Model Answer: Summer- 2019

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

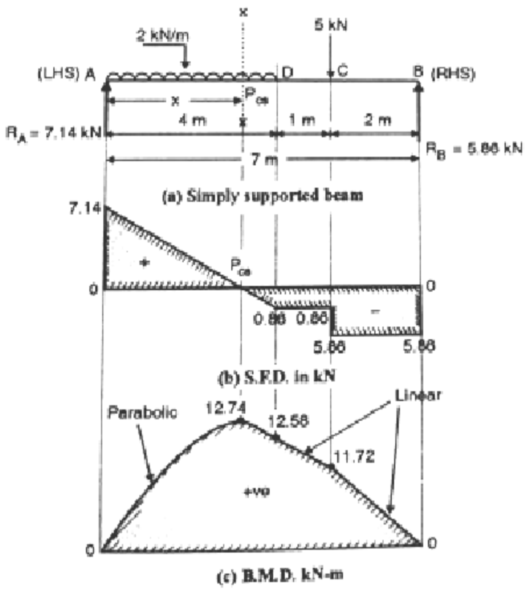
Important Instructions to Examiners

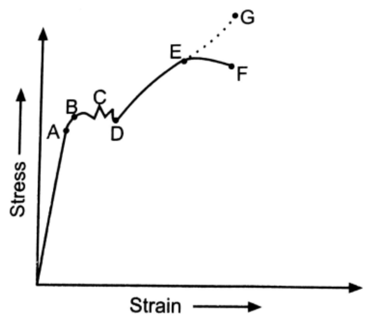
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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 Answer	Marks	Total Marks
Q. 1		**Attempt any SIX of the following:**		**(12)**
	a) (i)	**Define brittleness. Name two brittle materials.**		
	Ans.	It is the property of material due to which it can be directly broken without any further deformation.	**1**	
		OR		
		Brittleness is the lack of ductility.		
		e.g. Glass, Concrete, cast iron. etc.	**1**	**2**
	(ii)	**Define principal plane and principal stress.**		
	Ans.	**Principal Plane:** A plane which carries only normal stress and no shear stress is called a principal plane.	**1**	
		Principal Stress: The magnitude of normal stress acting on the principal plane is called principal stress.	**1**	**2**
	(iii)	**Define radius of gyration. State its S.I. units.**		
	Ans.	Radius of Gyration of a given area about any axis is that distance from the given axis at which the entire area is assumed to be concentrated	**1**	
		without changing the M. I. about the given axis. **Unit-** mm, cm, m.	**1**	**2**
	(iv)	**Define the term direct stress with formula.**		
	Ans.	The stresses which acts normal to the plane on which the forces acts axially are called as direct stress.	**1**	
		$\text{Direct Stress } (\sigma_0) = \dfrac{\text{Axial Load}}{\text{Cross Sectional Area}} = \dfrac{P}{A}$	**1**	**2**

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 1	a) (v) Ans.	**State the torsion equation along with meaning of each term in it.** Torsional Equation is $$\frac{G\theta}{L} = \frac{T}{I_p} = \frac{\tau}{R}$$	1	
		Where, T = Torque or Turning moment (N-mm) $I_p = I_{xx} + I_{yy}$ Polar momet of inertia of the shaft section (mm^4) G = 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) τ = Maximum shear stress induced at the outermost layer of the shaft (N/mm^2) R= Radius of the shaft (mm)	1	2
	(vi) Ans.	**Define factor of safety.** The ratio of the ultimate stress to the working stress for a material is called factor of safety.	2	2
	(vii) Ans.	**Write the equation of circumferential stress in thin cylinder and explain each term.** $$\sigma_C = \frac{pd}{2t}$$	1	
		Where, σ_c = Circumferential stress p = Internal pressure. d = Internal diameter of thin cylinder t = Thickness of thin cylinder	1	2
	(viii) Ans.	**Define the term core of section.** The centrally located portion of a section within which the load must act so as to produce only compressive stress is called a core of the section.	2	2

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.1	b)	**Attempt any <u>TWO</u> of the following:**		**(08)**
	(i)	**A steel rod 800mm long and 60mm X 20mm in cross section is subjected to an axial push of 89 kN. If the modulus of elasticity is 2.1 X 10^5 N/mm^2. Calculate the stress strain and reduction in the length of the rod.**		
	Ans.	Data: b = 60mm, d=20mm, L= 800mm, P= 89 kNE= 2.1 x 10^5 N/mm^2 Find= σ , e , δL		
		$\sigma = \frac{P}{A} = \frac{89\times10^3}{60\times20} = 74.17 N/mm^2$	1	
		$e = \frac{\sigma}{E} = \frac{74.17}{2.1\times10^5} = 3.53\times10^{-4}$	1	
		$\delta L = \frac{PL}{AE} = \frac{89\times10^3\times800}{60\times20\times2.1\times10^5} = 0.2825mm$	2	4
	(ii)	**A simply supported beam of span 7 m carries a uniformly distributed load of 2kN/m over 4 m length from the left support and a point load of 5 kN at 2 m from the right support. Draw SF and BM diagram.**		
	Ans.	I. Support Reactions: $\sum M_A = 0$ $2\times4\times2+5\times5-R_B\times7 = 0$ $7\times R_B = 41$ $R_B = 8.86$ kN	1	
		$\sum F_y = 0$ $R_A + R_B - 2\times4+5 = 0$ $R_A + R_B = 13$ $R_A = 7.14$ kN		
		SF Calculations: SF at A = +7.14 kN D = +7.14 – 8 = - 0.86 kN C_L = - 0.86 kN C_R = - 0.86 55 = - 5.86 kN B_L = - 5.86 kN B = - 5.86 + 5.86 = 0 kN	1	
		B.M. calculation: B.M at A and B = 0 Since support A and B are simple. B.M at D = (5.86 x 3) – (5 × 1) = 12.56 kN-m B.M at C = 5.86 × 2 =11.72 kN-m	1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 1	b)		1	4
	(iii)	**Determine the maximum bending stress developed in a beam of rectangular cross section 50mm X 150 mm when a bending moment of 600Nm is applied about x-x axis.**		
	Ans.	Data: b = 50 mm , d = 150mm, BM = 600N-m		
		Find: σ_b		
		$I_{NA} = I_{XX} = \frac{bd^3}{12} = \frac{50\times150^3}{12} = 14062500 mm^4$	1	
		$Y = \frac{d}{2} = \frac{150}{2} = 75mm$	1	
		$\sigma_b = \left(\frac{M}{I}\right)\times Y$	1	
		$\sigma_b = \left(\frac{600\times10^3}{14062500}\right)\times 75$		
		$\sigma_b = 3.2 N/mm^2$	1	4

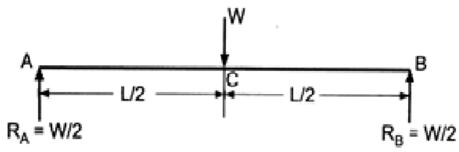
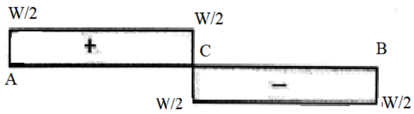
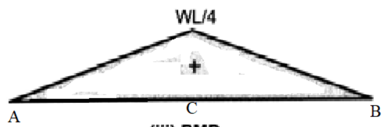
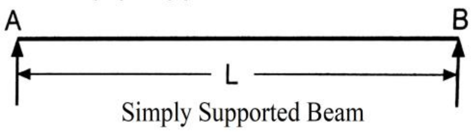
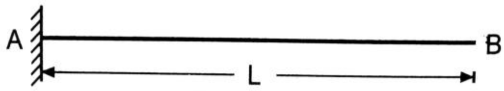
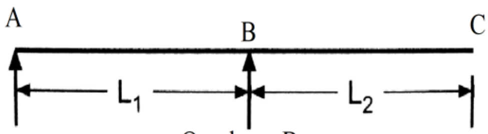
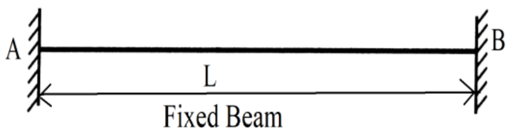
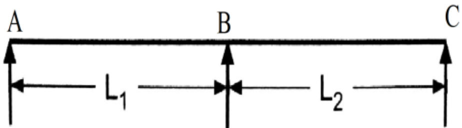
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.2	a)	**Attempt any FOUR of the following:**		(16)
	(i)	**Draw a stress-strain diagram of M.S. and show silent point on it.**		
	Ans.		1	
		Where, A = Limit of proportionality B = Elastic limit C = Upper yield point D = Lower yield point E = Ultimate load point F = Breaking point	1	
	(ii)	**State the Eular's formula and write the meaning of symbol used.**		
	Ans.	Euler's formula, $$P_e = \frac{\pi^2 E I_{min}}{L_e^{\ 2}}$$	1	
		Where, P = Euler's buckling load at failure. E = Modulus of elasticity of column material. I_{min} = Minimum moment of inertia of column section. Le = Effective length of the column which depends upon column end conditions.	1	4
	b)	**A circular steel bar of 10 mm diameter and 1.2m long is subjected to a compressive load in a testing machine. Assuming both ends hinged determine Euler's crippling load. E = 2x10^{5}N/mm^2. Also calculate the safe load if factor of safety is 3.**		

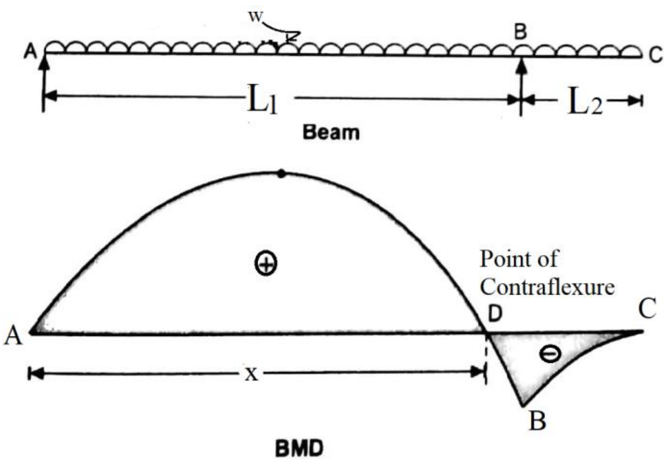
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 2	b) Ans.	Data: D = 10 mm, L =1.2m (both ends hinged), $E = 2\times10^5$ MPa Find: P_{Safe} $I_{min} = I_{XX} = I_{YY}$ $I_{min} = \frac{\pi d^4}{64} = \frac{\pi}{64}\times(10)^4$ $I_{min} = 490.87 mm^4$	1	
		$P_E = \frac{\pi^2 E I_{min}}{L_e^2}$	1	
		$P_E = \frac{\pi^2\times2\times10^5\times490.87}{(1200)^2}$ $P_E = 672.88N$	1	
		$P_{Safe} = \frac{P_E}{FOS} = \frac{672.83}{3} = 224.28N$	1	4
	c)	**A steel rod 10 mm diameter and 2 m in length is at 25° C. Find the new length of rod if the temperature is raised to 70° C. Find the magnitude and nature of the force required to prevent this expansion. Take Es = 2 x 10^5 N/mm^2 and α_S = 12 x 10^{-6} / ° C.**		
	Ans.	Data : d =10 mm, L = 2 m, T_1= 25°C, T_2= 70°C, E= 2 x 10^5 N/mm^2 and α_S = 12 x 10^{-6} / ° C Find: δL, σ, Nature of force $A = \frac{\pi d^2}{4} = \frac{\pi\times10^2}{4} = 78.54mm^2$ Free expansion	1	
		$\delta L = L\times\alpha\times T = L\times\alpha\times(T_2-T_1)$ $=2\times10^3\times12\times10^{-6}\times(70-25)$ $=1.08\,mm$	1	
		If the expansion is prevented, compressive force is developed in the steel rod. $P = \alpha\times T\times E\times A$	1	
		$=\alpha\times(T_2-T_1)\times E\times A$ $=12\times10^{-6}\times(70-25)\times2\times10^5\times78.54$ $=8482.32N$ P= 8.482 kN (C)	1	4

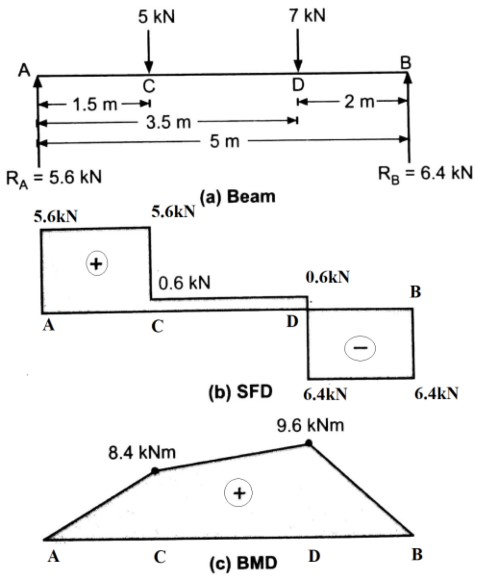
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 2	d)	**A concrete column 300mm X 300mm is reinforced with 4 bars of 20mm diameter and carries a compressive load of 400kN. The modular ratio is 15. Calculate the stresses in steel and concrete. Also calculate the load shared by each material.**		
	Ans.	Data: $A=300\times300\ mm^2$, d=20 mm ϕ No. of steel bar = 4, P = 400kN, m =15 Find: $\sigma_c, \sigma_s, P_c, P_s$ $A_s = n\times\frac{\pi d^2}{4} = 4\times\frac{\pi\times20^2}{4} = 1256.637mm^2$ $A_c = A_g - A_s$ $A_c = 300\times300-1256.637$ $A_c = 88743.363mm^2$ $\sigma_s = m\times\sigma_c$ $\sigma_s = 15\sigma_c$	1	
		$P = P_s + P_c$ $P = \sigma_s A_s + \sigma_c A_c$ $400\times10^3 = (15\sigma_c)\times1256.637 + \sigma_c\times88743.363$ $400\times10^3 = (18849.556+88743.363)\ \sigma_c$ $\boxed{\sigma_c = 3.717N/mm^2}$	1	
		$\sigma_s = 15\sigma_c$ $\sigma_s = 15\times3.717$ $\boxed{\sigma_s = 55.755N/mm^2}$	1	
		$P_s = \sigma_s A_s$ $P_s = 55.755\times1256.637$ $P_s = 70063.795N$ $\boxed{P_s = 70.0637kN}$ $P_c = \sigma_c A_c$ $P_c = 3.717\times88743.363$ $P_c = 329859.080N$ $\boxed{P_c = 329.859kN}$	1	4

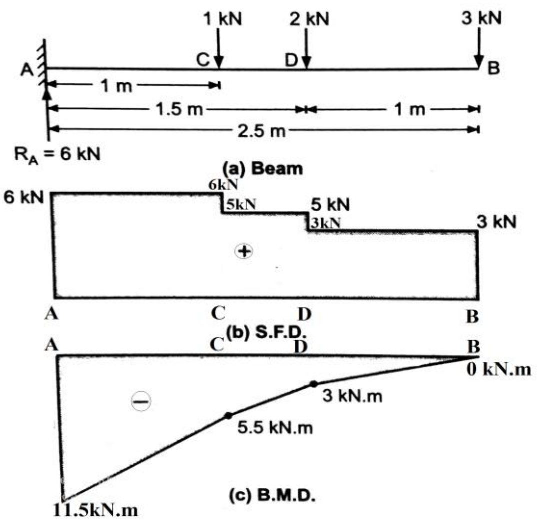
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 2	**e)**	**A bar is subjected to a tensile stress of 100 N/mm^2. Determine the normal and tangential stresses on a plane making an angle of 60^0 with the axis of tensile stress.**		
	Ans.	Data: σ_T = 100N/mm^2 Find: σ_n and σ_t		
		$\theta=90-60=30^0$		
		$\sigma_n=\frac{\sigma_x}{2}+\frac{\sigma_x}{2}\cos2\theta$	1	
		$\sigma_n=\frac{100}{2}+\frac{100}{2}\cos(2\times30)$		
		$\sigma_n=75N/mm^2\ (T)$	1	
		$\sigma_t=\frac{\sigma_x}{2}\sin2\theta$	1	
		$\sigma_t=\frac{100}{2}\sin(2\times30)$		
		$\sigma_t=43.30N/mm^2$	1	4
	f)	**A cylindrical shell 3 m long and 1 m in diameter is subjected to an internal pressure of 1 MPa. If the thickness of the cylindrical shell is 12 mm, find the change in volume of cylindrical shell. Take E= 2 X 10^{5}N/mm^2 and poisson's ratio = 0.3.**		
	Ans.	Data: L= 3m, d= 1m, p= 1 N/mm^2, E= 2 X 10^{5}N/mm^2 , μ= 0.3		
		$\sigma_c=\frac{pd}{2t}=\frac{1\times1000}{2\times12}=41.67N/mm^2$		
		$\sigma_L=\frac{1}{2}\sigma_c=\frac{41.67}{2}=20.83N/mm^2$	1	
		$e_c=\frac{1}{E}(\sigma_c-\mu\sigma_L)=\frac{1}{2\times10^5}(41.67-0.3\times20.83)=0.000177105$	1	
		$e_L=\frac{1}{E}(\sigma_L-\mu\sigma_C)=\frac{1}{2\times10^5}(20.83-0.3\times41.67)=0.000041645$		
		$V=\frac{\pi}{4}d^2\times L=\frac{\pi}{4}(1000)^2\times3000=2356194490mm^3$		
		$\frac{\delta v}{v}=(e_L+2e_c)$	1	
		$\delta v=(e_L+2e_c)V$		
		$\delta v=(0.000041645+2\times0.000177105)\times2356194490$		
		$\delta v=932711.3698mm^3$	1	4

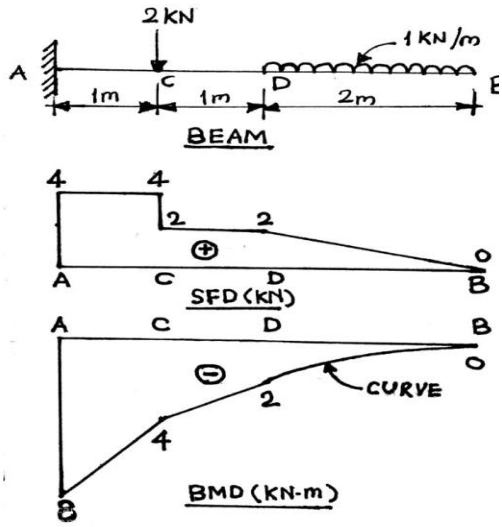
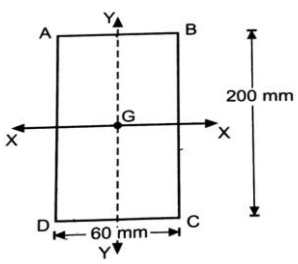
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 3		**Attempt any FOUR of the following:**		(16)
	a)	**Draw S.F. and B.M. diagram for simply supported beam of span 'L' carrying a central point load 'W'. Find the S.F. and maximum B.M.**		
	Ans.	**Support Reactions:** Due to symmetrical Loading $R_A = R_B = \frac{W}{2}$		
		SF Calculations: SF at A= $+\frac{W}{2}$ $C_L = +\frac{W}{2}$ $C_R = +\frac{W}{2} - W = -\frac{W}{2}$ $B_L = -\frac{W}{2}$ $B = -\frac{W}{2} + \frac{W}{2} = 0$ ($\therefore$ OK)	1	
		BM Calculations: BM at A and B = 0 Support A and B is simple BM at $C = +\frac{W}{2} \times \frac{L}{2} = +\frac{WL}{4}$	1	
		Max. S. F = $\frac{W}{2}$ Max. B.M = $\frac{WL}{4}$		

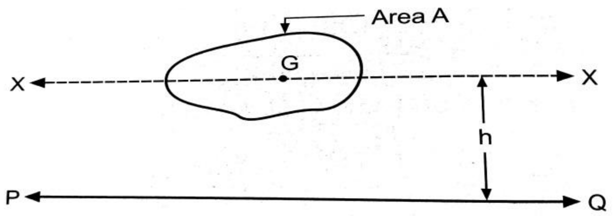
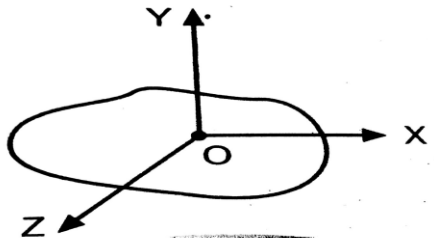
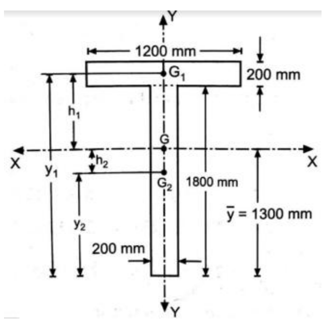
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 3	**a)**	 **(I) Simply supported beam**		
		 **(ii) SFD**	1	
		 **(iii) BMD**	1	4
	b) (i) **Ans.**	**Enlist various types of beam. Draw neat sketch.** **a) Simply Supported Beam** **b) Cantilever Beam**  Simply Supported Beam  Cantilever Beam **c) Overhang Beam**  Overhang Beam **d) Fixed Beam** **e) Continuous Beam**  Fixed Beam  Continuous Beam	2	

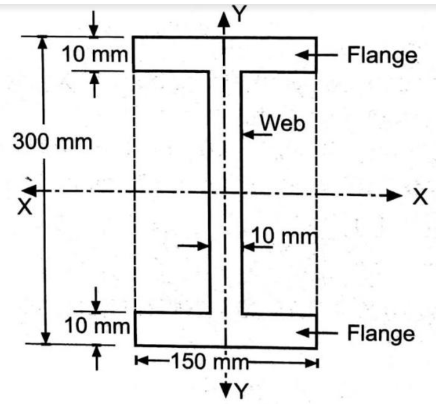
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 3	b) (ii)	**Define point of contraflexure with a neat sketch.**		
	Ans.	**Point of Contra-flexure:** It is the point in bending moment diagram where bending moment changes its sign from positive to negative and vice versa. At that point bending moment is equal to zero. This point is called as point of contra-flexure.	1	
			1	4
	c)	**A simply supported beam of span 5 m carries two point loads of 5kN and 7 kN at 1.5 m and 3.5 m from the left hand support respectively. Draw S.F.D. and B.M.D. showing the important values.**		
	Ans.	**I . Support Reaction:** $\sum M_A = 0$ $5\times1.5+7\times3.5-R_B\times5=0$ $5\times R_B=32$ $R_B = 6.4$ kN $\sum F_y = 0$ $R_A + R_B - 5 + 7 = 0$ $R_A + R_B = 12$ $R_A = 5.6$ kN	1	

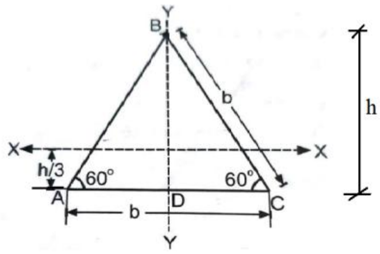
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 3	c)	**II SF Calculation:** SF at A = + 5.6 kN $C_L = +5.6kN$ $C_R = 5.6 - 5 = 0.6kN$ $D_L = +0.6kN$ $D_R = +0.6 - 7 = -6.4kN$ $B_L = -6.4kN$ $B = +6.4 - 6.4 = 0kN$ ($\therefore$ ok)	1	
		III. B.M. calculation: B.M at A and B= 0 Since support A and B are simple. B.M at C = 5.6 × 1.5=8.4 kN-m B.M at D = 6.4× 1.5=9.6 kN-m	1	
			1	4
	d)	**A cantilever beam of span 2.5m carries three point loads of 1kN, 2kN, and 3kN at 1m, 1.5m, and 2.5m from the fixed end. Draw S.F.D. and B.M.D.**		
	Ans.	**I. Support reaction:** $\Sigma Fy = 0$ $R_A - 1 - 2 - 3 = 0$ $R_A = 6kN$		

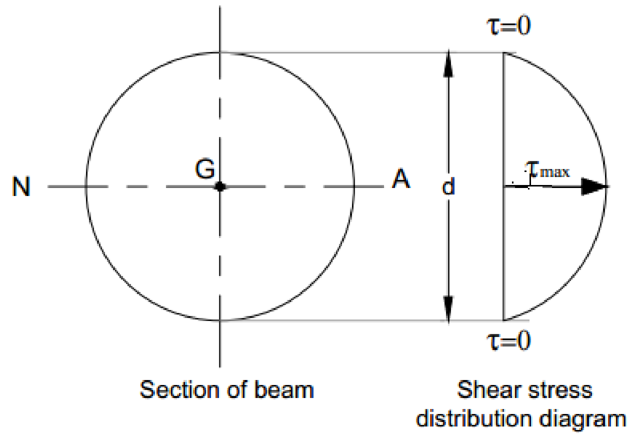
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 3	d)	**II. SF calculation:** SF at A = +6kN C_L = +6kN C_R = +6-1= 5kN D_L = +5kN D_R = +5-2= 3kN B_L = +3kN B= +3-3= 0 ($\therefore$ ok)	1	
		III. BM calculation: BM at B = 0 $\because$ B is free end. $D = -3\times1 = -3$kN-m $C = -3\times1.5 - 2\times0.5 = -5.5$kN-m $A = -3\times2.5 - 2\times1.5 - 1\times1 = -11.5$kN-m	1	
		 	1 1	4
	e)	**Draw bending moment and shear force diagram of a cantilever beam AB 4 m long having its fixed end at A and loaded with a uniformly distributed load 1 kN/m up to 2 m from B and with a concentrated load of 2 kN at 1 m from A.**		
	Ans.	**I. Support reaction:** RA= 2+ (1x 2)= 4 kN		

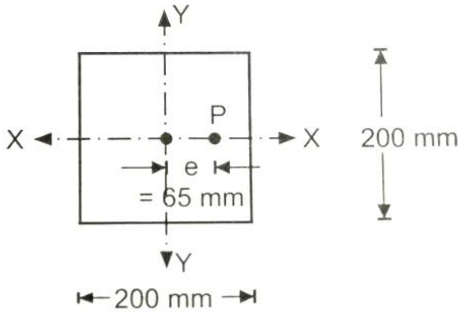
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 3	e)	**II. SF calculation:** SF at A = +4kN C_L = +4kN C_R = +4-2= 2kN D = +2kN B= +2-2= 0 (∴ ok) **III. BM calculation:** BM at B = 0 ∵ B is free end. D = (1× 2)×1= +2kN-m C = (1× 2)× 2=+4kN-m A = (1× 2) ×3+2×1 =+8kN-m 	1 1 1 1	4
	f) Ans.	**Find the moment of inertia of a rectangle 60 mm X 200 mm about its 200 mm edge.** Data: b= AB= 60mm , d= AD= 200mm Find: I_{AD} $I_{AD} = I_G + Ah^2$ $I_{AD} = \frac{db^3}{12} + (b\times d)h^2$ $I_{AD} = \frac{200\times60^3}{12} + (60\times200)\times30^2$ $I_{AD} = 144\times10^5 mm^4$ 	1 1 1 1	4

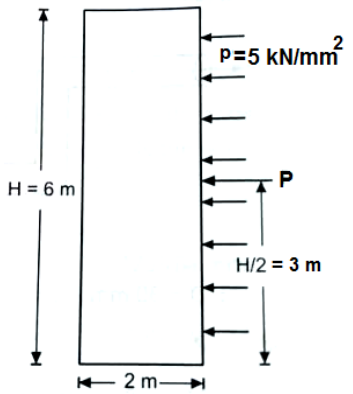
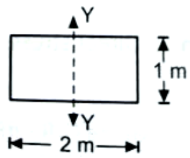
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 4		**Attempt any <u>FOUR</u> of the following:**		**(16)**
	a)	**State parallel axis theorem and perpendicular axis theorem of MI along with sketches.**		
	Ans.	**Parallel axis theorem:** It states that the M. I. of a plane section about any axis parallel to the centroidal axis is equal to the M. I. of the section about the centroidal axis plus the product of the area of the section and the square of the distance between the two axes. $I_{PQ} = I_G + Ah^2$	1	
			1	
		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. $I_{ZZ} = I_{XX} + I_{YY}$	1	
			1	4
	b)	**Calculate MI of a T-section about the centroidal axis XX. Top flange is 1200 x 200 mm and web is 1800 x 200 mm. Total height is 2000 mm.**		
	Ans.			

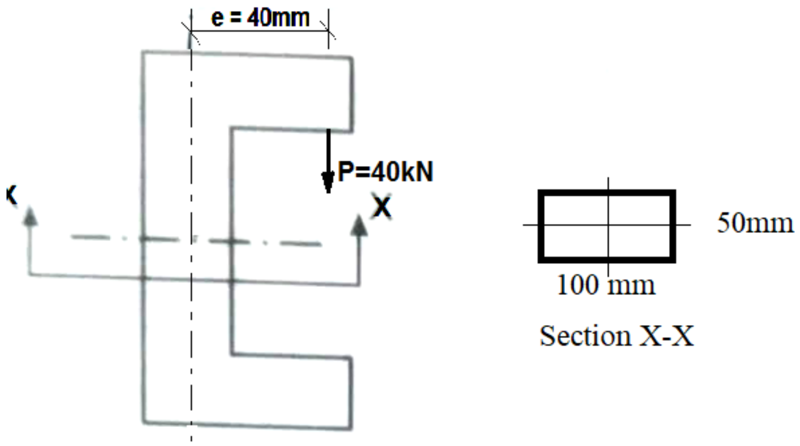
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 4	b)	$a_1 = 1200 \times 200 = 240000\ mm^2$ $a_2 = 1800 \times 200 = 360000\ mm^2$ $y_1 = \frac{200}{2} + 1800 = 1900\,mm$ $y_2 = \frac{1800}{2} = 900\,mm$		
		$\bar{Y} = \bar{Y}_{bottom} = \frac{a_1 y_1 + a_2 y_2}{a_1 + a_2} = \frac{(240000 \times 1900) + (360000 \times 900)}{240000 + 360000} = 1300\,mm$	1	
		$I_{XX} = I_{XX1} + I_{XX2}$ $= \left[I_G + Ah_y^2\right]_1 + \left[I_G + Ah_y^2\right]_2$ $= \left[\frac{bd^3}{12} + A \times \left(\bar{Y} - Y_1\right)^2\right]_1 + \left[\frac{bd^3}{12} + A \times \left(\bar{Y} - Y_1\right)^2\right]_2$	1	
		$= \left[\frac{1200 \times 200^3}{12} + 240000 \times 600^2\right] + \left[\frac{200 \times 1800^3}{12} + 360000 \times 400^2\right]$	1	
		$= \left(0.872 \times 10^{11}\right) + (1.548 \times 10^{11})$ $= 2.42 \times 10^{11}\ mm^4$	1	4
	c)	**A symmetrical I-section of overall depth of 300 mm has its flanges 150 mm x 10 mm and web 10 mm thick. Find the moment of inertia about its cenrtoidal axis, parallel to the flanges.**		
	Ans.		1	
		I_{XX} = 2[Moment of Inertia of 2 flanges] + Moment of inertia of web.	1	
		$I_{XX} = 2\left[\left(\frac{150 \times 10^3}{12}\right) + (150 \times 10) \times 145^2\right]_F + \left[\frac{10 \times 280^3}{12}\right]_W = 8.14 \times 10^7\,mm^4$	2	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 4	c)	**OR**		
		$I_{XX} = \left[\frac{BD^3 - bd^3}{12}\right] = \left[\frac{(150\times300^3)-(140\times280^3)}{12}\right] = 8.14\times10^7 mm^4$	3	4
	d)	**A base 'b' of an equilateral triangle is horizontal show that the centroidal moment of inertia with respect to horizontal and vertical axes are equal. State the value of moment of inertia in terms of 'b'.**		
	Ans.	Find: $I_{XX} = I_{YY}$		
				
		In a triangle ADB,		
		$\tan60^o = \frac{h}{b/2}$		
		$\sqrt{3} = \frac{2h}{b}$		
		$h = \left(\frac{\sqrt{3}}{2}\right)\times b$	1	
		MI of a triangle ABC about XX axis –		
		$I_{XX} = \frac{bh^3}{36} = \frac{b}{36}\left(\frac{\sqrt{3}}{2}b\right)^3 = \frac{b}{36}\times\frac{3\sqrt{3}}{8}b^3$	1	
		$I_{XX} = \frac{\sqrt{3}}{96}b^4$ --------------------- (i)	1	
		MI of a triangle ABC about YY axis –		
		$I_{YY} = \frac{hb^3}{48} = \left(\frac{\sqrt{3}}{2}b\right)\times\frac{b^3}{48}$		
		$I_{YY} = \frac{\sqrt{3}}{96}b^4$ --------------------- (ii)	1	4
		From the equations (i) and (ii)		
		$\mathbf{I_{XX} = I_{YY}} = \frac{\sqrt{3}}{96}b^4$		

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 4	e) Ans.	**State any four assumptions in the theory of simple bending.** 1. The material of the beam is homogeneous and isotropic i.e. the beam made of the same material throughout and it has the same elastic properties in all the directions. 2. The beam is 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 for the material has the same value in tension and compression.	1 (each any four)	4
	f)	**Draw shear stress distribution diagram for a circular section and locate the position of maximum shear stress.**		
	Ans.		4	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 5		**Attempt any FOUR of the following:**		(16)
	a)	**A circular beam of 120 mm diameter is simply supported over a span of 10 m and carries a u.d.l. of 1000 N/m. Find the maximum bending stress produced.**		
	Ans.	Data: d = 120 mm, L = 10 m, W = 1000 N/m. Find σ_{max}		
		BM = $\frac{WL^2}{8} = \frac{1000 \times 10^2}{8} = 12500$ N-m = 12.5 x 10^6N-mm	1	
		I = $\frac{\pi}{64} d^4 = \frac{\pi}{64}(120)^4 = 10.178 \times 10^6 \, mm^4$	1	
		y = $\frac{d}{2} = \frac{120}{2} = 60mm$		
		$\frac{M_{max}}{I} = \frac{\sigma_{max}}{y}$	1	
		$\sigma_{max} = \frac{12.5 \times 10^6}{10.178 \times 10^6} \times 60$		
		σ_{max} = 73.68 N/mm^2	1	4
	b)	**A shaft column 200 mm x 200 mm is subjected to an eccentric load of 90 kN at an eccentricity of 65 mm in the plane bisecting the two opposite faces. Find the maximum and minimum intensities of stress of the base.**		
	Ans.	Data: b = d = 200 mm, P = 95kN, e = 65 mm. Find: σ_{max}, σ_{min}  		
		A = b x d = 200 x 200 = 40000 mm^2		
		$\sigma_o = \frac{P}{A} = \frac{95 \times 10^3}{40000} = 2.375$ N/mm^2	1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 5	b)	$\sigma_b = \frac{M}{Z_{YY}} = \frac{P \times e}{\left(\frac{db^2}{6}\right)} = \frac{95 \times 10^3 \times 65 \times 6}{200 \times 200^2} = 4.63\,N/mm^2$	2	
		$\sigma_{max} = \sigma_o + \sigma_b = 2.375 + 4.63 = 7.005\ N/mm^2$ (C) $\sigma_{min} = \sigma_o - \sigma_b = 2.375 - 4.63 = -2.255\ N/mm^2$ (T)	1	4
	c)	**A masonary wall 6 m high, 2 m thick and 1 m wide is subjected to a horizontal wind pressure of 5 kN/m² on 1 m face. Find the values of resultant stresses at base of the wall masonary weights 20 kN/m³.**		
	Ans.	Data: H = 6 m, t = 2 m, b = 1 m, P = 5kN/mm², ρ = 20 kN/m³ Find: σ_{max} , σ_{min}   		
		Area of the section: A = 2 x 1 = 2 m² **Weight of wall:** W = ρ x A x H = 20 x 10³ x 2 x 6 = 240 x 10³ N		
		Total wind load: P = p x projected area = p x (b x H) = (5 x 10³) x (1 x 6) = 30 x 10³ N	1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 5	c)	$\sigma_o = \frac{W}{A} = \frac{240\times10^3}{2} = 120\times10^3$ N/mm^2	1	
		$\sigma_b = \frac{M}{Z} = \frac{P\times e}{Z} = \frac{P\times\frac{H}{2}}{\frac{b\times t^2}{6}} = \frac{30\times10^3\times\frac{6}{2}}{\frac{1\times2^2}{6}} = 135\times10^3$ N/mm^2	1	
		$\sigma_{max} = \sigma_o + \sigma_b = (120 \text{ x } 10^3) + (135 \text{ x } 10^3)$ $= 255 \text{ x } 10^3$ N/mm^2 (C) $\sigma_{min} = \sigma_o - \sigma_b = (120 \text{ x } 10^3) - (135 \text{ x } 10^3)$ $= - 15 \text{ x } 10^3$ N/mm^2 (T)	1	4
	d)	**A rectangular rod of size 50 mm x 100 mm is bent into C-shape and a load of 40 kN is applied at a distance of 40 mm from the centre of vertical side (eccentricity). Calculate the resultant stresses developed at centroidal section.**		
	Ans.	Data: b = 100 mm, d = 50 mm, P = 40 kN, e = 40 mm Find: Resultant stresses at section XX  A = b x d = 100 x 50 = 5000 mm^2		
		$\sigma_o = \frac{P}{A} = \frac{40\times10^3}{5000} = 8$ N/mm^2	1	
		$\sigma_b = \frac{M}{Z_{YY}} = \frac{P\times e}{db^2/6} = \frac{40\times10^3\times40\times6}{50\times100^2} = 19.2$ N/mm^2	2	
		$\sigma_{max} = \sigma_o + \sigma_b = 8 + 19.2 = 27.2$ N/mm^2 (T) $\sigma_{min} = \sigma_o - \sigma_b = 8 - 19.2 = - 11.2$ N/mm^2 (C)	1	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 5	e)	**Calculate the limit of eccentricity for a circular section having diameter 50 mm.**		
	Ans.	Data: d = 50 mm Find: e		
		For no tension condition, $e \le \frac{Z}{A}$	1	
		$Z = \frac{I}{Y} = \left(\frac{\frac{\pi d^4}{64}}{\frac{d}{2}}\right) = \frac{\pi}{32}\times d^3 = \frac{\pi}{32}\times 50^3 = 12.27\times10^3\ \text{mm}^3$	1	
		$A = \frac{\pi}{4}\times d^2 = \frac{\pi}{4}\times 50^2 = 1.96\times10^3\ \text{mm}^2$	1	
		$e = \frac{Z}{A} = \frac{12.27\times10^3}{1.96\times10^3}$ = 6.25 mm	1	4
	f)	**Calculate the power transmitted by a shaft of 300 mm, with a speed of 200 rpm. If permissible shear stress is 120 N/mm². Take maximum torque as 30% more than average torque.**		
	Ans.	Data: d = 300 mm, N = 200 rpm, τ = 120 N/mm², $T_{max} = 1.3\ T_{avg.}$ Find: P		
		$\frac{T_{max}}{J} = \frac{\tau}{R}$	1	
		$T_{max} = \frac{\pi}{16}\times\tau\times d^3 = \frac{\pi}{16}\times120\times300^3 = 636.173\times10^6$ N-mm $T_{max} = 636.173 \text{ x } 10^3$ N-m.	1	
		$636.173 \text{ x } 10^3 = 1.3\ T_{avg.}$ $T_{avg.} = \frac{636.173\times10^3}{1.3} = 489.36\times10^3$ N-m	1	
		$P = \frac{2\pi\times N\times T_{avg.}}{60} = \frac{2\pi\times200\times489.36\times10^3}{60} = 10.249\times10^6$ W P = 10.249 x 103 kW	1	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q 6.		**Attempt any FOUR of the following:**		(16)
	a)	**State the assumptions (any four) made in theory of pure torsion.**		
	Ans.	**Assumptions in theory of pure torsion:** 1. The shaft is homogeneous and isotropic. 2. The shaft is straight having uniform circular cross-section. 3. Twist along the shaft is uniform. 4. Circular sections remain circular even after twisting. 5. Stresses do not exceed the proportional limit. 6. Plain section before twisting remain plain after twisting and do not twist or wrap. 7. Shaft is loaded by twisting couples in the planes are perpendicular to the axis of the shaft.	1 (each any four)	4
	b)	**A solid circular shaft of 120 mm diameter is transmitting power of 100kW at 150 rpm. Find the intensity of the shear stress induced in the shaft. Take $T_{max.} = 1.4T_{avg.}$.**		
	Ans.	Data: d = 120 mm, P = 100 kW, N = 150 rpm., $T_{max.} = 1.4T_{avg.}$. Find: τ $P = \frac{2\pi \times N \times T_{avg.}}{60}$	1	
		$100 \times 10^3 = \frac{2\pi \times 150 \times T_{avg.}}{60}$ $T_{avg.} = \frac{100 \times 10^3 \times 60}{2\pi \times 150} = 6.37 \times 10^3$ N-m $T_{avg.} = 6.37 \times 10^6$ N-mm $T_{max.} = 1.4\, T_{avg.} = 1.4 \times 6.37 \times 10^6 = 8.91 \times 10^6$ N-mm	1	
		$\frac{T_{max.}}{J} = \frac{\tau}{R}$	1	
		$\tau = \frac{T_{max.}}{J} \times R = \frac{T_{max.}}{\frac{\pi}{32} \times d^4} \times \left(\frac{d}{2}\right) = \frac{8.91 \times 10^6}{\frac{\pi}{32} \times 120^4} \times \left(\frac{120}{2}\right) = 26.268 N/mm^2$ $\boxed{\tau = 26.268 \text{ N/mm}^2}$	1	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 6	c)	**A hollow circular shaft has internal diameter 3/4th of the external diameter and transmits 500 kW at 120 rpm. If the shear stress is limited to 80 N/mm^2 and the angle of twist is not to exceed 1.4^o in 3 m length. Calculate the external and internal diameter take C = 84 kN/mm^2.**		
	Ans.	Data: d = $\frac{3}{4}D$, P = 500 kW, N = 120 rpm, τ = 80 N/mm^2, θ = 1.4^o, L = 3 m, C = 84 kN/mm^2. Find: d and D P = $\frac{2\pi \times N \times T_{avg.}}{60}$ 500 x 10^3 = $\frac{2\pi \times 120 \times T_{avg.}}{60}$ $T_{avg.}$ = 39.79 x 10^3 N-m $T_{avg.}$ = 39.79 x 10^6 N-mm $T_{max.}$ = $T_{avg.}$ = 39.79 x 10^6 N-mm	1	
		Case – I **Diameters of hollow shaft based on Shear Strength Criteria:** $\frac{T_{max.}}{J} = \frac{\tau}{R}$ $\frac{T_{max.}}{J} = \frac{\tau}{R}$ J = $\frac{\pi}{32}\left(D^4 - d^4\right) = 0.098 \times \left(D^4 - 0.316D^4\right) = 0.067D^4$ R= $\frac{D}{2} = 0.5D$ $\frac{39.79 \text{ x } 10^6}{0.067D^4} = \frac{80}{0.5D}$ D^3 = 3.71 x 10^6 **D = 154.84 mm** d = $\frac{3}{4} \times D = \frac{3}{4} \times 154.84$ **d = 116.13 mm**	1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 6	c)	**Case – II** **Diameters of hollow shaft based on Rigidity (Stiffness) Criteria:** $\frac{T_{max.}}{J} = \frac{C\theta}{L}$ $\frac{39.79 \times 10^6}{0.067D^4} = \frac{84\times10^3\times\left(1.4\times\frac{\pi}{180}\right)}{3\times10^3}$	1	
		$D^4 = 868.032 \times 10^6$ **D = 171.64 mm** d = $\frac{3}{4}\times D = \frac{3}{4}\times171.64$ **d = 128.73 mm**	1	4
		Suitable diameters for hollow shaft to transmit the specified power is **External diameter (D) = 172 mm** **Internal diameter (d) = 129 mm**		
	d)	**Find the power that can be transmitted by a shaft 40 mm diameter rotating at 200 rpm, if the maximum permissible shear stress is 85 MPa.**		
	Ans.	Data: d = 40 mm, N = 200 rpm, τ = 85 MPa. Find: P $\frac{T}{J} = \frac{\tau}{R}$ J = $\frac{\pi}{32}\times d^4 = 0.098\times40^4 = 250.88\times10^3 mm^4$	1	
		R= $\frac{40}{2} = 20$ mm $\frac{T}{250.88\times10^3} = \frac{85}{20}$ T = 1066.24×10^3 N-mm T = 1066.24 N-m	1	
		P = $\frac{2\pi\times N\times T}{60} = \frac{2\pi\times200\times1066.24}{60} = 22.33\times10^3$ W	1	
		$\boxed{P = 22.33 \text{ kW}}$	1	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 6	e)	**A hollow shaft is required to transmit a torque of 24 kN-m. The inside diameter is 0.6 times the external diameter. Calculate both the diameters if the allowable shear stress is 80 MPa.**		
		Data: T = 24 kN-m, d = 0.6D, τ = 80 MPa. Find: D and d		
		$\frac{T}{J} = \frac{\tau}{R}$	1	
		J = $\frac{\pi}{32}\left(D^4 - d^4\right) = 0.098 \times \left(D^4 - 0.129D^4\right) = 0.0853D^4$	1	
		R= $\frac{D}{2} = 0.5D$		
		$\frac{24 \text{ x } 10^6}{0.0853D^4} = \frac{80}{0.5D}$	1	
		$D^3 = 1.757 \text{ x } 10^6$ **D = 120.67 mm** d = 0.6D = 0.6 x 120.67 **d = 72.40 mm**	1	4
		Suitable diameters for hollow shaft to transmit the specified Torque is **External diameter (D) = 121 mm** **Internal diameter (d) = 73 mm**		
	f)	**i) Define neutral axis.** **ii) Define the term 'torsional rigidity.**		
	Ans.	**i) Neutral axis:** 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.	2	
		ii) Torsional rigidity: The torque, which produces a twist of one radian in a shaft of unit length is called as 'torsional rigidity'. **OR** It is defined as the product of modulus of rigidity and polar moment of inertia when length of shaft and angle of twist is unity.	2	4