Model Answer: Winter 2016

Subject: - Mechanics of Structure

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, spelming 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
1.	A.	**Solve any six of the following:**		(12)
	a)	**Define moment of inertia.**		
	Ans.	**Moment of Inertia: -** It is the second moment of area which is equal to product of area which is equal to product of area of figure and square of distance of centroid from particular centroidal axis, is called moment of inertia. **OR** Moment of inertia of a body about any axis is defined as the second moment of area about that axis.	02	02
	b)	**If polar moment of inertia of a circular section is 2000 mm^4 then calculate diameter of the section.**		
	Ans.	*Given* : - $I_P = 2000mm^2$ for circular section $I_P = I_{xx} + I_{yy}$	01	
		$I_P = \frac{\pi}{64}D^4 + \frac{\pi}{64}D^4$ $2000 = \frac{2\pi}{64}D^4$		02
		$\boxed{D=11.946mm}$	01	

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Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
	c)	**Define modulus of rigidity.**		
	Ans.	**Modulus of Rigidity: -** It is defined as the ratio of shear stress to shear strain.	02	02
	d)	**State meaning of punching shear stress.**		
	Ans.	The shear stress produced due to punching in a plate is called punching shear stress.	02	02
	e)	**State four conditions for effective lengths of a column depend on their end fixities.**		
	Ans.	i. When both end of column are hinged, $L_e = L$ ii. When both end of column are fixed, $L_e = \frac{L}{2}$ iii. When one end is fixed and other end is hinged, $L_e = \frac{L}{\sqrt{2}}$ iv. When one end is fixed and other end is free, $L_e = 2.L$	½ Each	02
	f)	**State meaning of effective length of column.**		
	Ans.	**Effective length of column: -** It is a length between the point of contraflexture of buckled columned it depend on the end conditions of the column.	02	02
	g)	**Define resilience and modulus of resilience.**		
	Ans.	**Resilience: -**It is energy stored in the body, when it is strained within elastic limit, is called as Resilience or strain energy.	01	02
		Modulus of Resilience: - It is the proof resilience per unit volume of body is called as modulus of resilience.	01	

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Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1.	h)	**Differentiate between gradual load and suddenly applied load with respect to stress developed.**		
	Ans.			

	Gradual load	Suddenly applied load	Marks
i.	The stress due to gradual load is, $\sigma = \frac{P}{A}$	The stress due to suddenly applied load is, $\sigma = \frac{2P}{A}$	1
ii.	The stress developed is exactly half to that of stress due to sudden load for same loading.	The stress developed is almost double to that of stress due to gradual load for same loading.	1

Total Marks: 2

(B) **Solve <u>any two</u> of the following:** **(08)**

a) **State bending equation with meaning of each term used in it.**

Ans. **Bending equation or Flexural formula**,

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$ **02**

Where,

M = Maximum bending moment $(N.mm)$

I = Moment of inertia about $N.A.$ (mm^4)

σ = Maximum bending stress (N/mm^2) **02**

y = Distance of extreme fiber from $N.A.$ (mm)

E = Modulus of elasticity (N/mm^2)

R = Radius of curvature (mm)

Total Marks: **04**

b) **A beam of rectangular cross – section is subjected to shear force 'S'. Show that q maximum = 1.5 q avg.**

Ans.

$$q_{\max} = \frac{S.A.\bar{Y}}{b.I}$$ **01**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1.		$$q_{\max} = \frac{S \times b \times \frac{d}{2} \times \frac{d}{4}}{b \times \frac{bd^3}{12}}$$	01	04
		$$q_{\max} = \frac{3.S}{2.bd}$$	01	
		$$q_{\max} = 1.5\frac{S}{b.d}$$		
		$$\boxed{q_{\max} = 1.5 \times q_{avg}}$$	01	
	c)	**A column having diameter 200 mm is of length 3m, both ends of column are hinged. Find Euler's crippling load. Take E = 2 x 10^5 MPa.**		
	Ans.	*Given*:– D = 200mm, L = 3m = 3000mm (both ends hinged), E = $2\times10^5 MPa = 2\times10^5$ N/mm^2		
		$$\text{I}_{\min} = I_{XX} = I_{YY} = \frac{\pi}{64}(200)^4$$	01	
		$$\text{I}_{\min} = I_{XX} = I_{YY} = 78.539\times10^6 mm^4$$		
		By Euler's formula,		
		$$\text{P}_e = \frac{\pi^2 EI_{\min}}{L_e^2}$$	01	04
		$$\text{P}_e = \frac{\pi^2 \times 2\times10^5 \times 78.539\times10^6}{3000^2}$$	01	
		$$\text{P}_e = 17225530.22 N$$		
		$$\text{P}_e = 17225.53\ kN$$	01	
2.		**Solve <u>any two</u> of the following:**		(16)
	a)	**Find the least moment of Inertia about the centroidal axes X-X and Y-Y of an unequal angle section 125 mm x 75 mm x 10 mm as shown in figure no. 1.**		
	Ans.	*i*) *Calculation* centroid: -		
		$\text{A}_1 = 75\times10 = 750mm^2$, $\text{A}_2 = 115\times10 = 1150mm^2$		
		$\text{X}_1 = \frac{75}{2} = 37.5m$, $\text{X}_2 = \frac{10}{2} = 5mm$		

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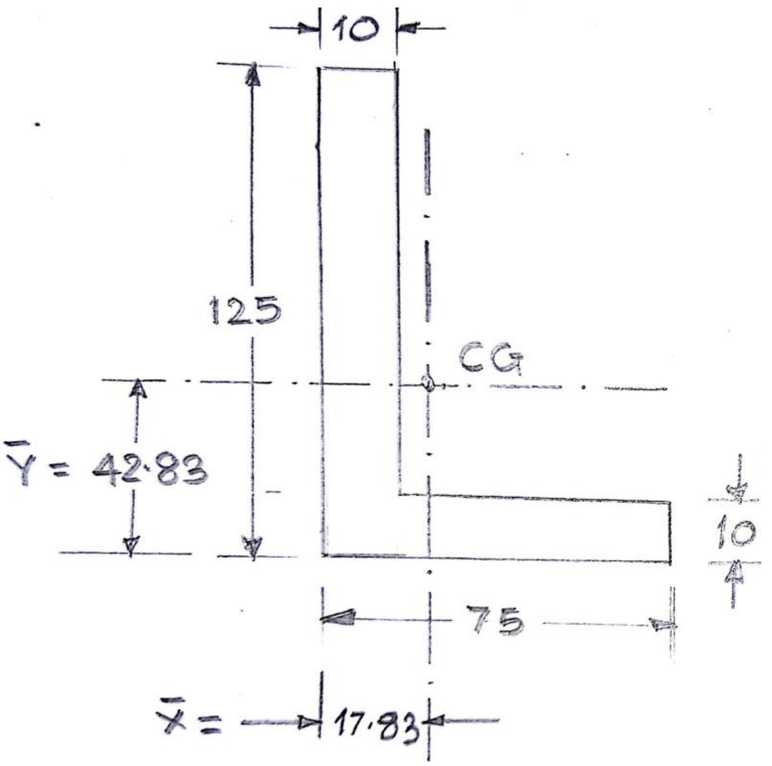
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2.		$Y_1 = \frac{10}{2} = 5mm,\quad Y_2 = 10 + \frac{115}{2} = 67.5mm$ $\bar{X} = \frac{A_1X_1 + A_2X_2}{A_1 + A_2} = 17.83mm,\quad \bar{Y} = \frac{A_1Y_1 + A_2Y_2}{A_1 + A_2} = 42.83mm$	02	
		 		
		ii) Calculation of I_{xx} :– $I_{xx} = I_{xx1} + I_{xx2}$ $I_{xx} = (I_{G1} + A_1 h_1^2) + (I_{G2} + A_2 h_2^2)$ $I_{xx} = (I_{G1} + A_1 h_1^2) + (I_{G2} + A_2 h_2^2)$ *Here,* $h_1 = \bar{Y} - Y = 42.83 - 5 = 37.83mm$ $h_2 = Y_2 - \bar{Y} = 67.5 - 42.83 = 24.67mm$ $I_{xx} = \left(\frac{75\times10^3}{12} + 750\times37.83^2\right) + \left(\frac{10\times115^3}{12} + 1150\times24.67^2\right)$ $\boxed{I_{xx} = 3.046\times10^6 mm^4}$	03	08

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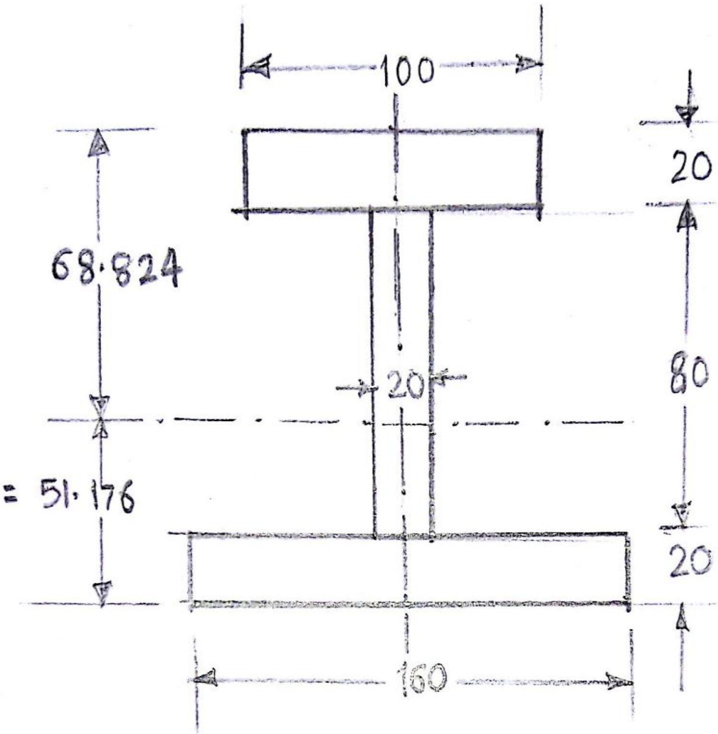
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2.		*iii*) *Calculation* of I_{YY} :– $I_{YY} = I_{YY1} + I_{YY2}$ $I_{YY} = (I_{G1} + A_1 h_3^2) + (I_{G2} + A_2 h_4^2)$ *Here*, $h_3 = \bar{X} - X = 37.5 - 17.83 = 19.67mm$ $h_4 = \bar{X} - X_2 = 17.83 - 5 = 12.83mm$ $I_{YY} = \left(\frac{10\times75^3}{12} + 750\times19.67^2\right) + \left(\frac{115\times10^3}{12} + 1150\times12.83^2\right)$ $\boxed{I_{YY} = 840.627\times10^3 mm^4}$	**03**	
	b)	**Determine moment of Inertia about the centroidal axes X-X and Y-Y of an unsymmetrical I section with the following details.** **Top flange - 100×20 mm** **Bottom flange - 160×20 mm** **Web - 80×20 mm**		
	Ans.	*i*) *Calculation* of centroid: - As given section is unsymmetrical about y-y axis, 		

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<tr><th>Que. No.</th><th>Sub. Que.</th><th>Model Answers</th><th>Marks</th><th>Total Marks</th></tr>
<tr><td>2.</td><td></td><td>

$\bar{X} = \frac{Large\ \text{flange width}}{2} = \frac{160}{2} = 80mm$

$A_1 = 160\times 20 = 3200mm^2,\quad A_1 = 80\times 20 = 1600mm^2,$

$A_3 = 100\times 20 = 2000mm^2$

$Y_1 = \frac{20}{2} = 10mm,\qquad Y_2 = 20 + \frac{80}{2} = 60mm,$

$Y_3 = 20 + 80 + \frac{20}{2} = 110mm,$

$\bar{Y} = \frac{(3200\times 10)+(1600\times 60)+(2000\times 110)}{6800} = 51.17mm,$

ii) Calculation of I_{xx} :−

$I_{xx} = I_{xx1} + I_{xx2} + I_{xx3}$

$I_{xx} = (I_{G1} + A_1 h_1^2) + (I_{G2} + A_2 h_2^2) + (I_{G3} + A_3 h_3^2)$

$I_{xx} = (\frac{bd^3}{12} + A_1 h_1^2) + (\frac{bd^3}{12} + A_2 h_2^2) + (\frac{bd^3}{12} + A_3 h_3^2)$

Here, $h_1 = \bar{Y} - Y_1 = 1.17 - 10 = 41.17mm$

$h_2 = Y_2 - \bar{Y} = 60 - 51.17 = 8.83mm$

$h_3 = Y_3 - \bar{Y} = 110 - 51.17 = 58.83mm$

$I_{xx} = \left(\frac{160\times 20^3}{12} + 3200\times 41.17^2\right) + \left(\frac{20\times 80^3}{12} + 1600\times 8.83^2\right) + \left(\frac{100\times 20^3}{12} + 2000\times 58.83^2\right)$

$\boxed{I_{xx} = 13.496\times 10^6 mm^4}$

iii) Calculation of I_{YY} :−

$I_{YY} = I_{YY1} + I_{YY2} + I_{YY3}$

$I_{YY} = (I_{G1} + A_1 h_1^2) + (I_{G2} + A_2 h_2^2) + (I_{G3} + A_3 h_3^2)$

$I_{YY} = (\frac{db^3}{12}) + (\frac{db^3}{12}) + (\frac{db^3}{12})$

$I_{YY} = \left(\frac{20\times 160^3}{12}\right) + \left(\frac{80\times 20^3}{12}\right) + \left(\frac{20\times 100^3}{12}\right)$

$\boxed{I_{YY} = 8.546\times 10^6 mm^4}$

</td><td>01

04

03</td><td>08</td></tr>
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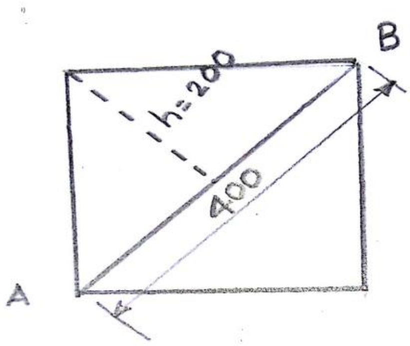
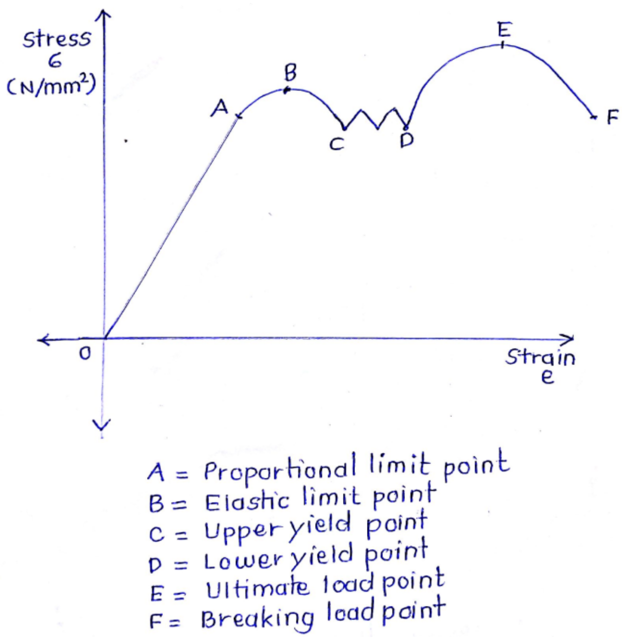
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2.	c)	**i) Find moment of Inertia about the diagonal of a square section having diagonal 400 mm.** **ii) Draw stress – strain curve for mild steel under tensile loading showing important points on it.**		
	Ans.	 **i)** *To* find MI at diagonal AB, $I_{AB} = 2\left(\frac{bh^3}{12}\right) \quad (MI \text{ at base of triangle})$ $I_{AB} = 2\left(\frac{400 \times 200^3}{12}\right)$ $\boxed{I_{AB} = 5.33 \times 10^8 mm^4}$	02 02	
		ii)  **Fig. Strain curve for Mild Steel**	02 02	08

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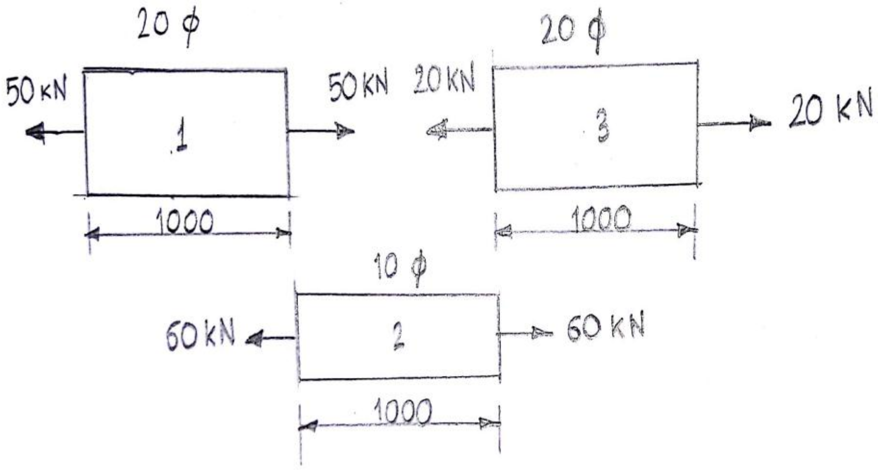
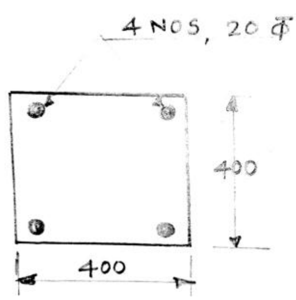
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3.		**Solve any two of the following :**		(16)
	a)	**Determine the total elongation of the bar shown in figure No. 2 Take E = 2 x 10^5 N/mm^2**		
	Ans.		01	08
		$\delta_L = \delta_{L1} + \delta_{L2} + \delta_{L3}$ $\delta_L = \left(\frac{PL}{AE}\right)_1 + \left(\frac{PL}{AE}\right)_2 + \left(\frac{PL}{AE}\right)_3$ $\delta_L = \frac{L}{E} \times \left(\frac{P_1}{A} + \frac{P_1}{A} + \frac{P_1}{A}\right)$ $\delta_L = \frac{1000 \times 10^3}{\frac{\pi}{4} \times (2 \times 10^5)}\left[\frac{50}{20^2} + \frac{60}{10^2} + \frac{20}{20^2}\right]$	06	
		$\boxed{\delta_L = 4.933\ mm}$	01	
	b)	**An RCC column 400 mm x 400 mm is reinforced with 4 bars of 20 mm diameter. Determine the stresses induced in steel and concrete. If it is subjected to an axial load of 500 kN and modular ratio is 13.**		
				

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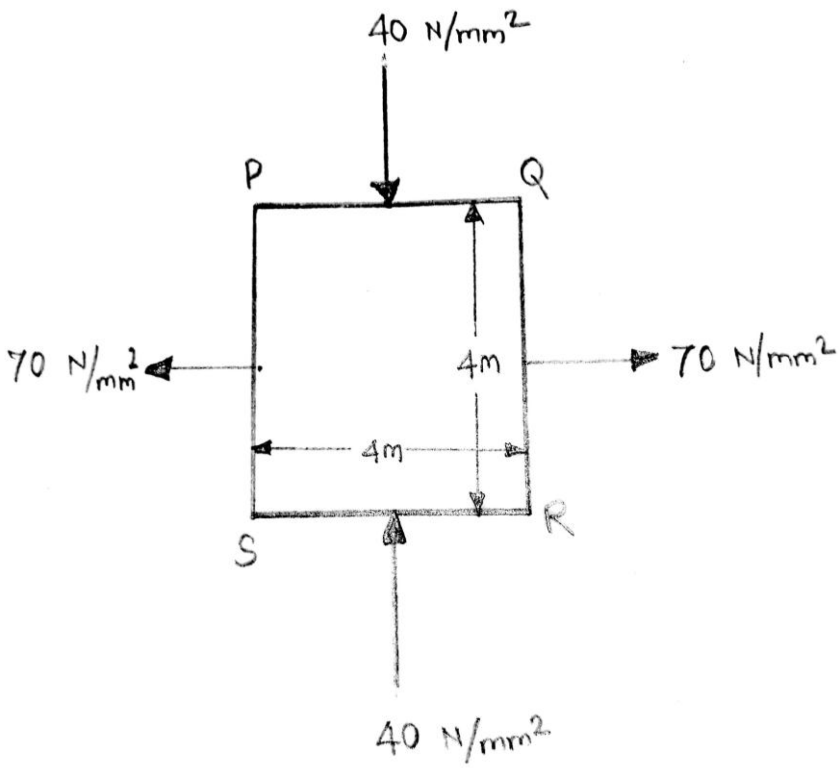
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3.	Ans.	$Given:-\quad P = 500kN$		
		$A_s = 4\times\frac{\pi}{4}(20)^2 = 1256.637mm^2$	02	
		$A_c = (400\times400) - 1256.637 = 158743.36mm^2$		
		$P = P_s + P_c$		
		$P = \sigma_s A_s + \sigma_c A_c$ ....(1)	01	
		$But,$		
		$M = \frac{E_s}{E_c} = \frac{\sigma_s}{\sigma_c} = 13$	01	08
		$\sigma_s = 13\times\sigma_c$	01	
		From equation (1),		
		$500\times10^3 = (13\times\sigma_c\times1256.637) + (\sigma_c\times158743.36)$	02	
		$\boxed{\sigma_c = 2.855\ \text{N/mm}^2}$	01	
		$\boxed{\sigma_s = 37.125\ \text{N/mm}^2}$		
	c)	**A bar of cross section 20 mm x 40 mm and length 500 mm is subjected to axial tensile force of 50kN. The change in lengths is 0.20mm. Determine change in depth and change in width and change in volume of bar. Take μ = 0.30 and E = 2 x 10⁵ N/mm².**		
	Ans.	$\mu = \frac{Lateral\ strain}{Linear\ strain} = \frac{\left(\frac{\delta_t}{t}\right)}{\left(\frac{\delta_L}{L}\right)}$	01	
		$\therefore\ \delta_t = \frac{\mu\times\left(\frac{\delta_L}{L}\right)}{t} = \frac{0.30\times\left(\frac{0.20}{500}\right)}{40} = \boxed{4.8\times10^{-3}mm}$	02	
		$\mu = \frac{lateral\ strain}{Linear\ strain} = \frac{\left(\frac{\delta_b}{b}\right)}{\left(\frac{\delta_L}{L}\right)}$		
		$\therefore\ \delta_b = \frac{\mu\times\left(\frac{\delta_L}{L}\right)}{b} = \frac{0.30\times\left(\frac{0.20}{500}\right)}{20} = \boxed{2.4\times10^{-3}mm}$	02	08

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3.		$\delta_V = e(1-2\mu)V$	01	
		$\delta_V = \frac{\delta_L}{L}(1-2\mu)V$		
		$\delta_V = \frac{0.2}{500}(1-2\times0.3)\times20\times10\times500$	01	
		$\boxed{\delta_V = 64\ mm^3}$	01	
4.		Solve **any two** of the following :		(16)
	a)	**In a biaxial stress systems shown in figure No. 3, the stresses along the two perpendicular directions. Calculate the strains along these two directions. Take E = 2.1 x 10^5N/mm^2 and μ = 0.28. Also find change in length in both directions if section is square of 4m.**		
				

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4.	Ans.	*Given*: – $\sigma_x = +70, \ \sigma_y = -40,$ $\mu = 0.28, \quad E = 2\times10^5 \ N/mm^2$		
		$e_x = \frac{\sigma_x}{E} - \mu\frac{\sigma_y}{E} = \frac{1}{E}(\sigma_x - \mu\sigma_y)$	01	
		$= \frac{1}{2\times10^5}(70-(0.28\times(-40)))$ $\boxed{= 3.687\times10^{-4}(T)}$	02	
		$e_y = \frac{\sigma_y}{E} - \mu\frac{\sigma_x}{E} = \frac{1}{E}(\sigma_y - \mu\sigma_x)$	01	08
		$= \frac{1}{2\times10^5}((-40)-(0.28\times70))$ $\boxed{= -2.838\times10^{-4}(C)}$	02	
		$e_x = \frac{\delta L_{PQ}}{PQ}$ $\delta L_{PQ} = (e_x)\times PQ = (3.867\times10^{-4})\times4000 \boxed{= 1.5467mm(Increase)}$	01	
		$e_y = \frac{\delta L_{QR}}{QR}$ $\delta L_{QR} = (e_y)\times QR = (2.838\times10^{-4})\times4000 \boxed{= 1.135mm(Decrease)}$	01	
	b)	**A rod is subjected to an initial compressive stress 50 N/mm2 and held in rigid supports at temperature of 50 ^oC. Find** **i) The temperature at which rod will become stress free.** **ii) What tensile stress will be developed at temperature 30 ^oC?** **iii) What will be compressive stress at temperature 30 ^oC?** **iv) What will be elongation of rod at temperature 30 ^oC?** **Take α = 12 x 10^{-6} /^oC** **E = 200 kN/mm^2** **c/s Area = 400 mm^2** **length = 4 m**		

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Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4.	**Ans.**	*The temperature at which rod will become stress free.* $\sigma = E\alpha T$ $\therefore$ T = $\frac{\sigma}{E\alpha}$ $T = \frac{50}{2\times10^5\times12\times10^{-6}}$ $\boxed{T = 20.833^0 C}$ *i.e.* The temperature is reduced by $20.833^0 C$ *The rod will become* Stress free *at* $50^0C - 20.833^0C \boxed{= 29.1667^0 C}$	**02**	
		Case ii) *What tensile stress will be developed at temperature* $30^o C$? *At* temp. $30^o C$ *the* stress will be $\sigma = E\alpha \Delta t$ $= 2\times10^5\times12\times10^{-6}\times(30)$ $\boxed{\sigma = 72 \text{ N/mm}^2}$ (T) $\therefore$ Net stress in the rod at 30^0C *will be* - 50 + 72 $\boxed{= 22 \text{N/mm}^2 (T)}$	**02**	
		Case iii) *What will be compressive stress at temperature* $30^o C$? At *temperature* $30^o C$ *compressive stress* is, $\sigma = E\alpha T$ $= 2\times10^5\times12\times10^{-6}\times(30\text{-}29.1667)$ $\boxed{\sigma = 1.99992 \text{ N/mm}^2}$ (C)	**02**	**08**
		Case iv) *What will be elongation of rod at temperature* $30^o C$? *A elongation of rod at temperature* $30^o C$ is Net stress T $30^o C$ is (+22 - 2) = 20 N/mm^2 *and* ΔT is $(50^o\text{C} - 30^o C) = 20^o C$ $\delta L = \delta L_1 + \delta L_2$ $= \frac{\sigma L}{E} + L\alpha T = \frac{20\times4000}{2\times10^5} + 4000\times12\times10^{-6}\times(20)$ = 0.4+0.96 = 1.36 mm $\boxed{\delta L = 1.36 \text{ mm}}$ (increase)	**02**	

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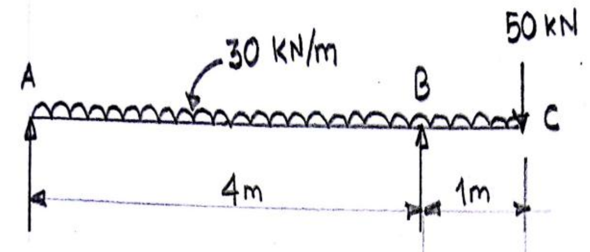
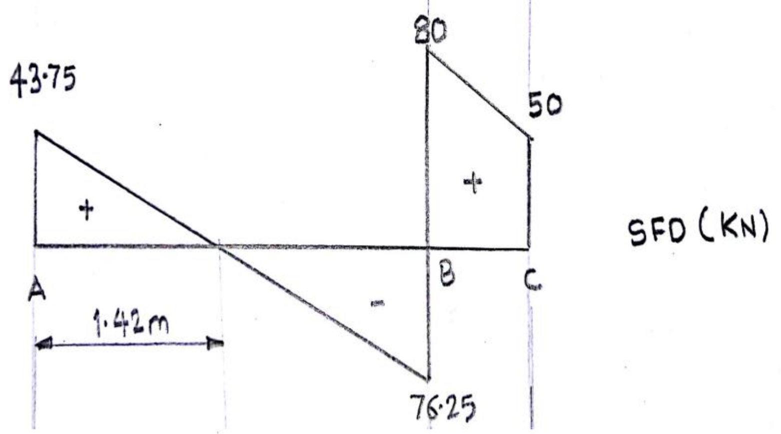
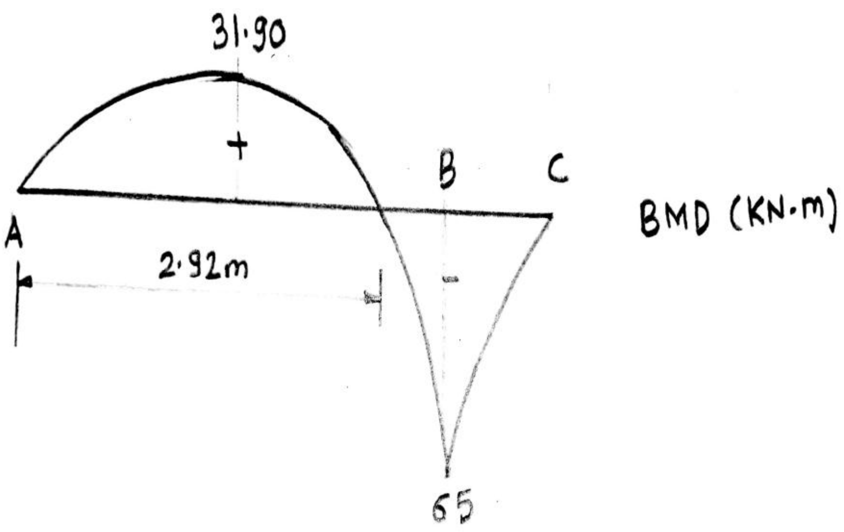
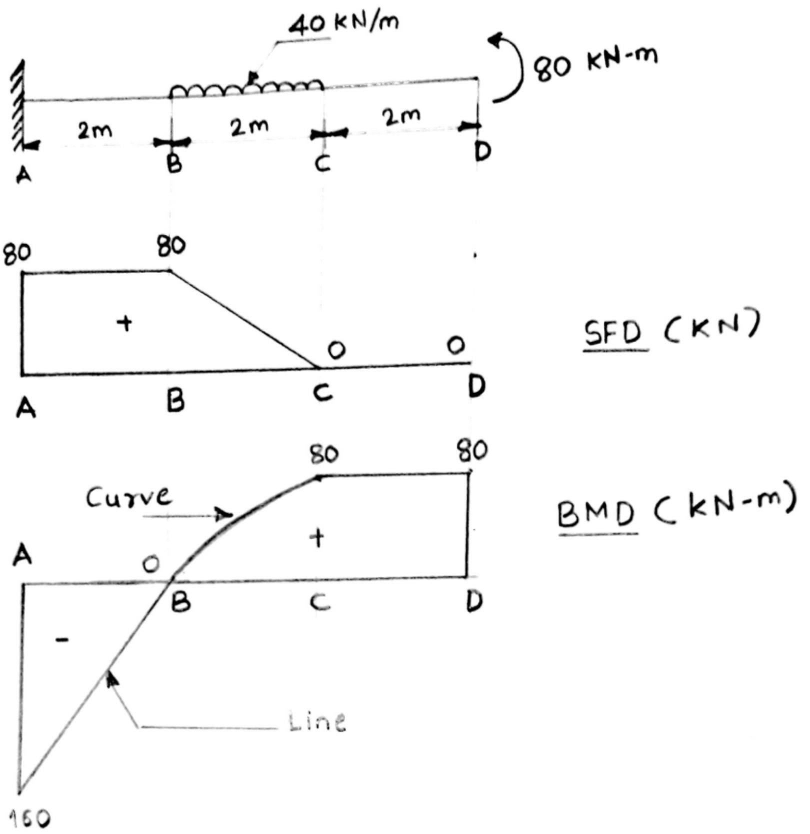
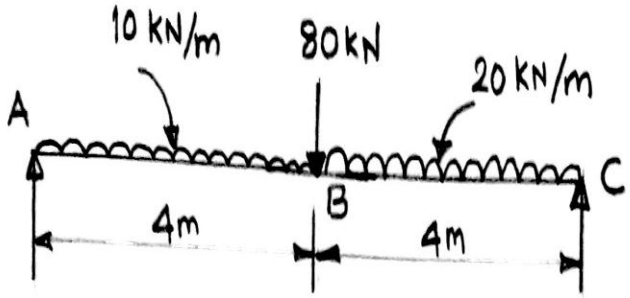
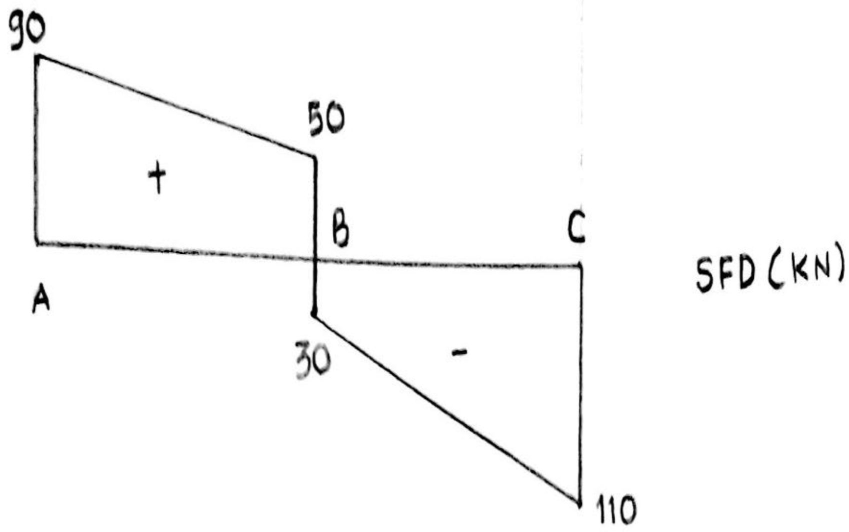
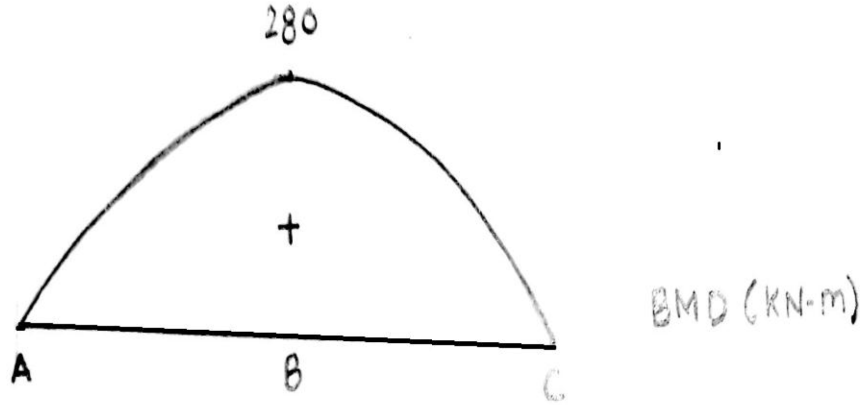
4.	c)	**An overhanging beam ABC is such that AB = 4m, BC = 1m, is supported at A and B. The beam ABC is subjected to VDL of 30 kN/m over the entire length ABC. It is subjected to point load 50 kN at the free end C. Draw SFD and BMD with calculations and locate the point of contra flexure.**		
	Ans.	*i) To calculte* the reactions at supports:- $R_B \times 4 = (30\times5\times2.5)+50\times5$ $\boxed{R_B = 156.25kN}$ $R_A = (30\times5\times50)-156.25$ $\boxed{R_A = 43.75kN}$	01	
		ii) Shear force c*alculations* SF at A = 43.75 kN SF at B_L = 43.75 - 30×40 = -76.25 kN SF at B_R = -76.25 + 156.25 = 80 kN SF at C_L = 80 - 30×1 = 50 kN SF at C = 50 - 50 = 0 $(\therefore Ok)$	01	
		iii)Bending moment calculations BM at A and C =0. BM at B = $-50\times1-30\times1\times\frac{1}{2}$ = - 65 kN-m	01	
		iv) To calcuate Maximum Bending Moment *SF at* x = 0, $\therefore 43.75 - 30\times x = 0$ $\therefore$ x = 1.458m from A	01	
		$BM_{max} = 43.75\times1.458-30\times\frac{1.458^2}{2}$ $\boxed{BM_{max} = 31.90kN-m}$	01	
		v)To locate point of contraflexure BM at x' = 0 $43.75\ x' - 30\times\frac{x'}{2} = 0$ $\boxed{x' = 2.916\ m \text{ from A}}$	01	08

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4.				
			**01**	
			**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5.		**Solve <u>any two</u> of the following:**		**(16)**
	a)	**Draw SFD and BMD with calculations for the beam shown in figure No. 4** i) Shear force *calculations* SF at A = 40 × 2 = 80 kN SF at B = 80 kN SF at B = 80 - 40 ×2 = 0 SF at D = 0	**02**	
		ii)Bending moment calculations BM at D = +80 kN-m BM at C = +80 kN-m BM at B = 80 - 40×2×1= 0 BM at A = 80 - 40×2×3= -160 kN-m	**02**	**08**
			**02** **02**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5.	b)	**i) State relation between shear force and rate of loading and also relation between shear force and bending moment.**		
		ii) Draw SFD and BMD with calculations for the beam shown in figure No. 5.		
	Ans.	**i)**		
		1) The relation between shear force and rate of loading : -		
		The rate of shear force w.r.t. distance is equal to the intensity of loading, i.e. $\frac{dF}{dx} = W$	02	
		2) The relation between shear force and bending moment: -		
		The rate of change of bending moment at any section is equal to shear force at that section i.e. $\frac{dM}{dx} = F$	02	
		Where, W – Intensity if loading F - Shear force M - bending moment x – distance		
		ii)		
		i) To calculte the reactions at supports:- $R_C \times 8 = (10 \times 4 \times 2) + 80 \times 4 + 20 \times 4 \times 6$ $\boxed{R_C = 110 kN}$ $R_A = (10 \times 4) + (20 \times 4) + 80 - 110$ $\boxed{R_A = 90\ kN}$		08
		ii) Shear Force c*alculations* SF at A = 90 kN SF at B_L = 90 - 10 × 4 = 50 kN SF at B_R = 50 - 80 = -30 kN SF at C_L = -30 - 20 × 4 = -110 kN SF at C = -110+110 = 0 $(\therefore Ok)$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5.				
			01	
			01	
		iii)*Bending* moment calculations BM at A and C =0. BM at B = $110\times4 - 20\times4\times2$ = 280 kN-m	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5.	c)	**A T section of flange 160 mm x 20 mm and web 180 x 20 mm is simply supported at the both ends. It carries two concentrated loads of 100 kN each acting 2m distance from each support. Span of the beam is 8m. Determine the maximum bending stress induced in the beam and draw bending stress distribution diagram and also find bending stress at the layer 100 mm from the bottom.**		
	Ans.	$\bar{Y} = \frac{a_1 y_1 + a_2 y_2}{a_1 + a_2} = \frac{(160\times20)\times190+(180\times20)\times90}{3200+3600}$	01	
		$\bar{Y} = 137.05\ mm\ \ from\ base$		
		$I_{NA} = I_{xx} = I_{xx1} + I_{xx2}$		
		$I_{NA} = I_{xx} = (I_{G1} + A_1 h_1^2) + (I_{G2} + A_2 h_2^2)$		
		$I_{NA} = I_{xx} = (\frac{bd^3}{12} + A_1 h_1^2) + (\frac{bd^3}{12} + A_2 h_2^2)$		
		$I_{NA} = I_{xx} = \left(\frac{160\times20^3}{12} + 3200\times52.94^2\right) + \left(\frac{20\times180^3}{12} + 3600\times47.06^2\right)$		
		$I_{NA} = I_{xx} = 26767843.15\ mm^4$	02	
		Maximum bending moment	01	
		M = 100$\times$2 = 200 kN-m = $200\times10^6 N-mm$		
		$\sigma_c = \frac{M}{I} y_c = \left[\frac{200\times10^6}{26767843.15}\right]\times62.94 = 470.265 N/mm^2 (C)$	01	
		$\sigma_t = \frac{M}{I} y_t == \left[\frac{200\times10^6}{26767843.15}\right]\times137.06 = 1024.06 N/mm^2 (T)$	01	08
		$\sigma_t = \frac{M}{I} y_{t(100)} = \left[\frac{200\times10^6}{26767843.15}\right]\times37.06 = 276.899 N/mm^2 (T)$	01	

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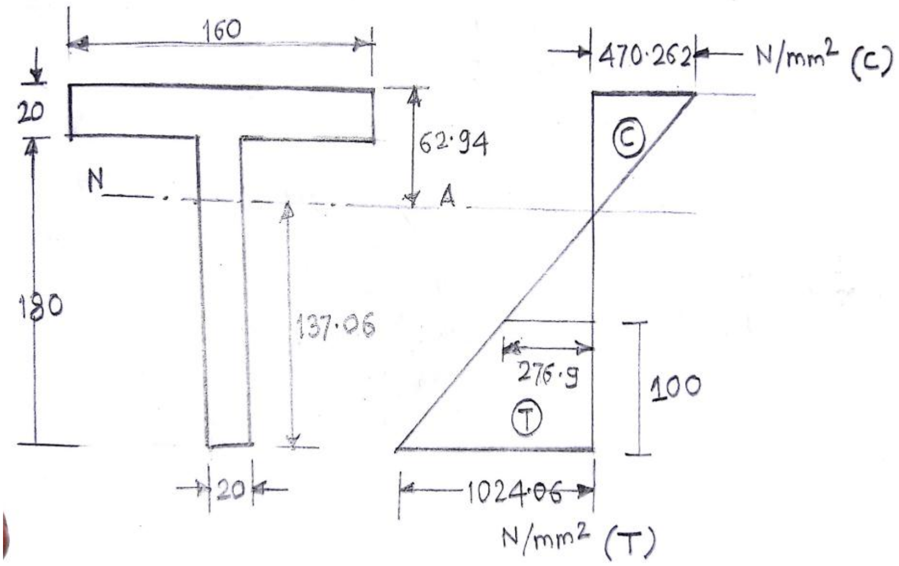
<table>
<tr><th>Que. No.</th><th>Sub. Que.</th><th>Model Answers</th><th>Marks</th><th>Total Marks</th></tr>
<tr><td>5.</td><td></td><td>



</td><td>01</td><td></td></tr>
<tr><td>6.</td><td></td><td>

Solve <u>any two</u> of the following:

</td><td></td><td>(16)</td></tr>
<tr><td></td><td>a)</td><td>

A beam has hollow rectangular section with external dimensions 80 mm x 160 mm and uniform thickness of section is 10 mm. Draw shear stress variation diagram. It section is subjected to the shear force 70kN. Also determine ratio of maximum shear stress and average shear stress.

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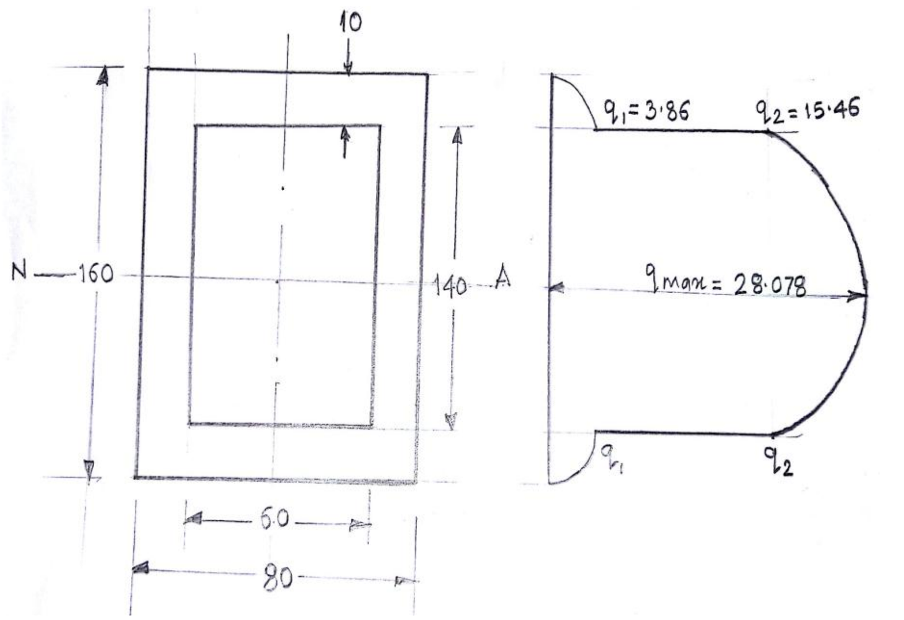
<tr><td></td><td>Ans.</td><td>



</td><td>01</td><td></td></tr>
</table>

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Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6.				
		$A=(BD-bd)=(80\times160-60\times140)$		
		$\boxed{A=4400\ mm^2}$	½	
		$I_{NA}=\frac{1}{12}(BD^3-bd^3)=\frac{1}{12}(80\times160^3-60\times140^3)$		
		$\boxed{I_{NA}=13586666.67\ mm^4}$	**01**	
		$q_{avg}=\frac{S}{A}=\frac{70\times10^3}{4400}$		
		$\boxed{q_{avg}=15.91 N/mm^2}$	**01**	
		$q_1=\frac{SA\bar{Y}}{bI}=\frac{70\times10^3\times(80\times10)\times75}{80\times13586666.67}$	**01**	
		$\boxed{q_1=3.864 N/mm^2}$		
		$q_2=q_1\times\frac{80}{20}=3.864\times40$	**01**	**08**
		$\boxed{q_2=15.456 N/mm^2}$		
		$q_{add}=\frac{SA\bar{Y}}{bI}=\frac{70\times10^3\times2(70\times10)\times35}{20\times13586666.67}$	**01**	
		$\boxed{q_{add}=12.622 N/mm^2}$		
		$q_{NA}=q_{\max}=q_2+q_{add}$ $=15.456+12.622$	**01**	
		$\boxed{q_{NA}=28.078 N/mm^2}$		
		Ratio, $\frac{q_{\max}}{q_{avg}}=\frac{28.078}{15.91}$		
		$\boxed{\frac{q_{\max}}{q_{avg}}=1.765}$	½	
	b)	**A hollow circular column 6m long has to transit a load of 800 kN, using Rankine's formula and factor of safety 4. Design a suitable section if both ends of columns are fixed. Take internal diameter = 0.8 x external dia. Fc = 550 Mpa, α = 1/1600**		
		$A=\frac{\pi}{4}(D^2-d^2)=\frac{\pi}{4}(D^2-(0.8D)^2)=0.28D^2$	½	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6.	**Ans.**	$I=\frac{\pi}{64}(D^4-d^4)=\frac{\pi}{64}(D^4-(0.8D)^4)=0.02898D^4$ $K^2=\frac{I}{A}=\frac{0.02898D^4}{0.28D^2}=0.1025D^2$ $\boxed{K^2=0.1025D^2}$ $Crippling\ load=Safe\ \text{load}\times\text{FOS}$ $=800\times 4$ $\boxed{Crippling\ load\ =3200\times 10^3 N}$ $L_e=\frac{L}{2}=\frac{6000}{2}=3000\ mm$ $P=\frac{\sigma_c.A}{1+\alpha\left(\frac{L_e}{K}\right)^2}$ $3200\times 10^3=\frac{550\times 0.28D^2}{1+\frac{1}{1600}\times\left(\frac{(3000)^2}{0.1025D^2}\right)}$ $3200\times 10^3=\frac{154D^2}{1+\frac{54878.048}{D^2}}$ $3200\times 10^3=\frac{154D^4}{D^2+54878.048}$ $\boxed{154D^4=(3200\times 10^3)\times D^2+1.756\times 10^{11}}$ $let, D^2=x$ $154x^4=(3200\times 10^3)\times x+1.756\times 10^{11}$ $x^2-20779.221x-1140323092=0$ $\therefore\ x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$ $x=\frac{20779.221\pm\sqrt{(20779.221)^2-4\times 1\times 1140323092}}{2\times 1}$ $x=\frac{20779.221\pm\ 70661.647}{2}$ $x=45720.4341$ $\text{D}^2=45720.4341$ $\boxed{\text{D}=213.82\text{mm}}$	**01** **01** **01** **½** **01** **02**	 **08**

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Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6.		$d = 0.8\times D = 0.8\times 213.82$ $\boxed{d = 171.056mm}$	01	
	c)	**A bar 10 mm diameter is subjected to following cases. Determine strain energy stored and modulus of resilience in following cases.** **i) A gradually applied load of 800N stretches bar by 0.3mm** **ii) An impact load of 800 N is dropped by 80 mm on the collar attached at the lower end of the bare. Take e = 200 GPa.**		
	Ans.	$\delta L = \frac{PL}{AE}$ $L = \frac{\delta L(AE)}{P} = \frac{0.3\times\frac{\pi}{4}\times(10)^2\times 2\times 10^5}{800}$ $\boxed{L = 5890.486mm}$	01	
		Case i) $\sigma = \frac{P}{A} = \frac{800}{\frac{\pi}{4}\times(10)^2}$ $\boxed{\sigma = 10.1859 N/mm^2}$	01	
		$U = \frac{\sigma^2}{2E}V = \frac{10.1859^2}{2\times 2\times 10^5}\times\frac{\pi}{4}(10)^2\times 5890.486$ $\boxed{U = 120.096 N-mm}$	01	
		$Modulus\text{ of Resiliance} = \frac{\sigma^2}{2E} = \frac{10.1859^2}{2\times 2\times 10^5}$ $\boxed{Modulus\text{ of Resiliance} = 2.5938\times 10^{-4} N-mm/mm^3}$	01	
		Case (ii) $\sigma = \frac{P}{A} + \sqrt{\left(\frac{P}{A}\right)^2 + \frac{2PhE}{AL}}$	01	
		$\sigma = \frac{800}{\frac{\pi}{4}(10)^2} + \sqrt{\left(\frac{800}{\frac{\pi}{4}(10)^2}\right)^2 + \frac{2\times 800\times 80\times 2\times 10^5}{\frac{\pi}{4}\times(10)^2\times 5890.486}}$		

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Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6.		$\boxed{\sigma = 245.64 N/mm^2}$	01	
		$U = \frac{\sigma^2}{2E} V = \frac{245.64^2}{2 \times 2 \times 10^5} \times \frac{\pi}{4}(10)^2 \times 5890.486$		
		$\boxed{U = 69787.746\ N-mm}$	01	
		$Modulus$ of Resiliance $= \frac{\sigma^2}{2E} = \frac{245.64^2}{2 \times 2 \times 10^5}$		
		$\boxed{Modulus \text{ of Resiliance } = 0.15084\ N-mm/mm^3}$	01	
		----------------***----------------		