		$B.M._C = 0$		
		$B.M.$ is zero at pt. E		
		Pt. E is at Y m from A		
		$B.M._E = (12\times Y)$-$\left(5\times Y\times\frac{Y}{2}\right) = 0$		
		$(12\times Y)$- $(2.5Y^2)$= 0		
		$\boxed{Y = 4.8 \text{ m from A}}$		
	e)	**A point in a strained material stresses are subjected to two mutually perpendicular tensile stresses of 200 Mpa and 100 Mpa. Determine the intensities of normal, shear a resultant stresses on a plane inclined at 30^0 with the axis of minor tensile stress.**		
	Ans.	*Given* data:		
		$\sigma_x = 200MPa,$ $\sigma_x = 200MPa$		
		$\theta = 90^0 - 30^0 = 60^0$ $\tau = 0$		
		1) *Analytical* Method		
		$\sigma_n = ?$ $\sigma_t = ?$ $\sigma_R = ?$		
		$\sigma_n = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau \sin 2\theta$	01	
		$\sigma_n = \frac{200+100}{2} + \left(\frac{200-100}{2}\right)\cos(2\times30) + 0$		
		$\boxed{\sigma_n = 125 \text{ N/mm}^2}$		
		$\sigma_t = \frac{\sigma_x - \sigma_y}{2}\sin 2\theta + \tau \cos 2\theta$	01	
		$\sigma_t = \left(\frac{200-100}{2}\right)\sin(2\times30) + 0$		
		$\boxed{\sigma_t = 43.301 \text{ N/mm}^2}$	01	

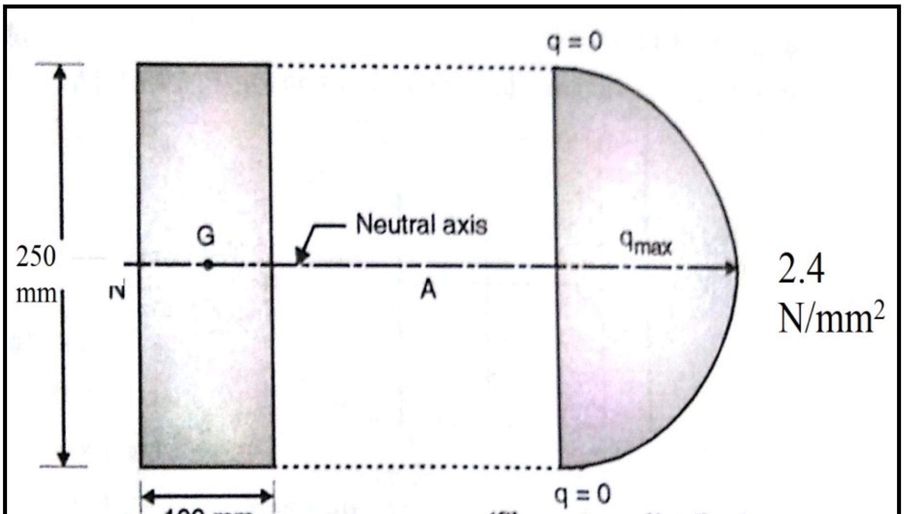
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3		Resultant Stress, $\sigma_R = \sqrt{\sigma^2{}_n + \sigma^2{}_t}$ $\sigma_R = \sqrt{(125)^2 + (43.301)^2}$ $\boxed{\sigma_R = 132.287 N/mm^2}$	01	04
		OR 2) Mohr's Circle method (Graphical)  	04	04
	f) Ans.	**Find the M.I. of a 'T' section having top flange 200 mm × 20 mm and web 200 mm × 20 mm about the centroidal axis X-X and Y-Y.** *Given data:* $b_1 = 20mm, \quad d_1 = 200mm$ $b_2 = 200mm, \quad d_2 = 20mm$ $A_1 = b_1 \times d_1 = 20 \times 200 = 4000mm^2$ $A_2 = b_2 \times d_2 = 200 \times 20 = 4000mm^2$ *as the T − section is symmetrical about y − axis* $\bar{X} = \frac{200}{2} = 100\ mm$ *To find* $\bar{Y}$ $y_1 = \frac{d_1}{2} = \frac{200}{2} = 100\ mm$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3		$y_2 = \frac{d_2}{2} + 200 = \frac{20}{2} + 200 = 210\ mm$ $\overline{Y} = \frac{(A_1Y_1)+(A_2Y_2)}{A_1+A_2}$ $\overline{Y} = \frac{(4000\times100)+(4000\times210)}{(4000+4000)}$ $\boxed{\overline{Y} = 155mm}$	01	
		To find M.I. about X − X $I_{xx} = I_{x_1} + I_{x_2}$ $I_{x_1} = \frac{b_1d_1^3}{12} + a_1h_1^2$ $h_1 = 155 - 100 = 55mm$ $I_{x_1} = \frac{(20\times200^3)}{12} + (4000\times55^2)$ $\boxed{I_{x_1} = 25.433\times10^6 mm^4}$ $I_{x_2} = \frac{b_2d_2^3}{12} + a_2h_2^2$ $h_2 = 210 - 155 = 55mm$ $I_{x_2} = \frac{(200\times20^3)}{12} + (4000\times55^2)$ $\boxed{I_{x_2} = 12.233\ \times10^6 mm^4}$ $I_{XX} = I_{X_1} + I_{X_2}$ $= 25.433\ \times10^6 + 12.233\ \times10^6$ $\boxed{I_{XX} = 37.666\times10^6 mm^4}$	02	04
		To find M.I. at Y-Y axis $\mathrm{I_{YY}} = I_{Y_1} + I_{Y_2}$ $I_{YY} = \left[\frac{d_1b_1^3}{12} + a_1h_1^2\right] + \left[\frac{d_2b_2^3}{12} + a_2h_2^2\right]$ $h_1 = h_2 = 0$ as symmetrical at Y axis $I_{YY} = \left[\frac{200\times20^3}{12}\right] + \left[\frac{20\times200^3}{12}\right]$ $\boxed{I_{YY} = 13.4633\times10^6\ mm^4}$	01	

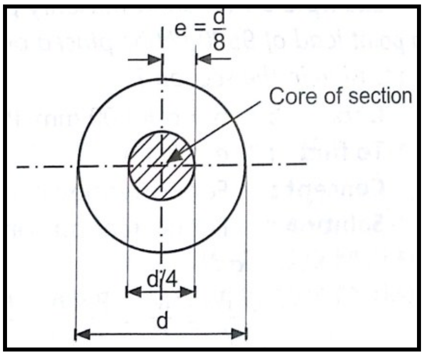
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4		**Attempt any FOUR of the following:**		**16**
	a)	**Find the moment of inertia of a square of side 'a' about its outer edge.**		
	Ans.	i) For a square of side 'a' $I_{xx} = \frac{a\ .\ a^3}{12} = \frac{a^4}{12}$	**01**	
		ii) Area of section, $A = a \times a = a^2$ *iii*) The outer edge is paralle to XX axis Distance between XX axis and Outer edge is $h = \frac{a}{2}$	**01**	**04**
		iv) Using the parallel axis theorom, M.I. about parallel axis = M.I. about centroidal axis + Ah^2 $I = I_{xx} + Ah^2$ $= \frac{a^4}{12} + a^2 \times \left(\frac{a}{2}\right)^2$ $= \frac{a^4}{12} + \frac{a^4}{4}$ $\boxed{I = \frac{a^4}{3}}$	**02**	
	b)	**A channel section 100cm × 100cm × 30cm thick. Find the moment of inertia about centroidal axis X-X and Y-Y.**		
	Ans.	$\overline{X} = \frac{a_1x_1 + a_2x_2 + a_3x_3}{a_1 + a_2 + a_3}$ $= \frac{(1000\times300)\times500 + (1000\times300)\times500 + (400\times300)\times150}{(1000\times300) + (1000\times300) + (400\times300)}$ $\overline{X} = 441.667mm$	**01**	
		$I_{XX} = \frac{BD^3}{12} - \frac{bd^3}{12}$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4		$I_{XX} = \frac{1}{12}\left[\left(1000\times1000^3\right)-\left(700\times400^3\right)\right]$ $I_{XX} = 7.96\times10^{10}\,mm^4$	01	04
		$I_{YY} = I_{Y_1Y_1} + I_{Y_2Y_2} + I_{Y_3Y_3}$ $I_{Y_1Y_1} = I_{Y_3Y_3} = \frac{1}{12}\left(bd^3\right) + Ah^2$ $I_{Y_1Y_1} = I_{Y_3Y_3} = \frac{1}{12}\times\left(300\times1000^3\right)+\left(1000\times300\right)\times58.333^2$ $\boxed{I_{Y_1Y_1} = I_{Y_3Y_3} = 2.602\times10^{10}\,mm^4}$ $I_{Y_2Y_2} = \frac{1}{12}\left(bd^3\right) + Ah^2$ $= \frac{1}{12}\times\left(400\times300^3\right)+\left(400\times300\right)\times291.667^2$ $= 5.308\times10^9\,mm^4$ $I_{YY} = 2.602\times10^{10} + 5.308\times10^9 + 2.602\times10^{10}$ $\boxed{I_{YY} = 5.7348\times10^{10}\,mm^4}$	02	
	c)	**An isosceles triangular section ABC has base width 80 mm and height 60 mm. Determine the M.I. of the section about the C. G. of the section and the base BC.**		
	Ans.	$I_{base} = \frac{bh^3}{12} = \frac{80\times60^3}{12}$	01	04
		$\boxed{I_{base} = 1440000\,mm^4}$	01	
		$I_{xx} = \frac{bh^3}{36} = \frac{80\times60^3}{36}$	01	
		$\boxed{I_{xx} = 480000\,mm^4}$	01	
	d)	**A hole of 100 mm diameter cut from a rectangular plate 600 mm wide and 400 mm deep. The center of hole is at 160 mm from the edge on an axis bisecting shorter side. Find M.I. of remaining plate about X-X and Y-Y axis.**		
	Ans.	$\bar{X} = \frac{a_1x_1 - a_2x_2}{a_1 - a_2} = \frac{(600\times400)\times300-\left(\frac{\pi}{4}\times100^2\right)\times160}{(600\times400)-\left(\frac{\pi}{4}\times100^2\right)}$ $\boxed{\bar{X} = 304.736\,mm}$	01	

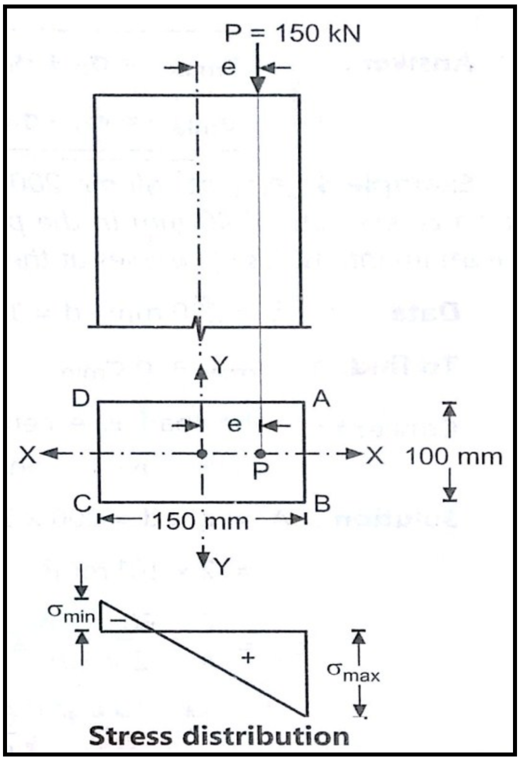
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4		$I_{XX}=\left(\frac{BD^3}{12}\right)-\left(\frac{\pi}{64}d^4\right)$	01	
		$I_{XX}=\left(\frac{600\times400^3}{12}\right)-\left(\frac{\pi}{64}\times(100)^4\right)$ $\boxed{I_{XX}=3195091261mm^4}$	01	04
		$I_{YY}=\left(\frac{DB^3}{12}+Ah^2\right)-\left(\frac{\pi}{64}d^4+Ah^2\right)$ $I_{YY}=\left(\frac{400\times600^3}{12}+\left(600\times400\right)\times4.736^2\right)-\left(\frac{\pi}{64}(100)^4+\frac{\pi}{4}(100)^2\times144.736^2\right)$ $\boxed{I_{YY}=7035945178mm^4}$	01	
	e) Ans.	**State any four assumptions made in the theory of simple bending.** **Assumptions** 1. The material of the beam is homogeneous and isotropic and follows the Hooke's Law. 2. The transverse section of the beam which is plane before bending will remain plane after bending. 3. Young's modulus for the material is same for tension and compression 4. Each layer is free to expand or contract independently. 5. The beam in initially straight and of constant cross section.	**1 mark each (any four)**	**04**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4	f)	**A beam 100mm wide and 250mm deep is subjected to a shear force of 40KN at a certain section find the maximum shear stress and draw the shear stress variation diagram.**		
	Ans.	$q_{av} = \frac{S}{A} = \frac{S}{bd} = \frac{40\times10^3}{250\times100}$	01	
		$\boxed{q_{av} = 1.6 N/mm^2}$		
		$q_{\max} = 1.5\times q_{av} = 1.5\times1.6$	01	
		$\boxed{q_{\max} = 2.4 N/mm^2}$	01	
		(Shear stress distribution diagram)	01	04

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		**Attempt any FOUR of the following:**		16
	a)	**A timber beam has a cross section 120 mm X 200 mm. It is simply supported over a span of 4 m and carries a u.d.l. of 1 kN/m over the entire span. Calculate the maximum bending stress induced in beam and the radius of curvature to which the beam will bend at the section.**		
	Ans.	$\frac{M}{I}=\frac{\sigma}{y}=\frac{E}{R}$	01	
		$M=\frac{wL}{8}=\frac{1\times 4^2}{8}=2\times 10^6\,N-mm$	½	
		$I=\frac{1}{12}bd^3=\frac{1}{12}\times 120\times 200^3=80\times 10^6\,mm^4$	½	
		$Y=\frac{d}{2}=\frac{200}{2}=100mm$		04
		$\sigma_b=\left(\frac{M}{I}\right)Y=\frac{2\times 10^6}{80\times 10^6}100=2.5N/mm^2$	01	
		$\frac{M}{I}=\frac{\sigma}{y}$ OR $\frac{\sigma}{y}=\frac{E}{R}$		
		$R=\frac{E}{M}\times I$ OR $R=\frac{E}{\sigma}\times Y$		
		$R=\frac{E}{\left(2\times 10^6\right)}\times\left(80\times 10^6\right)$ OR $R=\frac{E}{2.5}\times 100$	01	
		$\boxed{R=40E}$ OR $\boxed{R=40E}$		
		Note: - If suitable value of E is assume should be consider		
	b)	**A circular section of diameter 'd' is subjected to load 'P' eccentric to the axis the eccentricity of load is 'e' obtain the limit of eccentricity such that no tension is induced at the section.**		
	Ans.	To find : e=? Direct stress, $\sigma_0=\frac{P}{A}$ Bending stress, $\sigma_b=\frac{M}{Z}$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		*for circular section,* $I = \frac{\pi}{64} d^4$ $y = \frac{d}{2}$ $Z = \frac{I}{y} = \frac{\frac{\pi}{64} d^4}{\frac{d}{2}} = \frac{\pi}{32} d^3$	01	04
		for no tension condition, $\sigma_0 = \sigma_b$ $\frac{P}{A} = \frac{M}{Z}$ $\frac{P}{A} = \frac{P \times e}{Z}$ $\frac{1}{A} = \frac{e}{Z}$ $e = \frac{Z}{A} = \frac{\frac{\pi}{32} d^3}{\frac{\pi}{4} d^2}$ $\boxed{e = \frac{d}{8}}$  	01	
		The core of a section is circle of radius $e = \frac{d}{8}$ or diameter $\frac{d}{4}$	01	
	c)	**A rectangular column 150mm wide and 100mm thick carries a load of 150 kN at an eccentricity of 50mm in the plane bisecting the thickness. Find the maximum and minimum intensities of stress. Also draw stress distribution diagram.**		
	Ans.	Given data: b = 150 mm, d = 100mm P = 150 kN, e = 50mm σ_{max} =? σ_{min} =? Area of section, $A = b \times d = 150 \times 100 = 15 \times 10^3 mm^2$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		Direct stress, $\sigma_0 = \frac{P}{A}$ $\sigma_0 = \frac{150\times10^3}{15\times10^3}$ $\boxed{\sigma_0 = 10\ N/mm^2}$ (C) Bending Stress, $\sigma_b = \frac{M}{Z_{yy}}$ $\sigma_b = \frac{P\times e}{\frac{db^2}{6}}$ $\sigma_b = \frac{6\times P\times e}{db^2}$ $\sigma_b = \frac{6\times150\times10^3\times50}{100\times150^2}$ $\boxed{\sigma_b = 20\ N/mm^2}$ $\sigma_{max} = \sigma_0 + \sigma_b = 10 + 20$ $\boxed{\sigma_{max} = 30\ N/mm^2}$ (C) $\sigma_{min} = \sigma_0 - \sigma_b = 10 - 20$ $\boxed{\sigma_{min} = 10\ N/mm^2}$ (T)	½ Diag. ½ 02 ½ ½	04
	d)	**A square column 300mm X 300 mm carries an axial load of 200 kN. Find the position of 30 kN load acting along the axis bisecting the width of the cross section so that the stress developed at the other extreme of the column will be zero.**		
	Ans.	$\sigma_0 = \frac{P_1}{A} + \frac{P_2}{A} = \frac{P_1+P_2}{A} = \frac{(200+30)\times10^3}{300\times300}$ $\boxed{\sigma_0 = 2.55 N/mm^2}$ $M = (30\times10^3)e$ $Y = \frac{b}{2} = \frac{300}{2} = 150mm$ $I = \frac{b^4}{12} = \frac{300^4}{12} = 675\times10^6 mm^4$	01	



Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		$\sigma_b = \left(\frac{M}{I}\right)Y$ $\sigma_b = \left(\frac{(30\times10^3)e}{675\times10^6}\right)\times150 = (6.67\times10^{-3})e$ For no tension condition, $\sigma_0 = \sigma_b$ $2.55 = (6.67\times10^{-3})e$ $\boxed{e = 382.5mm}$	02 01	04
	e)	**A square pillar is 600mm X 600mm in section. At what eccentricity a point load of 6000 kN is placed on one of the centroidal axis of the section so as to produce no tension in the section.**		
	Ans.	For no tension condition, $\sigma_0 = \sigma_b$ $\frac{P}{A} = \frac{M}{Z}$ $\frac{P}{A} = \frac{P.e.Y}{I}$ $e = \frac{I}{A.Y}$ $= \frac{\left(\frac{600^4}{12}\right)}{(600\times600)\times300}$ $\boxed{e = 100mm}$	01 01 01 01	04
	f)	**A mild steel flat 50mm wide and 5mm thick is subjected to load 'P' acting in the plane bisecting the thickness at a point 10mm away of the centroid of the section. If the tensile stress is not to exceed 150 MPa, calculate the magnitude of 'P'.**		
	Ans.	*Given data*: $b = 50mm, \quad d = 5mm,$ $e = 10mm,$ $\sigma_{max} = 150MPa = 150\,N/mm^2\ (tensile)$ $P = ?$ $A = b\times d = 50\times5 = 250mm^2$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		$\sigma_0 = \frac{P}{A} = \frac{P}{250}$	01	
		$\sigma_b = \frac{M}{Z_{yy}} = \frac{P \times e}{d\,b^2/6} = \frac{6 \times P \times e}{db^2}$	01	
		$= \frac{6 \times P \times 10}{5 \times 50^2} = 0.0048P$		04
		$\sigma_{\max} = \sigma_0 + \sigma_b$		
		$150 = \frac{P}{250} + 0.0048P$	01	
		$150 = 0.0088P$		
		$P = \frac{150}{0.0048} = 17045.45N$		
		$\boxed{P = 17.045kN}$	01	
6		**Attempt any <u>FOUR</u> of the following:**		16
	a)	**A hollow shaft is of the same external diameter as that of the solid shaft. The inside diameter of the hollow shaft being half the external diameter. Both the shafts have the same material and length. Then show that the ratio of torque transmitted by hollow shaft to the torque transmitted by solid shaft is 0.9375.**		
	Ans.	$\frac{T}{J} = \frac{G\theta}{L}$	01	
		$T_{Hollow} = \left(\frac{G.\theta}{L}\right) J_{Hollow}$		
		$T_{Solid} = \left(\frac{G.\theta}{L}\right) J_{Solid}$		
		$\frac{T_{Hollow}}{T_{Solid}} = \frac{\left(\frac{G.\theta}{L}\right) J_{Hollow}}{\left(\frac{G.\theta}{L}\right) J_{Solid}}$		
		$\frac{T_{Hollow}}{T_{Solid}} = \frac{J_{Hollow}}{J_{Solid}}$	01	
		But,		
		$J_{Hollow} = \frac{\pi}{32}\left(D^4 - d^4\right)$		04
		$J_{Hollow} = \frac{\pi}{32}\left(D^4 - \frac{D}{2}^4\right)$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6		$J_{Solid}=\frac{\pi}{32}D^4$ $\frac{T_{Hollow}}{T_{Solid}}=\frac{\frac{\pi}{32}\left(D^4-\frac{D^4}{2}\right)}{\frac{\pi}{32}D^4}$ $=\frac{16D^4-D^4}{16D^4}$ $\boxed{\frac{T_{Hollow}}{T_{Solid}}=0.9375}$	01	
	b)	**A shaft is transmitting 150 kW at 200 RPM. If allowable shear stress is 80N/mm^2 and allowable twist is 1.5^0 per 4m, find the diameter of shaft. Take C = 0.8 X 10^5 N/mm^2**		
	Ans.	Power $P=150\text{ kW}=150\times10^3W$ Speed $N=200rpm$ Shear stress $f_S=80N/mm^2$ $\theta=1.5^0=\frac{1.5\times\pi}{180}$ rad Length $L=4\text{ m}=4000mm$ $C=0.8\times10^5N/mm^2$ Find $D=?$ Case i) $P=\frac{2\pi NT}{60}$ watts $150\times10^3=\frac{2\times\pi\times200\times T_{mean}}{60}$ $T_{mean}=7161.97N.m$ $\boxed{T_{mean}=7161.97\times10^3N.mm}$	01	
		Case ii) Diameter based on shear stress: $T_{mean}=T_{max}$ Using relation, $T_{max}=\frac{\pi}{16}\times f_S\times D^3$ $7161.97\times10^3=\frac{\pi}{16}\times80\times D^3$ $\boxed{D=76.96\text{ mm}}$	01	04

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6		Case iii) Diameter based on angle of twist Using relation, $\frac{T_{max}}{I_P} = \frac{C\theta}{L}$	01	
		$\frac{7161.97\times10^3}{\frac{\pi}{32}\times D^4} = \frac{0.8\times10^5\times1.5\times\frac{\pi}{180}}{4000}$ $\boxed{D=108.64\ mm}$	01	
		Note: - Adopt higher value of Diameter i.e. 108.64 mm because it will satisfy both shear stress and angle of twist.		
	c)	**Calculate the suitable diameter of the solid shaft to transmit 220 kW at 150 rpm if the permissible shear stress is 68 MPa.**		
	Ans.	*Given* data: Power = 220 kW = 220×10^3W 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	
		$220\times10^3 = \frac{2\times\pi\times150\times T}{60}$ T = 14005.6349 N.m $\boxed{T = 14005.6349 \times 10^3\ N\text{-}mm}$	01	04
		ii)Using the relation, $T = \frac{\pi}{16}\times f_S\times D^3$	01	
		$14005.6349 \times 10^3 = \frac{\pi}{16}\times68\times D^3$ $\boxed{D = 101.6\ mm}$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6	d)	**Select a suitable diameter for a solid shaft to transmit 200 HP at 180 rpm. The allowable shear stress is 80 N/mm^2.**		
	Ans.	Given data:		
		Power P=200HP		
		Speed N=180rpm		
		Shear stress $f_S=80N/mm^2$		
		$\theta=1^0=\frac{\pi}{180}$ rad		
		Length L=3m=3000mm		
		$C=0.82\times10^5 N/mm^2$		
		Find D=?		
		If the power is given in terms of HP then		
		$P=\frac{2\pi NT}{4500}$ HP	**01**	
		$200=\frac{2\pi\times180\times T}{4500}$		
		T=795.774kg.m		
		T=795.774×9.81=7806.549N.m	**01**	**04**
		$T=7806.549\times10^3 N.mm$		
		Diameter based on shear stress		
		Using relation,		
		$T=\frac{\pi}{16}\times f_S\times D^3$	**01**	
		$7806.5499\times10^3=\frac{\pi}{16}\times80\times D^3$	**01**	
		$\boxed{D=79.21\ mm}$		
		Note: - If suitable value modulus of rigidity assumed to calculate diameter of solid shaft should be consider.		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6	e)	**A hollow shaft is of external diameter and internal diameter 400mm and 200mm respectively. Find the maximum torque is can transmit, if the angle of twist is not to exceed 1.5^0 in a length of 10m. take $C = 0.8X10^5$ N/mm^2**		
	Ans.	Given data: External diameter, D = 400mm Internal diameter, d=200mm $\theta = 1.5^0 = 1.5\times\frac{\pi}{180} = 0.026$ rad	01	
		Length $L=10m=10\times10^3mm$ $C=0.8\times10^5 N/mm^2$ Find T=? By using torsional relation $\frac{T}{I_P} = \frac{C\theta}{L}$	01	04
		$T = I_P\times\frac{C\theta}{L} = \frac{\pi}{32}(D^4 - d^4)\times\frac{C\theta}{L}$ $T = \frac{\pi}{32}(400^4 - 200^4)\times\frac{0.8\times10^5\times0.026}{10\times10^3}$ $T = \frac{\pi}{32}\times2.4\times10^{10}\times0.208$ $\boxed{T = 493480220.1 N.mm}$	01	
		$\boxed{T = 493.48\ kN.m}$	01	
	f)	**(i) Difference between pure bending and ordinary bending** **(ii) Write the equation of torque transmitted by the O.C. shaft giving meaning and unit of each term.**		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6	Ans.	**(i) Difference pure bending and ordinary bending**		
		Pure Bending / **Ordinary Bending**		
		a) In pure bending the beam deflects into an arc of circle. / a) In ordinary bending beam dose not deflects into an arc of circle.	02	
		b) A beam is subjected to normal (bending)stresses of tensile or compressive in nature / b) A beam is subjected to normal and shear stresses in it		04
		(ii) The equation of torque transmitted by the O.C. shaft		
		a) Based on angle Twist: $\frac{T}{I_P}=\frac{G.\theta}{L}$, $T=\frac{G.\theta}{L}I_P$	01	
		b) Based on shear stress: $\frac{T}{I_P}=\frac{q}{R}$, $T=\frac{q}{R}I_P$		
		Where, T = Torque acting on shaft (N-mm); R = Radius of curvature shaft (mm); G = Modulus of rigidity (N/mm^2); L = Length of shaft (mm); I_P = Polar M.I. of shaft section (mm^4); θ = Angle of twist in radians; q = Max. shear stress at outer most fibre of shaft (N/mm^2)	01	