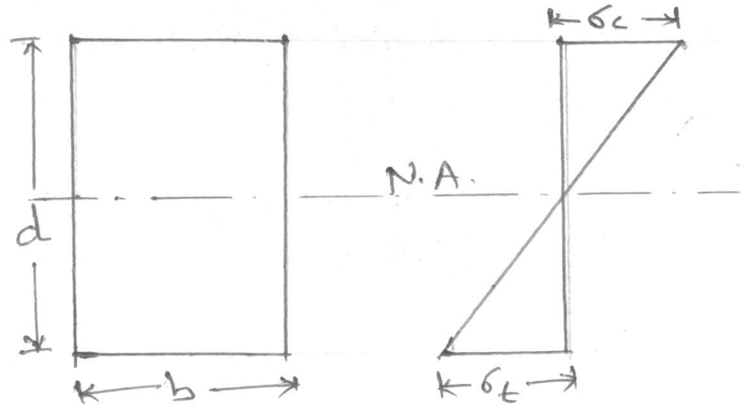
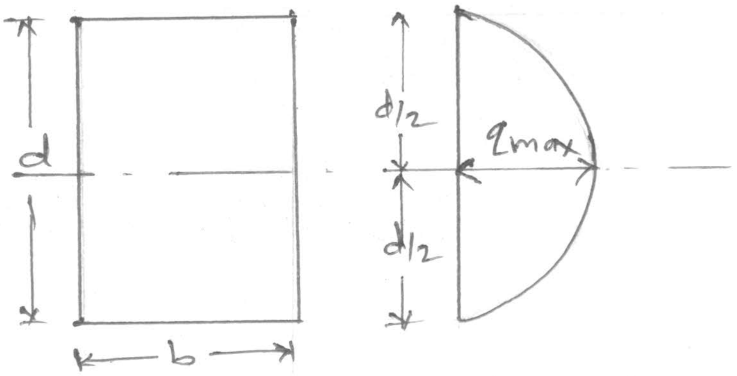
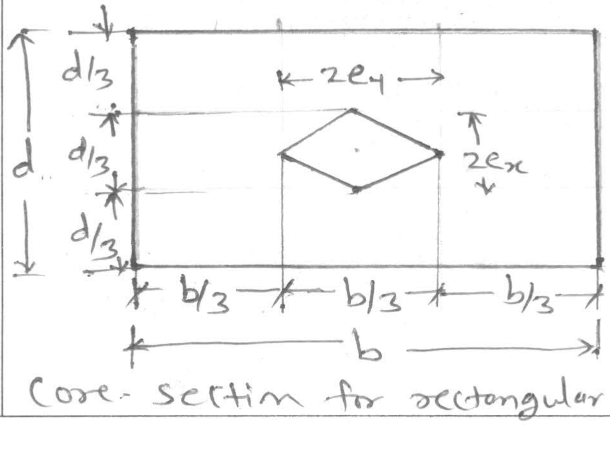
Important Instructions to examiners:

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 candidate and 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 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.

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
Q-1(A)			
(a)	Linear strain : The strain in the direction of applied force is known as linear strain.	1	
	Linear strain = $\frac{\delta L}{L}$		
	Lateral strain : The strain in the direction, right angle or normal to direction of applied force is known as lateral strain	1	
	Lateral strain = $\frac{\delta d}{d}$		2
(b)	Ductility : It is the property of material by virtue of which it can be drawn into wires	1/2 (any two properties with e.g.)	
	e.g. Gold and silver can be drawn in to wires	1/2	
	Malleability : It is the property of the material by virtue of which it can be rolled into thin sheets.	1/2	
	e.g. silver, Aluminium, copper.	1/2	2

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
1 (c)	 Rectangular section Bending stress distribution	1	
	 Rectangular section Shear-stress distribution	1	2
1 (d)	 $2e_x = \frac{d}{3}$ $\therefore e_x = \frac{d}{6}$ And $2e_y = \frac{b}{3}$ $\therefore e_y = \frac{b}{6}$ Core-section for rectangular section.	2	2

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
1 (e)	The phenomenon of material failure under cyclic loading is called as fatigue.	1	
	e.g. Machine parts such as axle shafts, springs etc. are generally subjected to cyclic loading conditions.	1	2
1 (f)	When a homogeneous material is loaded within its elastic limit, the ratio of the lateral strain to the linear strain is constant and is known as poisson's ratio. It is denoted by μ or $\frac{1}{m}$	2	2
1 (g)	In thin cylinder, circumferential stresses are developed in the tangential direction to the perimeter (circumference) of the cylinder.	1/2	
	As a result of circumferential stress, the cylinder has a tendency to split in two two troughs	1/2	

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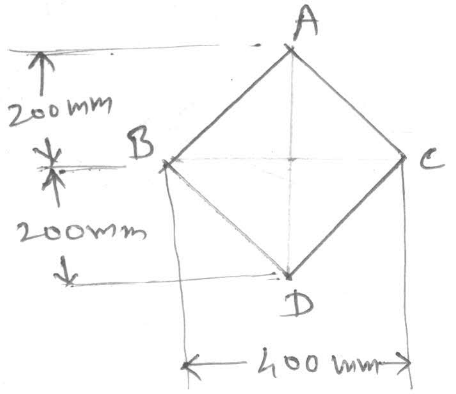
Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	Longitudinal stresses are developed in the direction parallel to the longitudinal axis of the cylinder	1/2	
	As a result of this cylinder has a tendency to split into two small cylinders.	1/2	2
1 (h)	Normal stress on an oblique section		
	$\sigma_n = \frac{\sigma_x}{2}(1+\cos 2\theta) + q \sin 2\theta$	1	
	shear stress on an oblique section		
	$\sigma_t = \frac{\sigma_x}{2} \sin 2\theta - q \cos 2\theta$	1	2
Q.1(B)			
(a)	Given data: $d = 20\,mm$, $t = 3\,mm$		
	shear stress $q = 180\,MPa = 180\,N/mm^2$		
	Shearing area of plate, (A) = Circumference of hole × thickness of plate		

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	$\therefore \quad A = \pi d \times t$	1	
	$= \pi \times 20 \times 3 = 188.495 \text{ mm}^2$	1	
	And, Shearing force, $(P) = q \times A$	1	
	$= q \times \pi d t$		
	$= 180 \times \pi \times 20 \times 3$		
	$= 33929.2 N$	1	
	$\therefore$ Required force to punch the hole is $P = 33929.2 N$		4
1.B (b)			
	Here $\Delta ABC = \Delta BCD$ $b = 400$ mm & $h = 200$ mm		
	M.I of square section about it's diagonal BC = M.I of ΔABC about its base BC + M.I of ΔCBD about its base BC		
	$\therefore I_{BC} = \left(\frac{bh^3}{12}\right)_{ABC} + \left(\frac{bh^3}{12}\right)_{CBD}$	1	

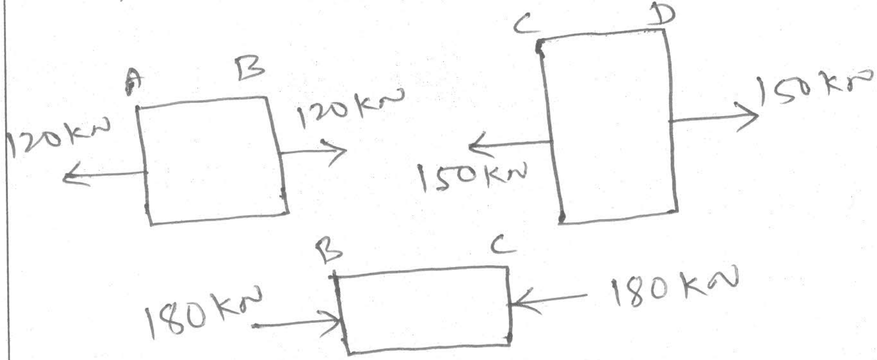
Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	$\therefore I_{BC} = 2 \times \frac{bh^3}{12}$	1	
	$= 2 \times \frac{(400 \times 200^3)}{12}$		
	$= 5.33 \times 10^8 \ mm^4$	2	4
1.B (C)	Given data: $d = 100\ mm$, $p = 10\ N/mm^2$	1	
	hoop stress $\sigma_c = 120\ N/mm^2$		
	Hoop stress, $\sigma_c = \frac{pd}{2t}$	1	
	$120 = \frac{10 \times 100}{2 \times t}$		
	$\therefore t = \frac{10 \times 100}{2 \times 120}$		
	$\Rightarrow t = 4.166\ mm$	2	4
Q.2			
(a)	Assumptions of Euler's theory	any four 4 (1 mark for each)	
	(1) The compressive load is exactly axial i.e it passes through the centroid of the column section.		

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	(2) The material of the column is perfectly homogeneous and isotropic. (3) The column is initially straight and of uniform lateral dimensions. (4) The column is long and fails due to buckling only. (5) Shortening of the column due to direct compression is neglected. (6) The self weight of the column is neglected. (7) The stress do not exceed the limit of proportionality.		4
2 (b)	Given data: Column area, $A = 400 \times 400 = 16 \times 10^4 \text{ mm}^2$ Area of steel, $A_s = 4 \times \frac{\pi d^2}{4} = 4 \times \frac{\pi (20)^2}{4} = 1256.64 \text{ mm}^2$ $\therefore$ Area of concrete, $A_c = A - A_s = 16 \times 10^4 - 1256.64 = 158743.36 \text{ mm}^2$		

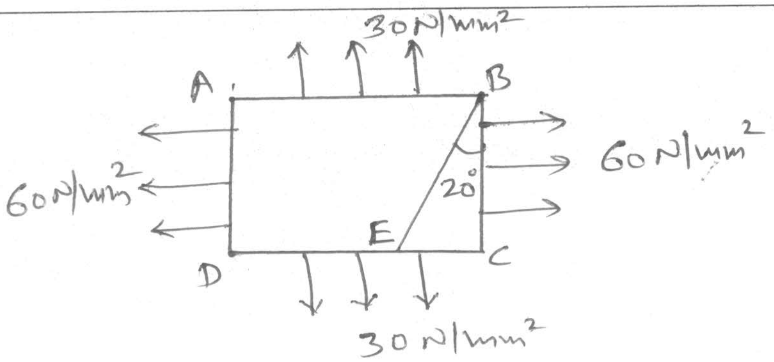
Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	Load, $P = 500\,kN = 500\times10^3\,N$ $E_s = 200\,GPa = 200\times10^3\,N/mm^2$ $\quad E_c = 100\,GPa = 100\times10^3\,N/mm^2$ By relation, $P = \sigma_s A_s + \sigma_c A_c$ $500\times10^3 = \sigma_s\times1256.64 + \sigma_c\times158743.36$ ——— (1)	1	
	Again by using, $\frac{\sigma_s}{E_s} = \frac{\sigma_c}{E_c}$ $\therefore \sigma_s = \frac{E_s}{E_c}\cdot\sigma_c$ $\therefore \sigma_s = \frac{200\times10^3}{100\times10^3}\cdot\sigma_c$ $\therefore \sigma_s = 2\sigma_c$	1	
	put this value in eq^n (1), $\therefore 500\times10^3 = 1256.64\times2\sigma_c + \sigma_c\times158743.36$ $500\times10^3 = 161256.64\times\sigma_c$ $\Rightarrow \sigma_c = 3.1\,N/mm^2$	1	

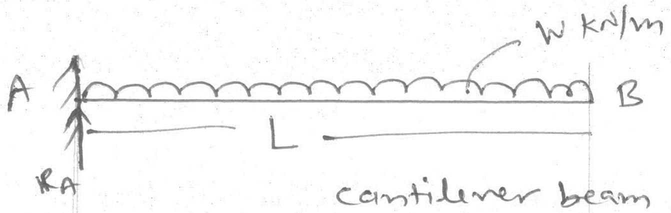
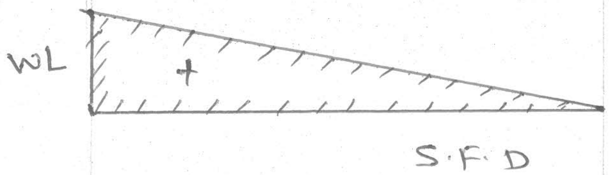
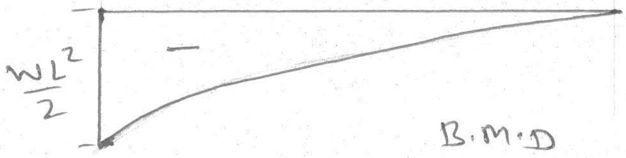
Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	$\therefore \sigma_s = 2\sigma_c$ $= 2 \times 3.1$ $= 6.2 \ N/mm^2$	1	4
2. (C)	For hollow cylinder, $D = 100mm \quad t = 10mm$ $\therefore$ Inside dia, $d = 100 - 2t$ $= 100 - 20$ $= 80mm$ $P = 250kN$, $E = 2\times10^5 \ MPa$ $= 250\times10^3 \ N$, $= 2\times10^5 \ N/mm^2$ $\mu = 0.25$ $L = 800mm$ Area of cylinder, $A = \frac{\pi}{4}(D^2 - d^2)$ $= \frac{\pi}{4}(100^2 - 80^2)$ $= 2827.43 \ mm^2$	1	
	$\therefore$ Change in length of cylinder $\delta L = \frac{PL}{AE}$ $= \frac{250\times10^3\times800}{2827.43\times2\times10^5}$ $= 0.353$ mm (increase)	1	

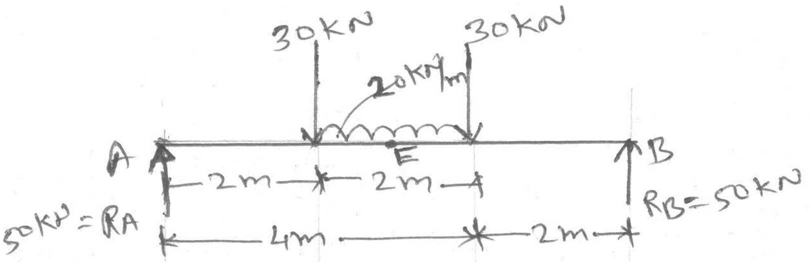
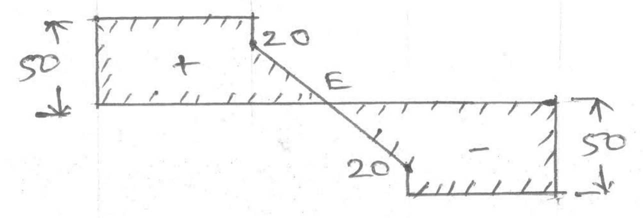
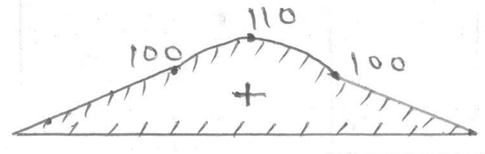
Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	Linear strain, $e = \frac{\delta L}{L} = \frac{0.353}{800}$		
	$\Rightarrow e = 0.000442$		
	Lateral strain, $e_L = \mu \cdot e$		
	$= 0.25 \times 0.000442$		
	$= 0.0001105$	1	
	also $e_L = \frac{\delta D}{D}$		
	$\therefore 0.0001105 = \frac{\delta d}{100}$		
	$\Rightarrow \delta D = 0.01105$ mm (decrease)	1	4
2 (d)			
	Diameter, $d = 30$ mm		
	fall in temperature, $t = 70 - 20$		
	$= 50^\circ c$		
	Length of bar $L = 10$ m		
	$= 10000$ mm		
	$\alpha = 12 \times 10^{-6} /^\circ c$, $E = 2 \times 10^5$ N/mm^2		
	$\therefore$ Temperature stress,		
	$\sigma = \alpha t E$	1	
	$= 12 \times 10^{-6} \times 50 \times 2 \times 10^5$		
	$= 120$ N/mm^2 (Tensile)	1	

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	Reactions at the clamps, $P = \sigma \cdot A$ $= \alpha t E \times \left(\frac{\pi d^2}{4}\right)$ $= 120 \times \frac{\pi (30)^2}{4}$ $= 84823\ N$	1	
	$= 84.823\ kN$	1	4
2. (e)	For the equilibrium of entire bar, $(\Sigma F_x = 0)$, $-120 + 200 - P + 150 = 0$ $\therefore P = 230\ kN$	1	
	F.B.D's for each section :  	1	
	Here section AB & CD are under tension and section BC is under compression. Now $\delta L_1 = \frac{P_1 L_1}{A_1 E}$		

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	$\therefore \delta L_1 = \dfrac{120\times10^3\times1000}{30\times30\times2\times10^5}$	1/2	
	$= 0.666\ mm$		
	$\delta L_2 = -\dfrac{P_2 L_2}{A_2 E}$		
	$= -\dfrac{180\times10^3\times1000}{20\times20\times2\times10^5}$		
	$= -2.25\ mm$	1/2	
	& $\delta L_3 = \dfrac{P_3 L_3}{A_3 E}$		
	$= \dfrac{150\times10^3\times1000}{40\times40\times2\times10^5}$		
	$= 0.468\ mm$	1/2	
	$\therefore$ Net change in the length		
	$\delta L = 0.666 - 2.25 + 0.468$		
	$= -1.116\ mm$	1/2	4
	(-Negative sign indicates decrease in the length of member ABCD)		

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
2. (f)	 		
	$\sigma_x = 60 N/mm^2$, $\sigma_y = 30 N/mm^2$		
	$\theta = 20^\circ$		
	Normal stress on plane BE,		
	$\sigma_n = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 2\theta$	1/2	
	$= \frac{60+30}{2} + \frac{60-30}{2} \cos(2\times 20)$		
	$= 45 + 15 \cos 40$		
	$= 56.49 N/mm^2$	1	
	Tangential stress on plane BE,		
	$\sigma_t = \frac{\sigma_x - \sigma_y}{2} \sin 2\theta$	1/2	
	$= \frac{60-30}{2} \times \sin(2\times 20)$		
	$= 15 \times \sin 40$		
	$= 9.641 N/mm^2$	1	

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	Angle of obliquity,		
	$\phi = \tan^{-1} \frac{\sigma_t}{\sigma_n}$	1/2	
	$= \tan^{-1} \frac{9.641}{56.49}$		
	$\therefore \phi = 9.68^\circ$	1/2	4
Q.3			
(a)			
		1	
		1	

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	Support Reaction: $\Sigma F_y = 0 \quad \therefore R_A - WL = 0$ $\therefore R_A = WL$ ---kN Shear force calculations: S.F at A, $F_A = R_A = WL$ S.F at B, $F_B = 0$	1	
	Bending moment calculations: B.M. at 'A' is maximum i.e $M_A = M_{max}$ & $M_A = -\frac{WL^2}{2}$ (Hogging)	01	4
3. (b)			
	SFD 	1	
	BMD 	1	

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<tr><th>Q. NO.</th><th>MODEL ANSWER</th><th>MARKS</th><th>TOTAL MARKS</th></tr>
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Support reactions :

$\Sigma F_y = 0$

$R_A - 30 - 40 - 30 + R_B = 0$

$\Rightarrow R_A + R_B = 100 \quad \text{--- (1)}$

$\Sigma M_A = 0$

$\therefore (30 \times 2) + (40 \times 3) + (30 \times 4) - R_B \times 6 = 0$

$60 + 120 + 120 = 6 R_B$

$\Rightarrow R_B = 50 \text{ kN}$

put this value in eq^n (1),

$R_A + 50 = 100$

$\therefore R_A = 50 \text{ kN}$

SF calculations :

$F_{A_L} = 0$, $F_{A_R} = 50$

(+) ↑ (−) ↓ sign. conv.

$F_{C_L} = 50 \text{ kN}$, $F_{C_R} = 50 - 30 = 20 \text{ kN}$

$F_{D_L} = 20 - 40 = -20 \text{ kN}$ $\quad F_{D_R} = -20 - 30 = -50 \text{ kN}$

$F_{B_L} = -50 \text{ kN}$ $\quad F_{B_R} = -50 + 50 = 0$

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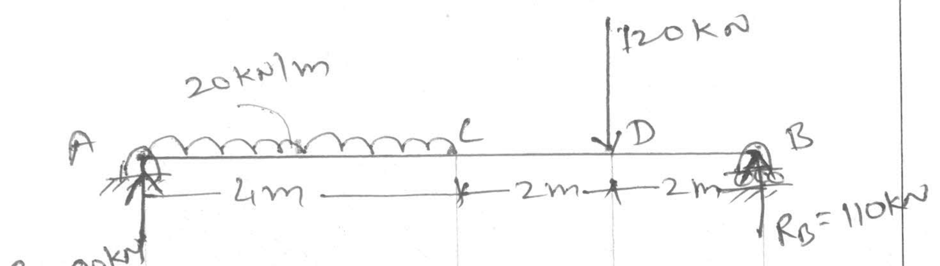
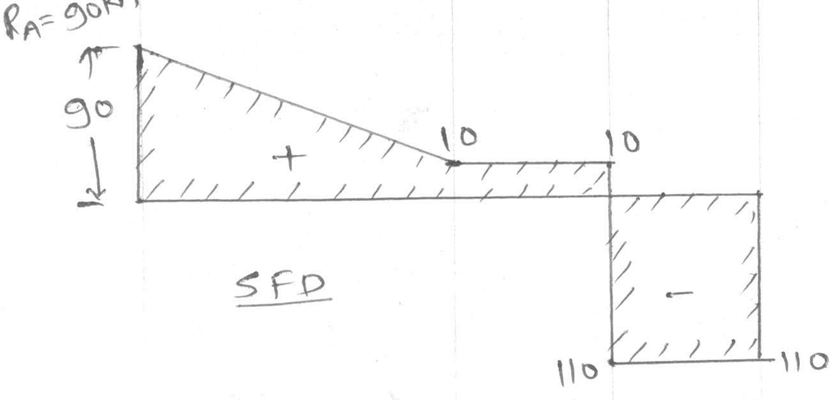
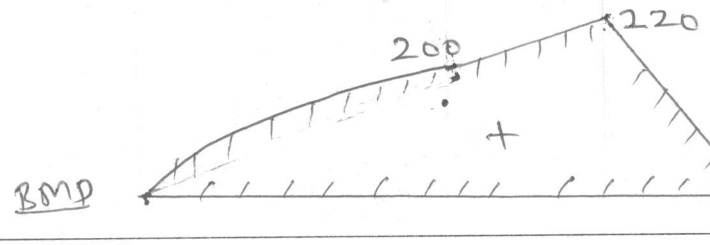
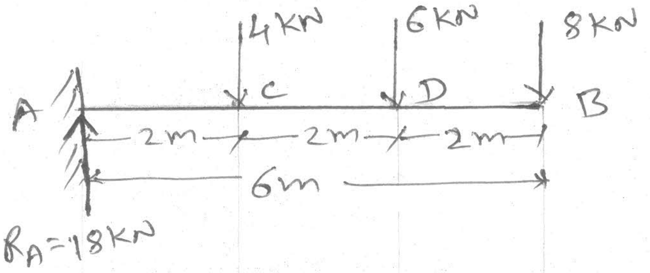
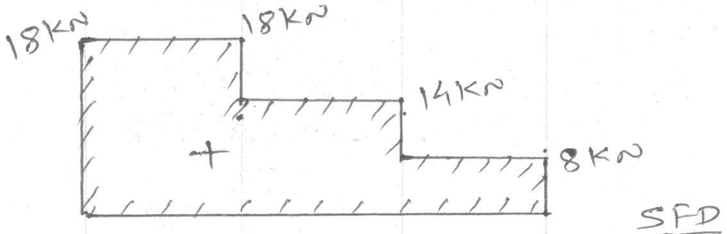
Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	B.M Calculations $M_A = 0$ & $M_B = 0$ $M_C = 50 \times 2$ $= 100$ kN.m $M_D = 50 \times 2$ $= 100$ kN.m $M_E = 50 \times 3 - (30 \times 1) - (20 \times \frac{1}{2})$ $= 110$ kN.m	$\frac{1}{2}$	4
3. (C)			
		1	
		1	

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	Support Reaction calculations: $\Sigma F_y = 0$, $R_A - 80 - 120 + R_B = 0$ $\therefore R_A + R_B = 200$ —— (1) $M_A = 0$, $(80\times2) + (120\times6) = 8R_B$ $160 + 720 = 8R_B$ $\therefore R_B = 110\ kN$ put this value in eq^n (1). $\therefore R_A + 110 = 200$ $\therefore R_A = 90\ kN$		4
	Shear Force calculations: $F_{A_L} = 0$ $F_{A_R} = 0$ $F_{C_L} = 90 - 80 = 10\ kN$ $F_{C_R} = 10\ kN$ $F_{D_L} = 10\ kN$ $F_{D_R} = 10 - 120 = -110\ kN$ $F_{B_L} = -110\ kN$ $F_{B_R} = -110 + 110 = 0$	1	
	Bending moment calculations: B.M at point A & B are zeros. i.e $M_A = 0$ & $M_B = 0$ B.M at 'C' $M_C = (90\times4) - (80\times2)$		

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	$\Rightarrow M_C = 200$ kN·m	1	
	B.M at 'D', $M_D = 110 \times 2$		
	$= 220$ kN·m		

3 (d)





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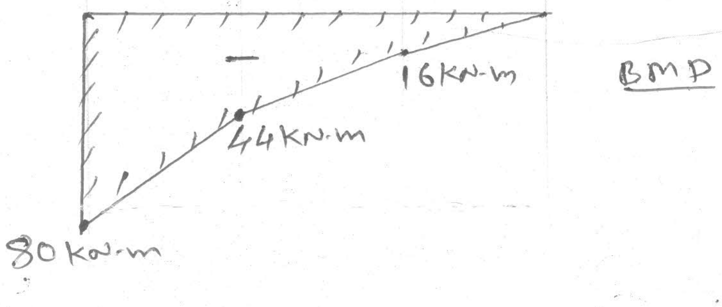

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Support reaction:

$\Sigma F_y = 0$,

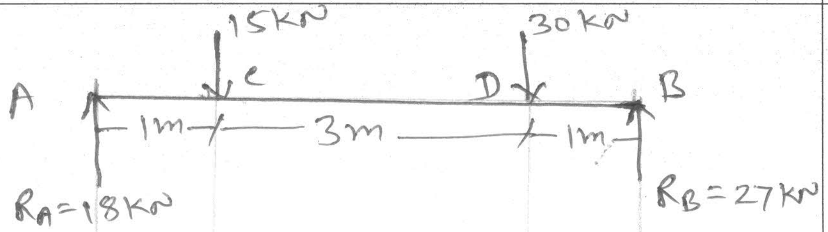
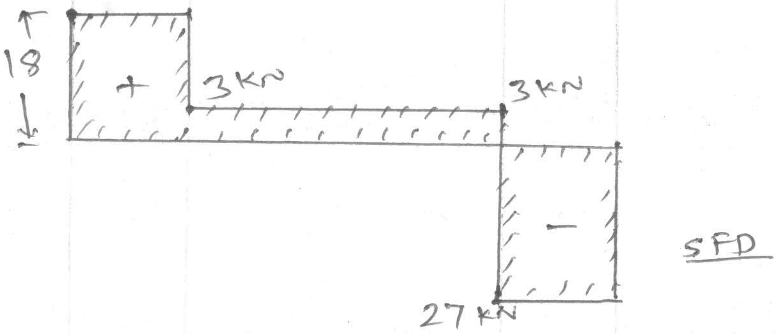
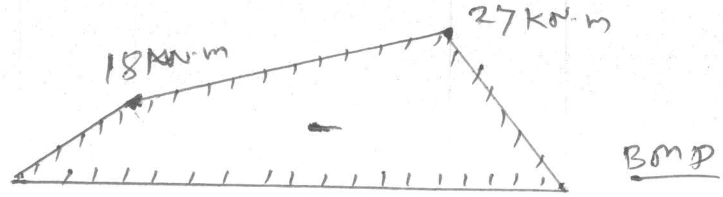
$R_A - 4 - 6 - 8 = 0$

$\Rightarrow R_A = 18$ kN

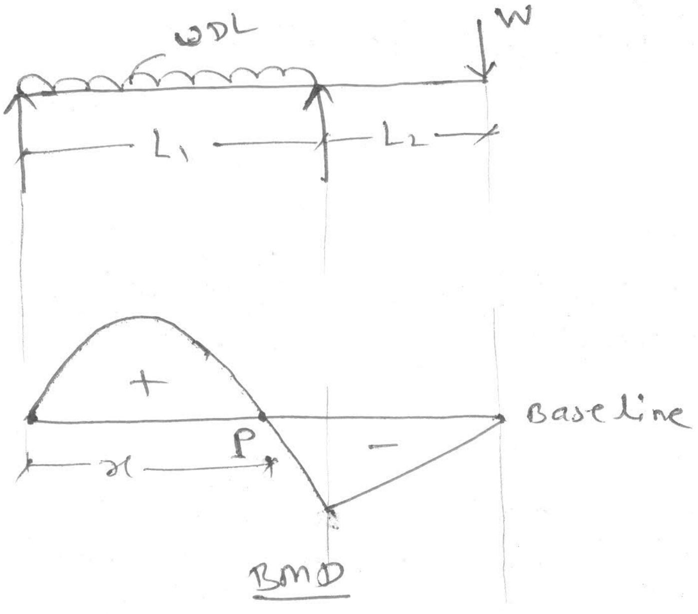
SF calculations:

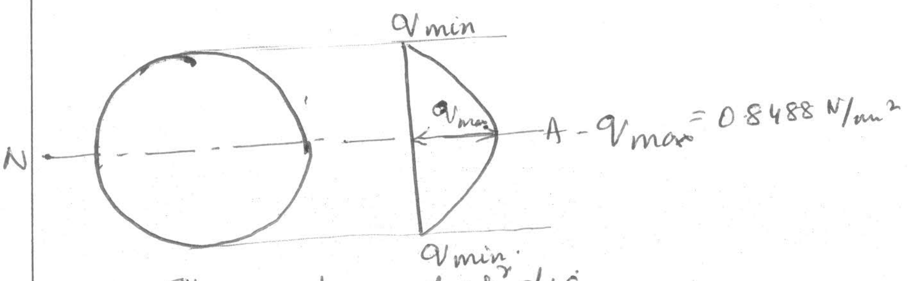
$F_{B_R} = 0$ $\quad F_{B_L} = 8$ kN

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	$F_{DR} = 8\,kN$ $\quad F_{DL} = 8+6 = 14\,kN$		
	$F_{CR} = 14\,kN$ $\quad F_{CL} = 14+4 = 18\,kN$	1	
	$F_{AR} = 18\,kN$ $\quad F_{AL} = 18-18 = 0$		
	BM calculations:		4
	B.M at free end is zero		
	i.e $M_B = 0$		
	$M_D = -8\times2 = -16\,kN.m$	1	
	$M_C = -(8\times4) - (6\times2) = -44\,kN.m$		
	$M_A = -(8\times6) - (6\times4) - (4\times2) = -48 - 24 - 8 = -80\,kN.m$		
3 e	Support reactions:		
	$R_A - 15 - 30 + R_B = 0$		
	$\Rightarrow R_A + R_B = 45$ —— (1)		

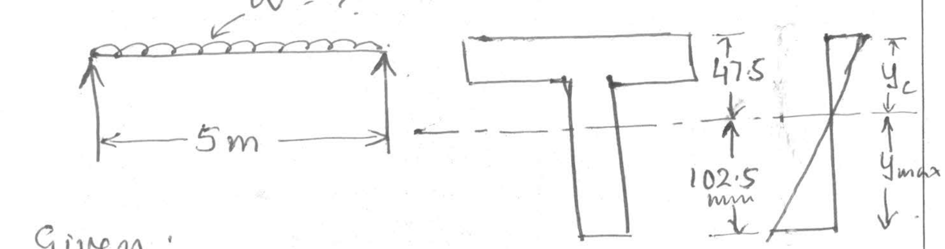
Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
3e			
		1	
		1	
	$\Sigma M_A = 0$		
	$(15\times1)+(30\times4)-5R_B=0$		
	$15+120=5R_B$		
	$\Rightarrow R_B = 27\,KN$		
	put in eqn (1),		
	$R_A + 27 = 45$		
	$\Rightarrow R_A = 18\,KN$		
	SF calculations:		
	$F_{A_L} = 0$ $\quad F_{A_R} = 18\,KN$		
	$F_{C_L} = 18\,KN$ $\quad F_{C_R} = 18-15 = 3\,KN$		

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	$F_{DL} = 3$ $F_{DR} = 3-30 = -27$ KN	1	
	$F_{BL} = -27$ KN $F_{BR} = -27+27 = 0$		4
	B.M. calculations: B.M at points A & B are zero i.e. $M_A = 0$, $M_B = 0$	1	
	$M_C = 18 \times 1 = 18$ KN.m $M_D = 18\times4 - (15\times3) = 27$ KN.m		
3 (f)	(i) The rate of change of shear force with respect to the distance is equal to the intensity of loading $\frac{dF}{dx} = w$	1	
	The rate of change of bending moment at any section is equal to the shear force at that section. $\frac{dM}{dx} = F$	1	2

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
	(ii) In an overhanging beam, due to variation of sagging and hogging, bending moment changes its sign w.r.t base line and crosses the base-line at a point called as point of contraflexure. At this point the B.M is zero	1	
	 P = point of contraflexure. (BM=0)	1	2

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
4. (a)	Given: $D = 100 mm,\ S = 5 kN = 5 \times 10^3 N$ Area $A = \frac{\pi}{4} D^2 = \frac{\pi}{4} \times 100^2 = 7853.98\ mm^2$		
	$q_{av} = \frac{S}{A} = \frac{5 \times 10^3}{7853.98} = 0.6366\ N/mm^2$	1	
	$q_{max} = \frac{4}{3} q_{av} = \frac{4}{3} \times 0.6366 = 0.8488\ N/mm^2$ $\boxed{q_{max} = 0.8488\ N/mm^2}$	1	4M.
	$\boxed{q_{min} = 0\ N/mm^2}$	1/2	
	 Shear stress dist^r dia	1 1/2	

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
4 (b)			4



Given :

$\sigma_{max} = 160 \text{ MPa} = 160 \text{ N/mm}^2$

$l = 5 \text{ m}$

$I_{xx} = 45 \times 10^6 \text{ mm}^4, \; C_{xx} = \bar{y}_{top} = 47.5 \text{ mm}$

$\bar{y}_{base} = \bar{y}_{max} = 150 - 47.5 = 102.5 \text{ mm}$ — 1/2

Using bending eq^n. — 1

$$\frac{M_{max}}{I_{xx}} = \frac{\sigma_{max}}{y_{max}}$$

$$\therefore M_{max} = \frac{\sigma_{max}}{y_{max}} \times I_{xx} = \frac{160}{102.5} \times 45 \times 10^6$$

$$= 70.243 \times 10^6 \text{ N-mm}$$ — 1/2

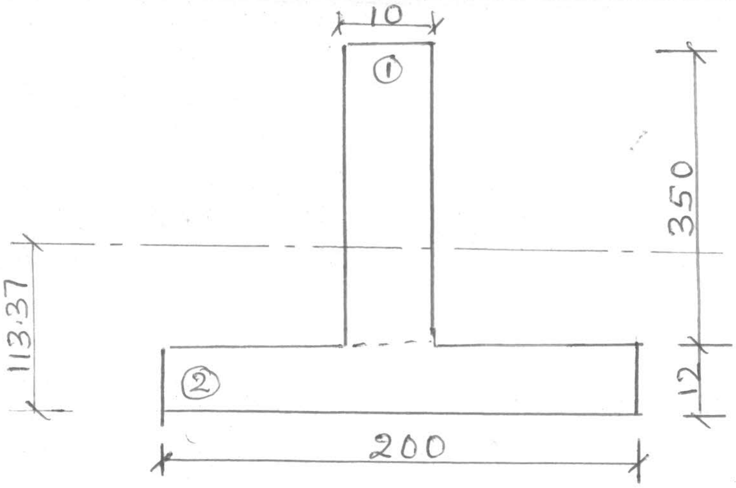
$$M_{max} = \frac{wl^2}{8}$$ — 1

Taking w in N/mm.

$$70.243 \times 10^6 = \frac{w (5 \times 10^3)^2}{8}$$

or $\boxed{w = 22.478 \text{ N/mm} = 22.478 \text{ kN/m}}$ — 1

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
4. (C)			



Given:

$a_1 = 350 \times 10 = 3500\ mm^2$ | $a_2 = 200 \times 12 = 2400\ mm^2$

$y_1 = 12 + \frac{350}{2} = 187\ mm$ | $y_2 = \frac{12}{2} = 6\ mm.$

$a = a_1 + a_2 = 5900\ mm^2$

$\bar{y}_{bottom} = \frac{a_1 y_1 + a_2 y_2}{a} = \frac{(3500 \times 187) + (2400 \times 6)}{5900} = 113.37\ mm$ — 1

$h_1 = y_1 - \bar{y} = 187 - 113.37 = 73.63\ mm$

$h_2 = \bar{y} - y_2 = 113.37 - 6 = 107.37\ mm.$

$I_{xx_1} = \frac{b_1 d_1^3}{12} + a_1 h_1^2 = \frac{10 \times 350^3}{12} + 3500(73.63)^2$ — 1 — Total: 4

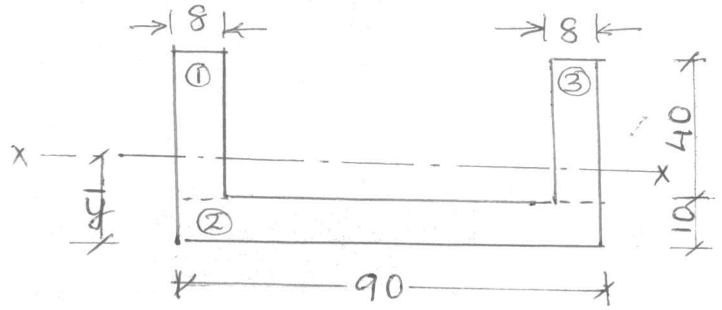
$I_{xx_1} = \underline{54703985}.82\ mm^4$

$I_{xx_2} = \frac{b_2 d_2^3}{12} + a_2 h_2^2 = \frac{200 \times 12^3}{12} + 2400(107.37)^2$ — 1

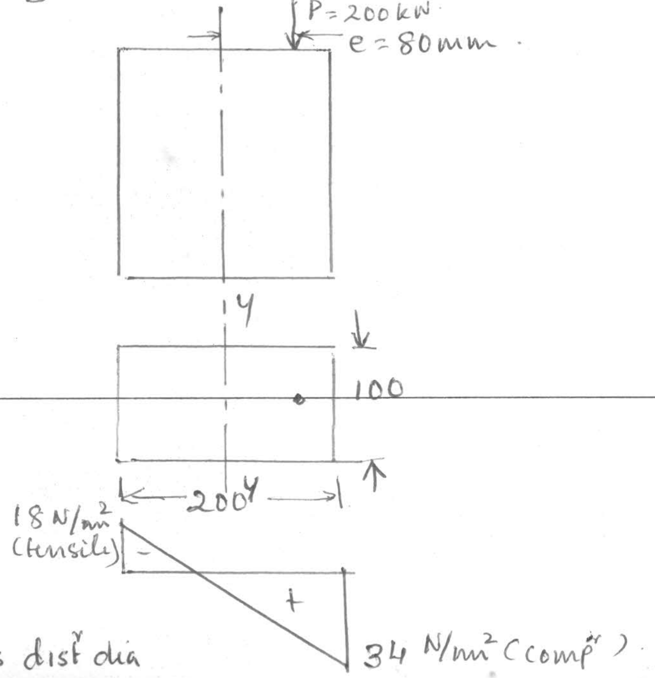
$I_{xx_2} = 27696760.56\ mm^4.$

$\therefore I_{xx} = I_{xx_1} + I_{xx_2} = 82400746.38\ mm^4.$ — 1

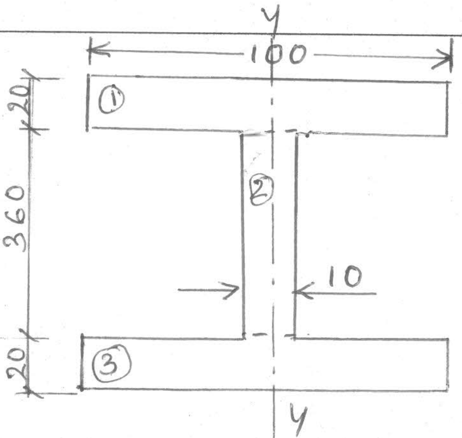
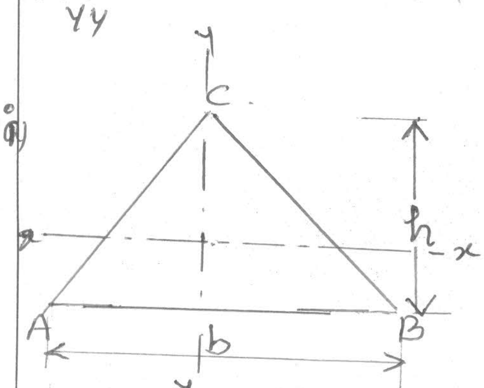
$\boxed{I_{xx} = 82.4 \times 10^6\ mm^4}$

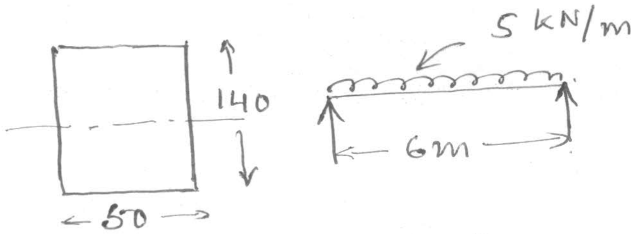
Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
4. (d).			
	$a_1 = 8 \times 40 = 320\ mm^2 = a_3$, $a_2 = 90 \times 10 = 900\ mm^2$.		
	$y_1 = 10 + \frac{40}{2} = 30\ mm = y_3$, $y_2 = 10/2 = 5\ mm$.		
	$h_1 = y_1 - \bar{y} = 30 - 15.39 = 14.61\ mm = h_3$.		
	$h_2 = \bar{y} - y_2 = 15.39 - 5 = 10.39\ mm$.		
	$A = a_1 + a_2 + a_3 = 1540\ mm^2$.		
	$\bar{y}_{bottom} = \frac{a_1 y_1 + a_2 y_2 + a_3 y_3}{A} = \frac{2(320 \times 30) + (900 \times 5)}{1540} = 15.39\ mm$	1	
	$I_{xx_1} = I_{xx_3} = \frac{b_1 d_1^3}{12} + a_1 h_1^2$		
	$I_{xx_1} = I_{xx_3} = \frac{8 \times 40^3}{12} + 320(14.61)^2 = 110971.339\ mm^4$	1	
	$I_{xx_2} = \frac{b_2 d_2^3}{12} + a_2 h_2^2 = \frac{90 \times 10^3}{12} + 900(10.39)^2$		4
	$I_{xx_2} = 104656.89\ mm^4$.	1	
	$I_{xx} = 2(I_{xx_1}) + I_{xx_2} = 2(110971.34) + 104656.89$		
	$I_{xx} = 32.66 \times 10^4\ mm^4$.		
	$k_{xx} = \sqrt{\frac{I_{xx}}{A}} = \sqrt{\frac{32.66 \times 10^4}{1540}} = 14.56\ mm$.	1	

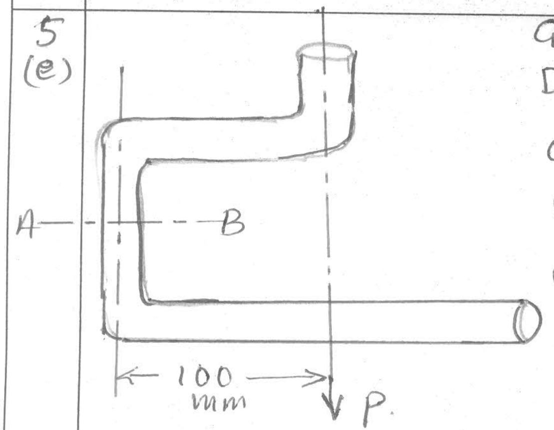
Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
5 (c)	For no tension cond^n		
	$D = 40\,mm$, $A = \frac{\pi}{4} D^2$ & $\sigma_0 = \sigma_b$, $\frac{P}{A} = \frac{M}{Z} = \frac{P.e}{Z}$		
	Limit of eccentricity 'e' $= \frac{Z}{A}$	1	
	$Z = \frac{I}{y} = \frac{\pi/64\, D^4}{D/2} = \frac{\pi}{32} D^3$	1½	4
	$\therefore\ e = \frac{Z}{A} = \frac{\pi/32\, D^3}{\pi/4\, D^2} = D/8 = \frac{40}{8} = \underline{\underline{5\,mm}}$	1½	
5 (d)	$P = 200\,kN$, $e = 80\,mm$, $b = 200\,mm$, $d = 100\,mm$.		
	$A = b \times d = 2 \times 10^4\,mm^2$		
	Direct stress $\sigma_0 = \frac{P}{A} = \frac{200 \times 10^3}{2 \times 10^4} = 10\,N/mm^2$	1	
	Bending stress $\sigma_b = \frac{M}{Z_{yy}} = \frac{P.e}{db^2/6} = \frac{6P.e}{db^2}$		
	$\sigma_b = \frac{6 \times 200 \times 10^3 \times 80}{100 \times 200^2} = 24\,N/mm^2$	1	
	$\sigma_{max} = \sigma_0 + \sigma_b = 10 + 24 = 34\,N/mm^2$ (Comp^r)	1	4
	$\sigma_{min} = \sigma_0 - \sigma_b = 10 - 24 = -18\,N/mm^2$ (tensile)		
		1	



Stress dist^r dia

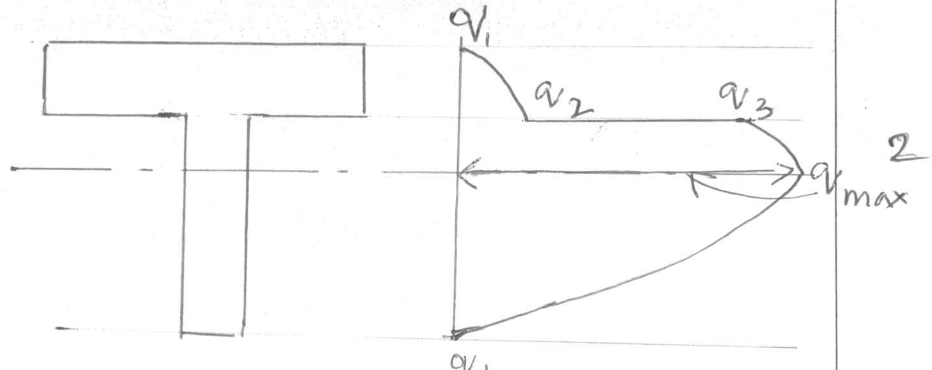
Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
4. (e)	$I_{yy} = I_{yy_1} + I_{yy_2} + I_{yy_3}$ $= 2\left(\frac{d_1 b_1^3}{12}\right) + \frac{d_2 b_2^3}{12}$ $= 2\left(\frac{20 \times 100^3}{12}\right) + \left(\frac{360 \times 10^3}{12}\right)$  $I_{yy} = 3363333.333 = 33.63 \times 10^5\ mm^4$	1 1 1 1	4
4 (f)(i)	 $I_{base} = \frac{bh^3}{12}$ $I_{xx} = \frac{bh^3}{36}$ or $I_{yy} = \frac{hb^3}{48}$	1 1	
4 f(ii)	Parallel Axis Theorem : The moment of inertia of a plane section about any axis parallel to the centroidal axis is equal to the sum of moment of inertia of the section about centroidal axis and product of area of the section and square of distance between two axes. Perpendicular Axis Theorem. If I_{xx} and I_{yy} are the moment of inertia of plane section about two mutually perpendicular axes, then moment of inertia I_{zz} about the third axis z-z, perpendicular to the plane & passing through the intersection of x-x & y-y is given by $\boxed{I_{zz} = I_{xx} + I_{yy}}$	1 1	4

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
5 (a)	$D = 300\ mm,\ t = 50\ mm,\ P = 200 \times 10^3\ N$.		
	$d = D - 2t = 200\ mm$.		
	For no tension condition, $\sigma_0 \geq \sigma_b$. $\frac{P}{A} = \frac{M}{Z} = \frac{P.e}{Z}$	1	
	$e_{max} = \frac{Z}{A}$.		
	$Z_{xx} = Z_{yy} = \frac{\pi}{32} \frac{(D^4 - d^4)}{D.} = \frac{\pi}{32} \frac{(300^4 - 200^4)}{\times 300}$		4
	$Z = 2127120.026\ mm^3$.	1	
	$A = \frac{\pi}{4}(D^2 - d^2) = \frac{\pi}{4}(300^2 - 200^2) = 39270\ mm^2$	1	
	$\therefore \boxed{e_{max} = \frac{Z}{A} = 54.17\ mm}$	1	
5 (b)			
	$M_{max} = \frac{wl^2}{8} = \frac{5 \times 10^3 (6)^2}{8} = 22,500\ N\text{-}m$	1	
	$= 22500 \times 10^3\ N\text{-}mm$.		
	$I_{xx} = \frac{bd^3}{12} = \frac{50 \times 140^3}{12} = 11.43 \times 10^6\ mm^4$.	1	
	$y_{max} = d/2 = \frac{140}{2} = 70\ mm$.	1/2	4
	Using bending eq^n $\rightarrow \frac{M_{max}}{I} = \frac{\sigma_b}{y_{max}}$	1/2	
	$\therefore \sigma_{b_{max}} = \frac{M}{I} \times y = \frac{22.5 \times 10^6}{11.43 \times 10^6} \times 70$		
	$\boxed{\sigma_{b_{max}} = 137.80\ N/mm^2}$	1	

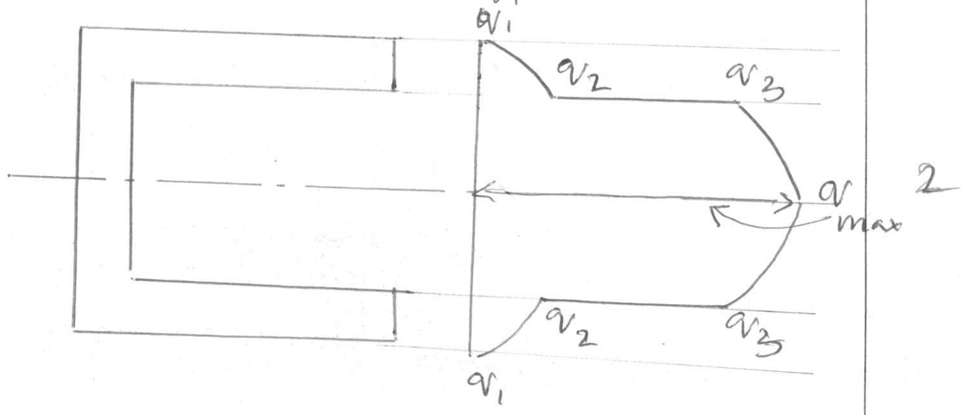
Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
5 (e)	 Given: $D = 50\ mm,\ t = 10\ mm$; $d = D - 2t = 30\ mm$; $\sigma_r = 100\ N/mm^2$ (tensile); $\sigma_r = 25\ N/mm^2$ (comp^r); $e = 100\ mm$.		
	$A = \frac{\pi}{4}(D^2 - d^2) = \frac{\pi}{4}(50^2 - 30^2) = 1256.64\ mm^2$	1/2	
	$I = \frac{\pi}{64}(D^4 - d^4) = \frac{\pi}{64}(50^4 - 30^4) = 267035.38\ mm^4$	1/2	
	$y_{max} = D/2 = \frac{50}{2} = 25\ mm$		
	$Z = I/y = \frac{267035.38}{25} = 10681.42\ mm^3$	1/2	
	Direct stress $\sigma_0 = \frac{P}{A} = \frac{P}{1256.64} = 7.96 \times 10^{-4} P$	1/2	
	Bending stress $\sigma_b = \frac{M}{Z} = \frac{P.e}{Z} = \frac{100P}{10681.42} = 9.36 \times 10^{-3} P$	1/2	
	Resultant stress in tension $\rightarrow \sigma_r = \sigma_0 + \sigma_b$ $\therefore 100 = 7.96 \times 10^{-4} P + 9.36 \times 10^{-3} P$ $\therefore P = 9846.4\ N = 9.85\ kN$	1/2	
	Resultant stress in Comp^r $\rightarrow \sigma_r = \sigma_0 - \sigma_b$ $\therefore -25 = 7.96 \times 10^{-4} P - 9.36 \times 10^{-3} P$ $\therefore P = 2919.2\ N = 2.92\ kN$	1/2	
	Selecting lesser of the two 'P' values as safe load $\boxed{P = 2.92\ kN}$	1/2	4

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS

5. f



2



2

4

6 (a)

Given:

$\varnothing = 100\ mm$, $L = 2.7\ m$, $T = 30\ kN\text{-}m = 30 \times 10^6\ kN\text{-}mm$

$G = 75\ GPa$.

Find – τ_{max}.

Using relation $T = \frac{\pi}{16} \cdot \tau \cdot D^3$ — 1

$30 \times 10^6 = \frac{\pi}{16} \times \tau \times 100^3$ — 1

or $\boxed{\tau = 152.79\ N/mm^2}$. — 2

4

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
6. (b)	Assumptions in theory of pure torsion :-		
1)	The material of shaft is homogeneous and isotropic	Any 4 (1M for each)	
2.	Stresses are within elastic limit i.e shear stress is proportional to shear strain.		
3.	Cross sections which are plane before applying twisting moment remain plane after its application i.e no warping takes place.		
4.	Twist along the shaft is uniform.		
5.	All diameters of the cross section of the shaft remain straight before and after the twist.		4
	— x —		
6. (c)	Given: $T = 24\ kN{\cdot}m = 24 \times 10^6\ N\text{-}mm$ $d = 0.6D$, $\tau = 80\ MPa = 80\ N/mm^2$		
	Using relation $\rightarrow$ $T = \frac{\pi}{16}\left(\frac{D^4 - d^4}{D}\right)\tau$	1	
	or $24 \times 10^6 = \frac{\pi}{16}\left(\frac{D^4 - (0.6D)^4}{D}\right) \times 80$		
	$\frac{D^4 - 0.13D^4}{D} = 1527887.45$	1	
	or $D^3 = 1756192.476$	1	
	or $\boxed{D = 120.65\ mm}$		
	$\therefore \boxed{d = 0.6D = 72.39\ mm}$	1	4

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
6 (d)	Given : $P = 100\,kW = 100 \times 10^3\,W$, $N = 180\,rpm$		
	$\tau = 60\,N/mm^2$, $\theta = 1^\circ = \frac{\pi}{180} = 0.0174532\,rad$		
	$l = 3\,m = 3 \times 10^3\,mm$, $C = 80\,\frac{kN}{mm^2} = 80 \times 10^3\,N/mm^2$		
	$P = \frac{2\pi N T_{mean}}{60}$	1/2	
	$100 \times 10^3 = \frac{2 \times \pi \times 180 \times T_{mean}}{60}$ or $T_{mean} = 5305.16\,N\text{-}m$		
	or $T_{mean} = T_{max} = 5305.16 \times 10^3\,N\text{-}mm$	1/2	
	$J = \frac{\pi}{32} D^4$	1/2	
	① Diameter based on shear stress	1/2	
	$\frac{T}{J} = \frac{\tau}{R}$		
	or $\frac{5305.16 \times 10^3}{\pi/32\, D^4} = \frac{60}{D/2}$		
	$D^3 = 450315.97$	1/2	
	$\boxed{D = 76.65\,mm}$		
	② Diameter based on angle of twist	1/2	
	$\frac{T}{J} = \frac{G\theta}{l}$		
	or $\frac{5305.16 \times 10^3}{\pi/32\, D^4} = \frac{80 \times 10^3 \times 0.0174532}{3 \times 10^3}$	1/2	
	$D^4 = 116{,}106{,}035.1$ or $\boxed{D = 103.8\,mm}$		
	Selecting higher diameter $\boxed{D = 103.8\,mm}$	1/2	4

Q. NO.	MODEL ANSWER	MARKS	TOTAL MARKS
6. (e) (i)	Torsional eq^n for shaft – $\boxed{\frac{T}{I_p} = \frac{C\theta}{L} = \frac{\tau}{R}}$	1	
	Where T = Torque / Turning moment I_p or J = Polar moment of inertia of shaft Section C or G = Modulus of rigidity of shaft material θ = Angle of twist in radians L = Length of shaft f_s or τ = Maximum Shear Stress R = Radius of the shaft.	1	2
6 e (ii)	Polar modulus is the ratio of polar moment of inertia of the Section and radius of the shaft	1	
	Polar modulus $\boxed{Z_p = \frac{J \text{ or } I_p}{R}}$	1	2
6 (f)	Given : $D = 100$ mm, $d = 60$ mm, $T = 2$ kN-m or $T = 2 \times 10^3$ N-m, $N = 300$ rpm. Find Power. $P = \frac{2\pi N T}{60}$	1	
	$= \frac{2 \times \pi \times 300 \times 2 \times 10^3}{60}$	1	
	or $\boxed{P = 62{,}831.85 \text{ W} = 62.83 \text{ KW}}$	2	4