WINTER – 13 EXAMINATION

Subject Code: 17311 **Model Answer** Total Page No: 39 / N

Important Instruction to Examiners:-

1) The answers should be examined by key words & not as word to word as given in the model answers scheme.

2) The model answers & answers written by the candidate may vary but the examiner may try to acssess the understanding level of the candidate.

3) The language errors such as grammatical, spelling errors should not be given more importance.

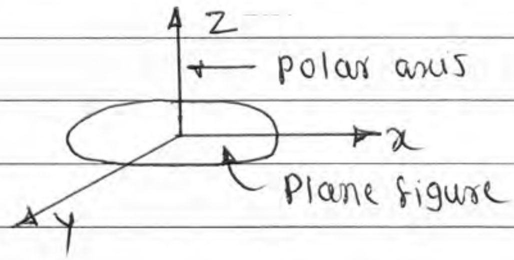
4) While assessing figures, examiners, may give credit for principle components indicated in the figure.

The figures drawn by candidate & model answer may vary. The examiner may give credit for any equivalent figure drawn.

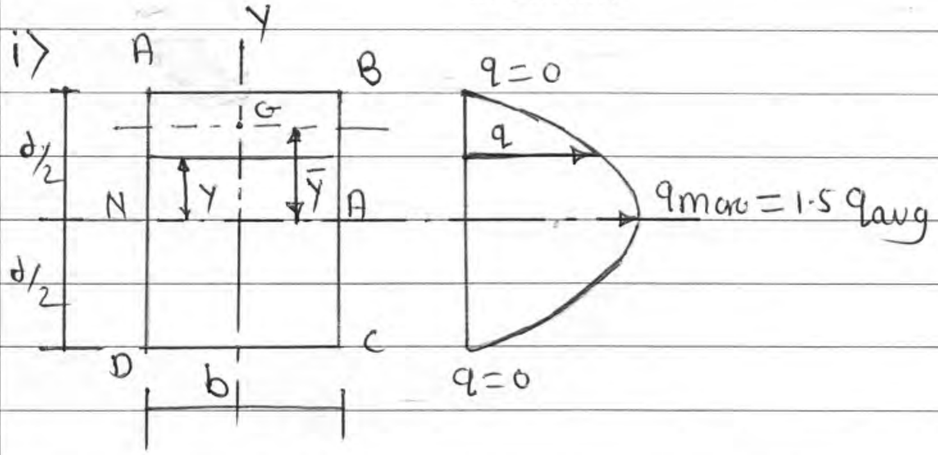
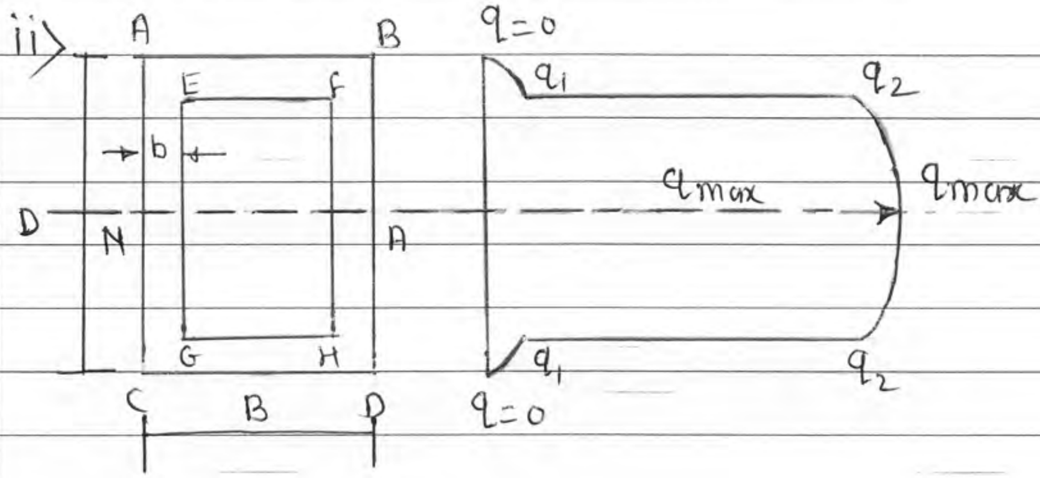
5) Credit may be given step wise for numerical problems. In some cases, the assumed contact values may vary and there may be some difference in the candidate's answers and model answer.

6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidates understanding.

7) For programming language papers, credit may be given to any other programme based on equivalent concept.

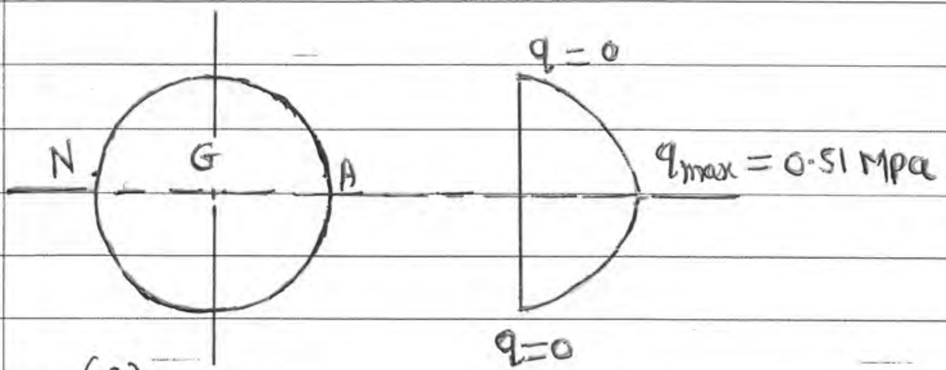
Q .NO	SOLUTION	MARKS
Q-1		
(a) (i)	i> Statement_	
	it states that the moment of inertia of a plane section about an axis perpendicular to the figure and passing through the centroid is equal to the sum of moment of inertia of the plane figure about two mutually perpendicular axis passing through the C.G or centroid 'G'	01
	ii> 	
	$I_{zz} = I_{xx} + I_{yy}$	01
(a) (ii)	i> Elasticity_	
	The property by virtue of which a material regains it's shape & size on removal of external load is called as elasticity.	01
	ii> Elastic limit_	
	A material remains in the elastic condition only upto a certain limit of the applied force on increasing the applied force beyond this limit, the material looses the property of elasticity. the normal stress produced up to the limit of limit of elasticity is called as elastic limit	01

Q .NO	SOLUTION	MARKS
Q-1 (a) (iii)	i) Modulus of Elasticity With in elastic limit, the ratio of stress to strain is a constant and this constant is called as modulus of elasticity it is denoted by E	1/2
	$\therefore E = \frac{\sigma}{e}$	1/2
	ii) Modulus of Rigidity The ratio of shear stress to shear strain is called as modulus of rigidity it is denoted by G, C or N	1/2
	$\therefore G = \frac{q}{\phi}$	1/2
Q-1 (a) (iv)	Temperature stress – When ever a body is heated, it expand & on cooling it contracts hence due to this stresses are occured & that corresponding stress is called as Temperature stress	01
	– $\sigma = E\alpha t$ where σ = Temperature stress E = modulus of elasticity α = Coeff. of linear or contraction t = Rise or fall in Temp.	01

Q .NO	SOLUTION	MARKS
Q-1 (a) (v)	i) 	01
	ii) 	01
Q-1 (a) (vi)	Euler's Theory assumptons i) The material of the column is perfectly homogenous & isotropic ii) The column is initially straight & of uniform lateral dimensions iii) The load on the column is exactly axial iv) The column is long and fails due to buckling or bending only v) The self weight of the column is neglected vi) The column is stressed up to the limit of proportionality	01 M for each

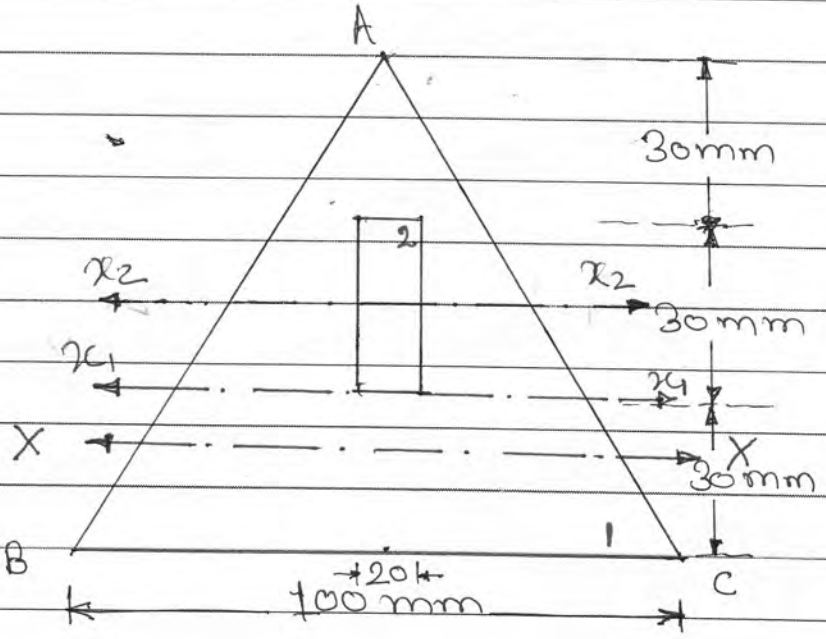
Q .NO	SOLUTION	MARKS
Q-1 (a) (vii)	i) Slenderness ratio	
	– The ratio of effective length to minimum radius of gyration is called as slenderness ratio	
	– $\lambda = \frac{Le}{K}$ where λ = Slendernes ratio, Le = eff. Length of column, K = min. radius of gyration	01
	ii) Effective length of column	
	– The length of column which deflects or bends as if it is hinged at it's end is called effective length.	
	– it is also called equivalent length of column	
	– effective length of column depends upon the end conditions of the column.	01
Q-1 (a) (viii)	i) Proof resilience (U_{max})	
	– the max. amount of strain energy which can be stored by a member or a body without exceeding the elastic limit is called proof resilience	½
	– $U_{max} = \frac{6^2}{2E} \cdot V$	0½
	ii) Modulus of resilience	
	– proof resilience per unit volume is called as modulus of resilience	½
	– Modulus of resilience $= \frac{6^2}{2E}$	½

Q .NO	SOLUTION	MARKS
Q-1 (b)	given data	
i)	i) rectangular beam = 300 mm deep	
	ii) span = 4m = 4000 mm	
	iii) σ_b = 120 N/mm^2	
	iv) $I = 8 \times 10^6$ mm^4	
	v) W = udl = ?	
	i) M = Maximum B.M $= \frac{wL^2}{8} = \frac{w \times 4^2}{8}$	
	$= 2w$ N-m	
	$\therefore M = 2w \times 10^3$ N-mm	01
	y = Distance of extreme layer from Neutral axis = $d/2$	
	Y = 150 mm	01
	from Flexural formula	
	$\frac{M}{I} = \frac{\sigma_b}{y}$	
	$\frac{2w \times 10^3}{8 \times 10^6} = \frac{120}{150}$	
	$w = \frac{120}{150} \times \frac{8 \times 10^6}{2 \times 10^3}$	
	$w = 0.8 \times 4000 = 3.2 \times 10^3$ N/m	02
	w = 3.2 KN/m	

Q .NO	SOLUTION	MARKS
Q-1 (b) (ii)	given data –: $d = 100 mm$ $F = 3 KN = 3 \times 10^3 N$	
		01
	(a) Section (b) shear stress distribution diagram	
	To find the max. shear stress (q_{max}) and minimum shear stress (q_{min})	
	$A = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times 100^2 = 7853.98 mm^2$	
	q_{av} = avg. shear stress	
	$q_{av} = \frac{F}{A} = \frac{3 \times 10^3}{7853.98} = 0.38 N/mm^2$	01
	For circular section $q_{max} = \frac{4}{3} q_{av} = \frac{4}{3} \times 0.38 = 0.506 \simeq 0.51 Mpa$	
	shear stress is alway zero at the extreme layer or fibre $q_{min} = 0$	02

Q .NO	SOLUTION	MARKS
Q-1		
(b)	D = diameter of a column = 200mm	
(iii)	L = Length of column = 3m = 3000mm	
	E = 2×10^5 Mpa	
	To determine Euler's crippling load 'P'	
	since both ends of column are hinged $L_e = L$	
	$L_e = L = 3000$	01
	for circular section	
	$I = \frac{\pi}{64} D^4 = \frac{\pi}{64} \times 200^4 = 78.53 \times 10^6 \, mm^4$	01
	$P = \frac{\pi^2 EI}{(L_e)^2} = \frac{\pi^2 \times 2\times10^5 \times 78.53\times10^6}{(3000)^2}$	
	$P = 17.22 \times 10^6 \, N$	02

Q.NO	SOLUTION	MARKS
2.	Attempt any TWO of the following	16
a.		



Solution: [Note: Considering Rectangular portion at centre]
Considering triangle as a section no. 1
& substracting rectangular section as no. 2
So,

$y_1 = \frac{H}{3} = \frac{90}{3} = 30$ mm from base

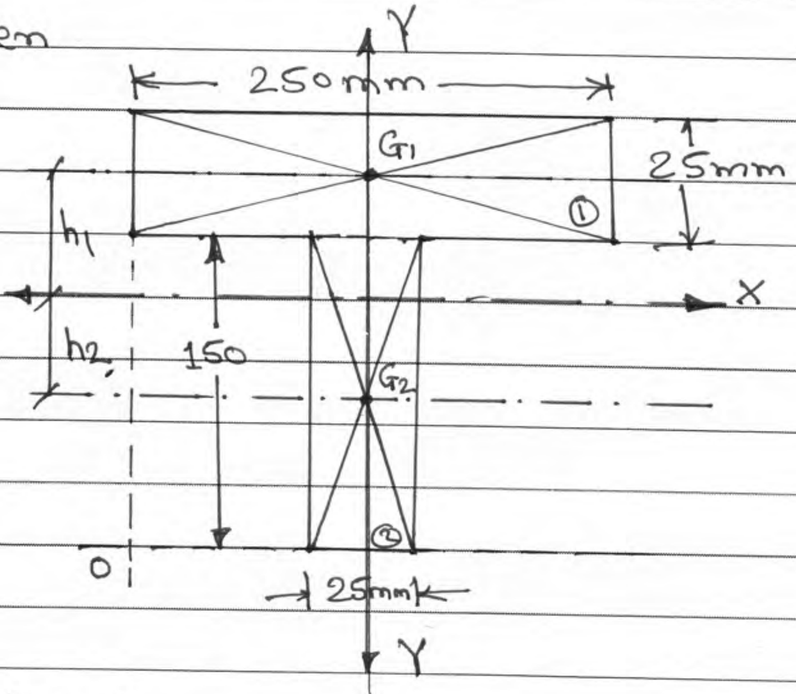
& $y_2 = 30 + \frac{30}{2} = 45$ mm from base

also $A_1 = \frac{1}{2} b \times h = \frac{1}{2} \times 100 \times 90 = 4500\ mm^2$

& $A_2 = 30 \times 20 = 600\ mm^2$

$\therefore \bar{y} = \frac{y_1 A_1 - y_2 A_2}{A_1 - A_2} = \frac{(30 \times 4500) - (45 \times 600)}{(4500 - 600)}$

Q.NO	SOLUTION	MARKS
	$\therefore \bar{y} = 27.69$ mm from base.	2m
	Case I[st] :	
	$\therefore h_1 = y_1 - \bar{y} = 30 - 27.69 = 2.31$ mm	
	& $h_2 = y_2 - \bar{y} = 45 - 27.69 = 17.31$ mm	1m
	Now MI about XX-axis passing through C.G.	
	$\therefore I_{xx_T} = I_{xx_1} - I_{xx_2}$	
	$\therefore I_{xx_T} = \left(\frac{b_1 H^3}{36} + A_1 h_1^2\right) - \left(\frac{b_2 d_2^3}{12} + A_2 h_2^2\right)$	
	$= \left[\frac{100 \times 90^3}{36} + 4500 \times 2.31^2\right] - \left[\frac{20 \times 30^3}{12} + 600 \times 17.31^2\right]$	
	$= 2.049 \times 10^6 - 224.78 \times 10^3$	
	$I_{xx_T} = 1.824 \times 10^6$ mm^4 .... MI @ XX axis	2m
	Case - II[nd] :	
	MI about the base BC.	
	$\therefore h_1 = y_1 = 30$ mm	
	& $h_2 = y_2 = 45$ mm	1m
	$\therefore I_{xx_T} = I_{xx_1} - I_{xx_2}$	
	$= \left(\frac{b_1 H^3}{36} + A_1 h_1^2\right) - \left(\frac{b_2 d_2^3}{12} + A_2 h_2^2\right)$	
	$= \left[\frac{100 \times 90^3}{36} + 4500 \times 30^2\right] - \left[\frac{20 \times 30^3}{12} + 600 \times 45^2\right]$	
	$= 6.075 \times 10^6 - 1.26 \times 10^6 = 4.815 \times 10^6$ mm^4	2m

Q.NO	SOLUTION	MARKS
2a Cotd.	[Or] Alternate Solution for case 2nd.	
	$A_S = I_{xx_T} = I_{xx_1} - I_{xx_2}$	
	$= \frac{b_1 H_1^3}{12} - \left(\frac{b_2 d_2^3}{12} + A_2 h_2^2\right)$	2m
	$= \frac{100 \times 90^3}{12} - \left[\frac{20 \times 30^3}{12} + 600 \times 45^2\right]$	
	$= 6.075 \times 10^6 - 1.26 \times 10^6$	
	$I_{xx_T} = 4.815 \times 10^6\ mm^4$ ...... MI @ base BC	2 m
Q.2 b)	Given  Solution: $x_1 = x_2 = \frac{250}{2} = 125\ mm$ $y_1 = 150 + \frac{25}{2} = 162.5\ mm$ $y_2 = \frac{150}{2} = 75\ mm.$	

Q.NO	SOLUTION	MARKS
	$A_1 = 250 \times 25 = 6250\ mm^2$	
	$A_2 = 25 \times 150 = 3750\ mm^2$	
	$\therefore \bar{y} = \frac{a_1 y_1 + a_2 y_2}{a_1 + a_2}$	
	$= \frac{(6250 \times 162.5) + (3750 \times 75)}{(6250 + 3750)}$	
	$\bar{y} = 129.69$ mm from base	---- 1m
	& $\bar{x} = x_1 = x_2 = 125$ mm from origin.	
	ii) Calculation of I_{xx}.	
	$h_1 = y_1 - \bar{y} = 162.5 - 129.69$	
	$= 32.81$ mm	
	$h_2 = \bar{y} - y_2 = 129.69 - 75$	
	$= 54.69$ mm	---- 1m
	$I_{xx_T} = I_{xx_1} + I_{xx_2}$	
	$= \left(\frac{b_1 d_1^3}{12} + A_1 h_1^2\right) + \left(\frac{b_2 d_2^3}{12} + A_2 h_2^2\right)$	
	$= \left[\frac{250 \times 25^3}{12} + 6250 \times 32.81^2\right]$	
	$+ \left[\frac{25 \times 150^3}{12} + 3750 \times 54.69^2\right]$	
	$= 7.05 \times 10^6 + 18.247 \times 10^6$	
	$I_{xx_T} = 25.3 \times 10^6\ mm^4$	--- 3 m

Q.NO	SOLUTION	MARKS

ii) Calculation of I_{YY}.

as $\bar{x} = x_1 = x_2 = 125$ mm

$h_1 = h_2 = 0$

$\therefore I_{YY_T} = I_{yy_1} + I_{yy_2}$

$= \frac{d_1 b_1^3}{12} + \frac{d_2 b_2^3}{12}$

$= \frac{25 \times 250^3}{12} + \frac{150 \times 25^3}{12}$

$= 32.55 \times 10^6 + 195.31 \times 10^3$

$I_{YY_T} = 32.747 \times 10^6 \text{ mm}^4$ ---3 m

C) Given :

i) Length $= L = 10$ m

ii) $t_1 = 10°$ & $t_2 = 70°$

$\therefore t = t_2 - t_1 = 70 - 10 = 60°$

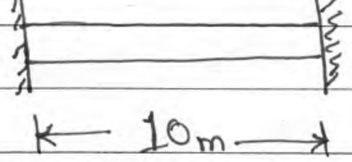
iii) $E = 2.1 \times 10^5$ N/mm²

iv) $\alpha = 12 \times 10^{-6}$ /°C

v) Free Expansion is prevented.

Find: Magnitude & Nature of Stress = ?

Solution:



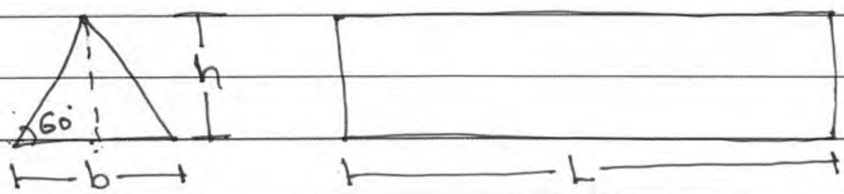
Rise in temperature $t = 70 - 10 = 60°$ ... 2m

Stress $\delta_t = \alpha t E$ 2m

$= 12 \times 10^{-6} \times 60 \times 2.1 \times 10^5$

$\delta_t = 151.2$ N/mm² 2m

As free expansion is prevented nature of stress is compressive 2m

Q.NO	SOLUTION	MARKS
3	Attempt any TWO of the following	16
a)	Given :	
	i) Equilateral triagular bar of 15 mm side	
	ii) Length 'L' = 2.5 m = 2500 mm	
	iii) Change in Length $\delta l = 2$ mm.	
	iv) $E = 20 \times 10^4$ N/mm².	
	Find :	
	i) Push 'P'	
	ii) Stress 'σ'	
	iii) Strain 'e'	
	Solution :	
	Cross sectional area $A = \frac{1}{2} bh$	
		
	$\therefore h = \sin 60° \times b = \sin 60° \times 15$	
	$\therefore h = 12.99$ mm	
	$\therefore$ Area $A = \frac{1}{2} bh = \frac{1}{2} \times 15 \times 12.99$	
	$A = 97.425 \text{ mm}^2$ —	2 m

Q.NO	SOLUTION	MARKS
	Young's Modulus $E = \frac{\delta}{e}$	
	$\because\ e = \text{strain} = \frac{\delta l}{l} = \frac{2}{2500}$	
	$\therefore\ \boxed{e = 8 \times 10^{-4}}$ —	2m
	$\therefore\ E = \frac{\delta}{e}$	
	$\therefore\ 20 \times 10^{4} = \frac{\delta}{8 \times 10^{-4}}$	
	$\therefore\ \delta = 20 \times 10^{4} \times 8 \times 10^{-4}$	
	$\therefore\ \delta = 160\ N/mm^2$	
	$\therefore\ \boxed{\text{Stress} = \delta = 160\ N/mm^2}$ —	2m
	& So. Stress $\delta = \frac{P}{A}$	
	$\therefore\ 160 = \frac{P}{97.425}$	
	$\therefore\ P = \text{Force} = 160 \times 97.425$	
	$\therefore\ \boxed{P = \text{Push} = 15588\ N = 15.588\ kN}$ —	2m

Q.NO	SOLUTION	MARKS
b)	Given :	
	i) Diameter of mild Steel $D_s = 20$ mm	
	ii) External diameter of copper tube $D_c = 30$ mm	
	iii) Internal diameter of copper tube $d_c = 25$ mm	
	iv) Length of rod = 300 mm	
	v) Axial pull = 40 kN ⇒ $P = 40 \times 10^3$ N.	
	vi) $E_s = 200$ GN/m² $= 2 \times 10^5$ N/mm²	
	vii) $E_c = 100$ GN/m² $= 1 \times 10^5$ N/mm²	
	Find :	
	i) stress in steel $\delta_s = ?$	
	ii) Stress in copper tube $\delta_c = ?$	
	iii) Extension $\delta l = ?$	
	Solution :	
	Using $P = \delta_s A_s + \delta_c A_c$	
	∵ A_s = Area of Steel Rod $= \frac{\pi}{4} D_s^2$	
	$A_s = \frac{\pi}{4} 20^2 = 314.16$ mm²	
	∵ A_c = Area of copper tube $= \frac{\pi}{4}(D_c^2 - d_c^2)$	
	$= \frac{\pi}{4}(30^2 - 25^2) = 215.98$ mm²	

Q.NO	SOLUTION	MARKS
	$\therefore P = \delta s As + \delta c Ac$	
	$\therefore 40 \times 10^3 = \delta s \times 314.16 + \delta c \times 215.98$ .... (1)	1m
	Also using $\delta s = \frac{Es}{Ec} \delta c$	
	$\therefore \delta s = \frac{200 \times 10^3}{100 \times 10^3} \delta c$	
	$\therefore \delta s = 2 \delta c$ .... (2)	1m
	Substituting this value in equation (1)	
	$\therefore 40 \times 10^3 = 2 \times 314.16 \times \delta c + 215.98 \times \delta c$	
	$\therefore 40 \times 10^3 = 844.3 \ \delta c$	
	$\therefore \delta c = \frac{40 \times 10^3}{844.3}$	
	$\therefore$ $\boxed{\delta c = 47.376 \ N/mm^2}$	2m
	& $\delta s = 2 \times \delta c = 2 \times 47.376$	
	$\therefore$ $\boxed{\delta s = 94.75 \ N/mm^2}$	2m
	Using $\delta l = \frac{\delta s L}{Es} = \frac{94.75 \times 300}{200 \times 10^3}$	
	$= 0.142$ mm	
	[or] $\delta l = \frac{\delta c L}{Ec} = \frac{47.376 \times 300}{100 \times 10^3}$	
	$\boxed{\delta l = 0.142 \ mm}$	2m

Q.NO	SOLUTION	MARKS
c)	Given :	
	i) Diameter $D = 30$ mm	
	ii) Pull $P = 60$ KN $= 60 \times 10^3$ N	
	iii) Length $L = 200$ mm	
	iv) Elongation $\delta L = 0.09$ mm	
	v) Change in diameter $\delta d = 0.0039$ mm	
	Find :	
	i) Poisson's ratio 'μ' = ?	
	ii) Values of three moduli E, G & K.	
	Solution :	
	As. Poisson's Ratio $\mu = \frac{\text{Lateral Strain}}{\text{Linear Strain}}$	
	So, ∴ Lateral Strain $= \frac{\delta d}{D}$	
	$= \frac{0.0039}{30}$	
	$= 1.3 \times 10^{-4}$	
	& Linear Strain $= \frac{\delta l}{L}$	
	$e = \frac{0.09}{200}$	
	$e = 4.5 \times 10^{-4}$	
	∴ Poisson's Ratio $= \mu = \frac{1.3 \times 10^{-4}}{4.5 \times 10^{-4}} = 0.289$	

Q.NO	SOLUTION	MARKS
	$\therefore$ Poisson's Ratio = 0.29	2m
	We know that $E = \frac{\sigma}{e}$	
	$\therefore \sigma = \frac{P}{A} = \frac{60 \times 10^3}{\frac{\pi}{4} \times 30^2} = 84.88\ N/mm^2$	
	$\therefore E = \frac{84.88}{4.5 \times 10^{-4}} = 188.622 \times 10^3\ N/mm^2$	2m
	Now, using $E = 2G(1+\mu)$	
	$\therefore 188.622 \times 10^3 = 2 \times G(1 + 0.29)$	
	$\therefore G = \frac{188.622 \times 10^3}{2(1+0.29)}$	
	$\therefore G = 73.109 \times 10^3\ N/mm^2$	2m
	& using $E = 3K(1-2\mu)$	
	$\therefore 188.622 \times 10^3 = 3 \times K(1 - 2 \times 0.29)$	
	$\therefore K = \frac{188.622 \times 10^3}{3(1-0.58)}$	
	$K = 149.7 \times 10^3\ N/mm^2$	2m

Q.NO	SOLUTION	MARKS
4.	Attempt any TWO of the following.	16
a.	Given :	
	i) Side of cube $L = 50\ mm$	
	ii) $E = 200\ kN/mm^2 = 200 \times 10^3\ N/mm^2$	
	iii) $m = \frac{10}{3}$	
	iv) Tensile force in X-direction $P_X = 6\ kN$	
	v) Compresive force in Y-direction $P_Y = 8\ kN$	
	vi) Tensile force in Z-direction $P_Z = 4\ kN$.	
	Find :	
	i) Change in the volume 'δV' = ?	
	Solution:	
	As, Poisson's ratio $= \mu = \frac{1}{m}$	
	$\therefore \mu = \frac{1}{(10/3)} = 0.3$	1m
	Now, Stresses in three directions.	
	$\sigma x = \frac{P_X}{A} = \frac{6 \times 10^3}{50 \times 50} = +2.4\ N/mm^2$	1m
	$\sigma y = \frac{P_Y}{A} = \frac{-8 \times 10^3}{50 \times 50} = -3.2\ N/mm^2$	1m
	$\sigma z = \frac{P_Z}{A} = \frac{4 \times 10^3}{50 \times 50} = +1.6\ N/mm^2$	1m

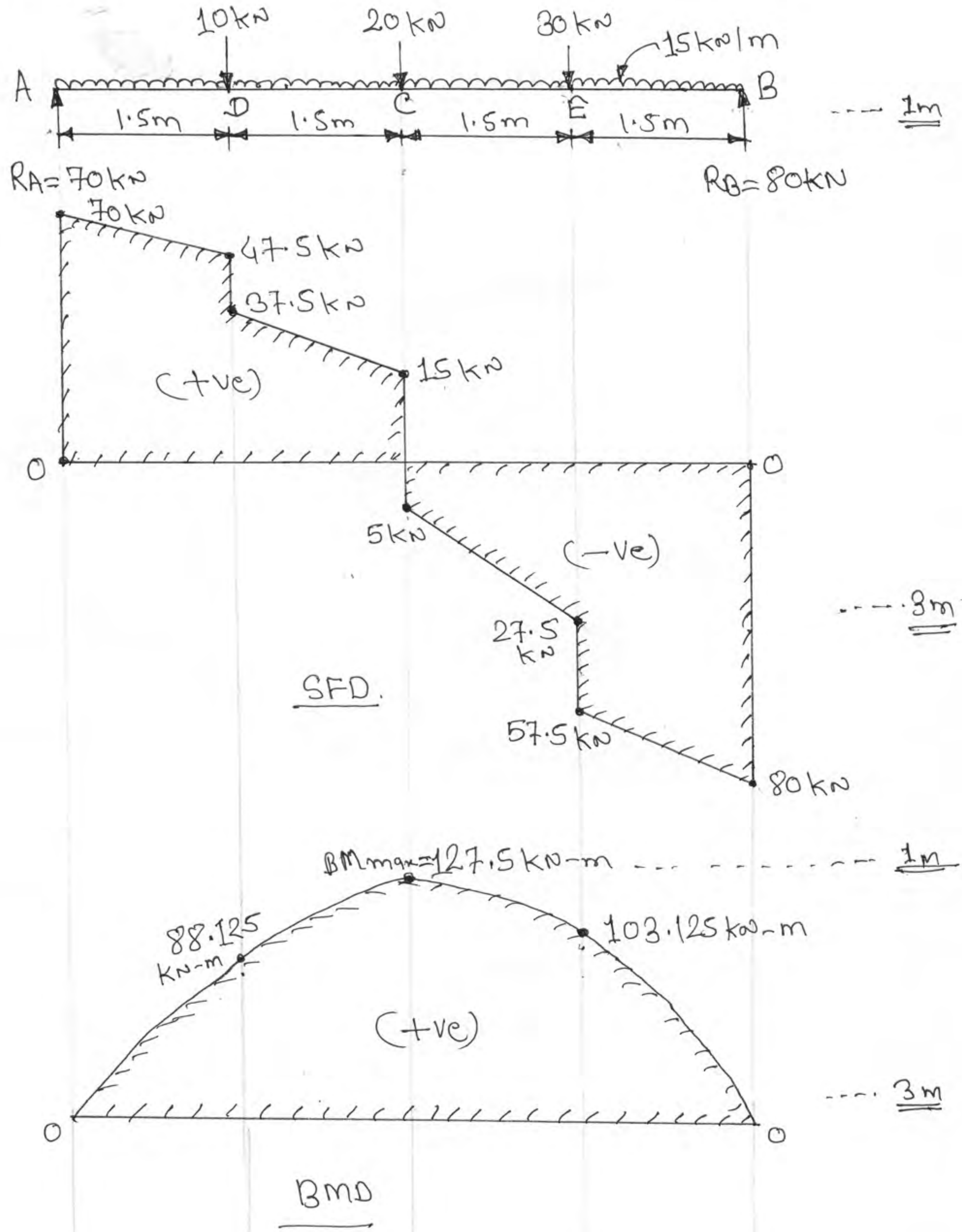
Q.NO	SOLUTION	MARKS
	As. Volumetric strain of a rectangular block subjected to triaxial loading is given by	
	$e_v = \frac{\delta V}{V} = \frac{\delta x + \delta y + \delta z}{E}(1-2\mu)$	2m
	$\therefore \frac{\delta V}{50 \times 50 \times 50} = \frac{2.4 - 3.2 + 1.6}{200 \times 10^3}(1 - 2 \times 0.3)$	
	$\therefore \frac{\delta V}{125 \times 10^3} = \frac{0.8 \times 0.4}{200 \times 10^3}$	
	$\therefore \boxed{\delta V = 0.2\ mm^3}$	2m
b)	Given:	
	i) Diameter $D = 40$ mm	
	ii) Pull $P = 80$ kN $= 80 \times 10^3$ N	
	iii) Change in diameter $\delta d = 0.00775$ mm	
	iv) Modulus of Rigidity $G = 0.4 \times 10^5$ mpa	
	Find:	
	i) Poisson's Ratio 'μ' = ?	
	ii) Modulus of Elasticity 'E' = ?	
	Solution:	
	Using $E = 2G(1+\mu)$	

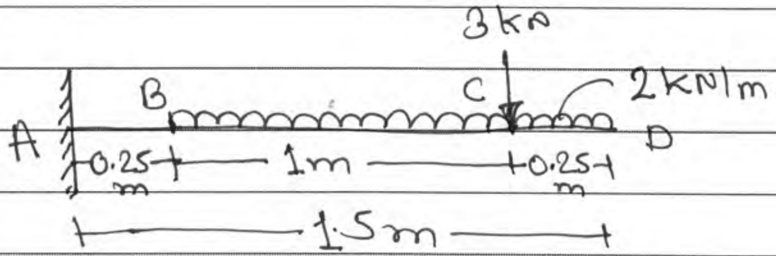
Q.NO	SOLUTION	MARKS
	So, $E = \frac{\delta}{e}$	
	$\therefore \delta = \frac{P}{A} = \frac{80 \times 10^3}{\frac{\pi}{4} \times 40^2} = 63.66\ N/mm^2$	
	& $\mu = \frac{\text{Lateral Strain}}{e}$	
	$\therefore$ Lateral Strain $= \frac{\delta d}{D} = \frac{0.00775}{40}$	
	$= 1.9375 \times 10^{-4}$	
	$\therefore e = \frac{1.9375 \times 10^{-4}}{\mu}$	
	$\therefore E = \frac{63.66}{\frac{1.9375 \times 10^{-4}}{\mu}}$	
	$E = 328567.74\ \mu$ ---- (1)	....2m
	As $E = 2G(1+\mu)$	
	$\therefore 328567.74\mu = 2 \times 0.4 \times 10^5 (1+\mu)$	
	$\therefore \frac{328567.74 \times \mu}{2 \times 0.4 \times 10^5} = 1+\mu$	
	$\therefore 4.1\mu = 1+\mu$	
	$\therefore 4.1\mu - \mu = 1$	
	$\therefore 3.1\mu = 1$	
	$\therefore \mu = \frac{1}{3.1} = 0.322$	......4m

Q.NO	SOLUTION	MARKS
	$\therefore E = 328567.75\ \mu$	
	$= 328567.75 \times 0.32$	
	$E = 105.14168 \times 10^3\ N/mm^2$	....2m
C)	Given:	
	i) Simply Supported Beam of span 6m	
	$\therefore L = 6m$	
	ii) UdL = 15 kN/m	
	iii) Load of 10 kN at the left quarter point i.e. at $\frac{6}{4} = 1.5m$ from Left end	
	iv) Load of 20 kN at centre i.e at 3m from ends.	
	v) Load of 30 kN at the right quarter point i.e. at $\frac{6}{4} = 1.5m$ from right end.	
	Find: Max BM & Draw SFD & BMD.	
	Solution:	
	i) Calculation of support reaction:	
	$\Sigma Fy = 0$	
	$\therefore R_A + R_B = (15 \times 6) + 30 + 20 + 10 = 150$	
	$\Sigma M @ A = 0$	
	$(R_B \times 6) - (15 \times 6 \times \frac{6}{2}) - (30 \times 4.5) - (20 \times 3)$	
	$- (10 \times 1.5) = 0$	
	$\therefore R_B = 80\ kN$	
	$\& \ R_A = 150 - 80 = 70\ kN.$	

Q .NO	SOLUTION	MARKS
	ii) Shear force Calculations : (↑-ve, ↓+ve)	
	SF@B(R) = 0	
	(L) = -80 kN	
	SF@E(R) = -80 + (15×1.5) = -57.5 kN	
	(L) = -57.5 + 30 = -27.5 kN	
	SF@C(R) = -80 + (15×3) + 30 = -5 kN	
	(L) = -5 + 20 = 15 kN	
	SF@D(R) = -80 + (15×4.5) + 30 + 20 = 37.5	
	(L) = 37.5 + 10 = 47.5 kN.	
	SF@A(R) = -80 + (15×6) + 30 + 20 + 10 = 70	
	(L) = 70 - 70 = 0	
	iii) Bending Moment Calculation : (↻+ve, ↺-ve)	
	BM@B = 0	
	BM@E = $(80 \times 1.5) - (15 \times 1.5 \times \frac{1.5}{2})$	
	= 103.125 kN.m	
	BM@C = $(80 \times 3) - (15 \times 3 \times \frac{3}{2}) - (30 \times 1.5)$	
	= 127.5 kN-m.	
	BM@D = $(80 \times 4.5) - (15 \times 4.5 \times \frac{4.5}{2}) - (30 \times 3)$	
	$- (20 \times 1.5)$	
	= 88.125 kN-m	
	BM@A = 0	
	∴ Max BM = BM@C = 127.5 kN-m.	

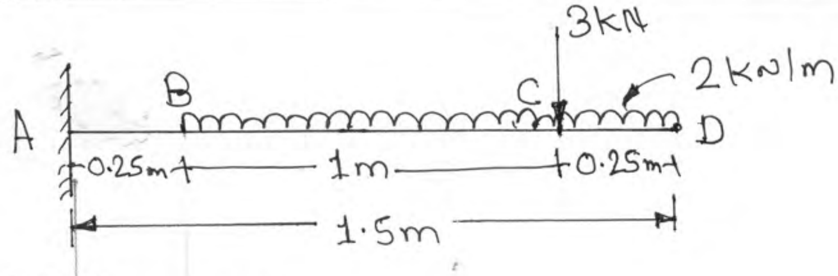
Q.4(C) →

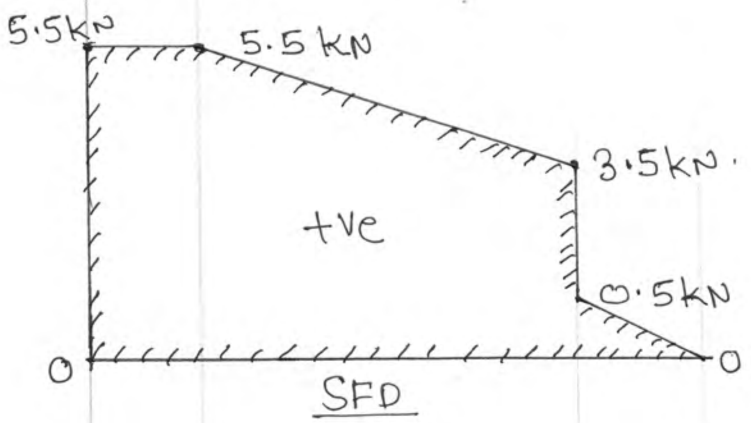

10kN
20kN
30kN
15kN/m
A
B
D
C
E
1.5m
1.5m
1.5m
1.5m
--- 1m
RA=70kN
RB=80kN
70kN
47.5kN
37.5kN
15kN
(+ve)
0
0
5kN
(−ve)
--- 3m
27.5 kN
57.5kN
80kN
SFD.
BMmax=127.5kN-m
--- 1m
88.125 kN-m
103.125kN-m
(+ve)
--- 3m
0
0
BMD

Q.NO	SOLUTION	MARKS
5	Attempt any TWO of the following	16
a)		
	Given:	
		
	i) Support Reaction Calculation	
	$\Sigma fy = 0$	
	$\therefore RA = (2 \times 1.25) + 3 = 5.5$ kN	1m
	$\Sigma M @ A = 0$ (↻ +ve)(↺ -ve)	
	$-(2 \times 1.25 \times (\frac{1.25}{2} + 0.25)) - (3 \times 1.25) + M_A = 0$	
	$\therefore M_A = 5.9375$ kN-m.	1m
	ii) Shear force Calculation (↑ -ve, ↓ +ve)	
	SF @ D = 0	
	SF @ C(R) = $(2 \times 0.25) = 0.5$ kN.	
	(L) = $0.5 + 3 = 3.5$ kN.	
	SF @ B = $(2 \times 1.25) + 3 = 5.5$ kN.	
	SF @ A(R) = 5.5 kN.	
	(L) = $5.5 - 5.5 = 0$	
	iii) Bending Moment Calculation (↺ -ve)(↻ +ve)	
	BM @ D = 0	
	BM @ C = $-(2 \times 0.25 \times \frac{0.25}{2}) = -0.0625$ kN-m	
	BM @ B = $-(2 \times 1.25 \times \frac{1.25}{2}) - (3 \times 1) = 4.5625$ kN-m	

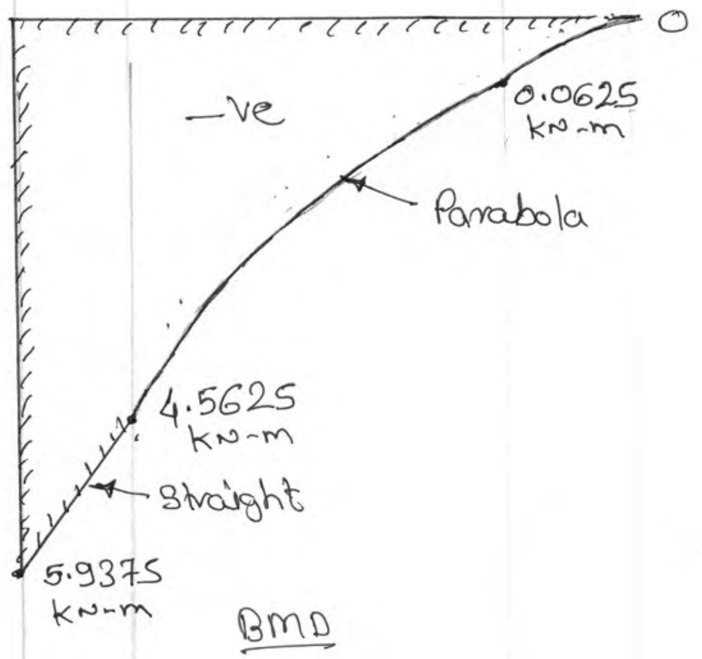
Q.NO	SOLUTION	MARKS
	$BM @ A (R) = -(2 \times 1.25 \times (\frac{1.25}{2} + 0.25)) - (3 \times 1.25)$	
	$= -5.9375\ kN\text{-}m$	
	$(L) = -5.9375 + 5.9375 = 0$	

Q. 5(a)


3kN
2kN/m
A
B
C
D
0.25m
1m
0.25m
1.5m


5.5kN
5.5 kN
3.5kN
+ve
0.5kN
0
0
SFD

...... 3m


0
-ve
0.0625 kN-m
Parabola
4.5625 kN-m
Straight
5.9375 kN-m
BMD

..... 3m

Q.NO	SOLUTION	MARKS
b)	Draw SFD & BMD	
	i) Support Reaction calculation:	
	$\Sigma fy = 0$	
	$RA + RB = (16 \times 2.5) + 40 + 80 + (10 \times 5)$	
	$= 210$ kN	
	$\Sigma M @ A = 0$	
	$\therefore -(16 \times 2.5 \times (\frac{2.5}{2} + 12.5)) + (R_B \times 12.5)$	
	$-(40 \times 7.5) - (80 \times 5) - (10 \times 5 \times \frac{5}{2}) = 0$	
	$\therefore$ RB = 110 kN	
	$\therefore$ RA = 210 − 110 = 100 kN	
	ii) Shear Force calculation; (↑ −ve, ↓ +ve)	
	SF @ E = 0	
	SF @ B (R) = (16 × 2.5) = 40 kN	
	(L) = 40 − 110 = −70 kN	
	SF @ D (R) = −70 kN	
	(L) = −70 + 40 = −30 kN.	
	SF @ C (R) = −30 kN	
	(L) = −30 + 80 = 50 kN.	
	SF @ A (R) = 50 + (10 × 5) = 100 kN	
	(L) = 100 − 100 = 0	
	iii) Bending Moment Calculation: (↻ −ve, ↺ +ve)	
	BM @ E = 0	
	BM @ B = $-(16 \times 2.5 \times \frac{2.5}{2})$	
	= −50 kN-m	

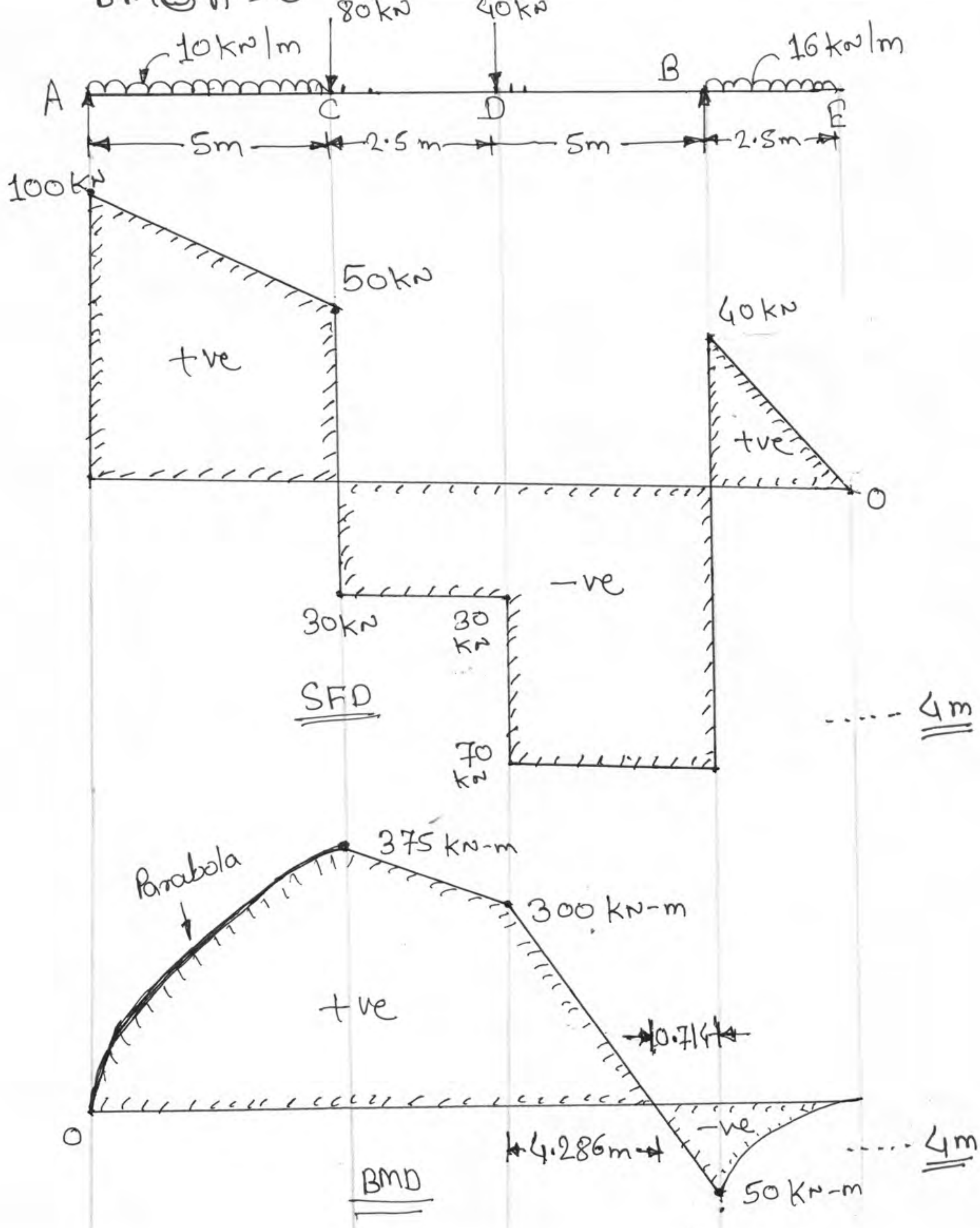
Q.5.(b)

$$BM@D = -\left(16 \times 2.5 \times \left(\frac{2.5}{2} + 5\right)\right) + (110 \times 5)$$

$$= 300 \text{ kN-m.}$$

$$BM@C = -\left(16 \times 2.5 \times \left(\frac{2.5}{2} + 7.5\right)\right) + (110 \times 7.5) - (40 \times 2.5) = 375 \text{ kN-m}$$

$$BM@A = 0$$



Q.NO	SOLUTION	MARKS

C. Given :

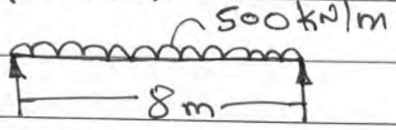
i) Udl of 500 kN/m over span of 8m.

Find:

i) Maximum bending stress

Solution:

Note: In given problem, type of beam is not mension so assuming beam is simply supported.

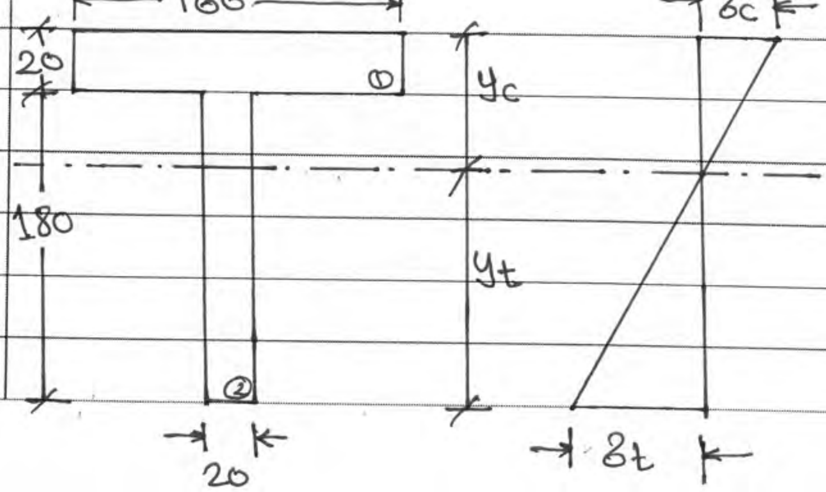


$\therefore M_{max} = \frac{wl^2}{8}$

$= \frac{500 \times 8^2}{8} = 4000$ kN-m.

$= 4000 \times 10^6$ N-mm. 1m

As the beam is simply supported, the compression zone will be above N.A. & the tension zone will be below N.A.



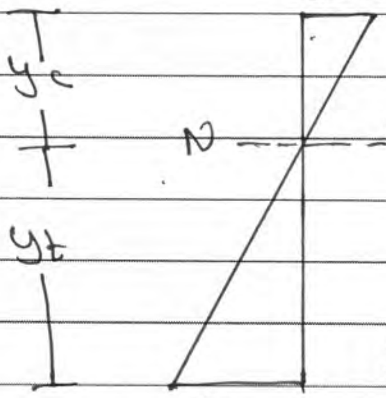
Q.NO	SOLUTION	MARKS
	$\therefore \bar{y} = \dfrac{a_1 y_1 + a_2 y_2}{a_1 + a_2}$	
	$= \dfrac{(160 \times 20) \times 190 + (180 \times 20) \times 90}{(160 \times 20) + (180 \times 20)}$	
	$= 137.06$ mm from base	
	$\therefore y_t = \bar{y} = 137.06$ mm	
	& $y_c = 200 - \bar{y} = 200 - 137.06 = 62.94$ mm	--- 1m
	Now $I_{xxT} = I_{xx1} + I_{xx2}$	
	$I_{xxT} = \left[\dfrac{160 \times 20^3}{12} + (160 \times 20)(62.94 - 10)^2\right] + \left[\dfrac{20 \times 180^3}{12} + (20 \times 180)(137.06 - 90)^2\right]$	
	$= 9.075 \times 10^6 + 17.69 \times 10^6$	
	$= 26.7678 \times 10^6$ mm^4	--- 2m
	Now using Bending Stress Equation	
	$\dfrac{M}{I} = \dfrac{\delta c}{y_c} = \dfrac{\delta t}{y_t}$	
	$\therefore \dfrac{4000 \times 10^6}{26.7678 \times 10^6} = \dfrac{\delta c}{62.94} = \dfrac{\delta t}{137.06}$	
	$\therefore \delta c = \dfrac{4000 \times 10^6 \times 62.94}{26.7678 \times 10^6} = 9405.33$ N/mm^2	
	$= 9.405 \times 10^3$ N/mm^2	--- 2m

Q.NO	SOLUTION	MARKS

& $\sigma_t = \frac{4000 \times 10^6 \times 137.06}{26.7678 \times 10^6} = 20481.32 \ N/mm^2$

$= 20.481 \times 10^3 \ N/mm^2$ 2m

$\sigma_c = 9.4 \times 10^3 \ N/mm^2$



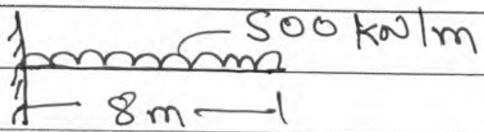
Stress Distribution Diagram

$\sigma_t = 20.481 \times 10^3 \ N/mm^2$

[or]

Note: In given problem, type of beam is not mension so, assuming beam is cantilever type

$\therefore M_{max} = \frac{wL^2}{2}$

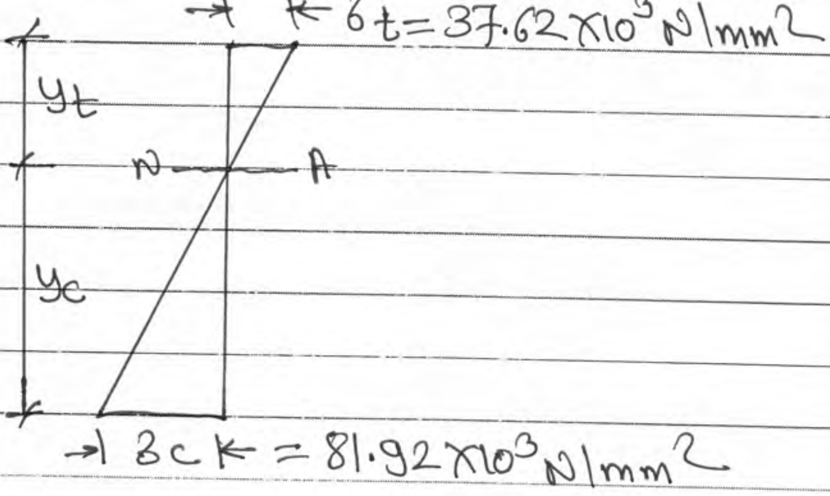


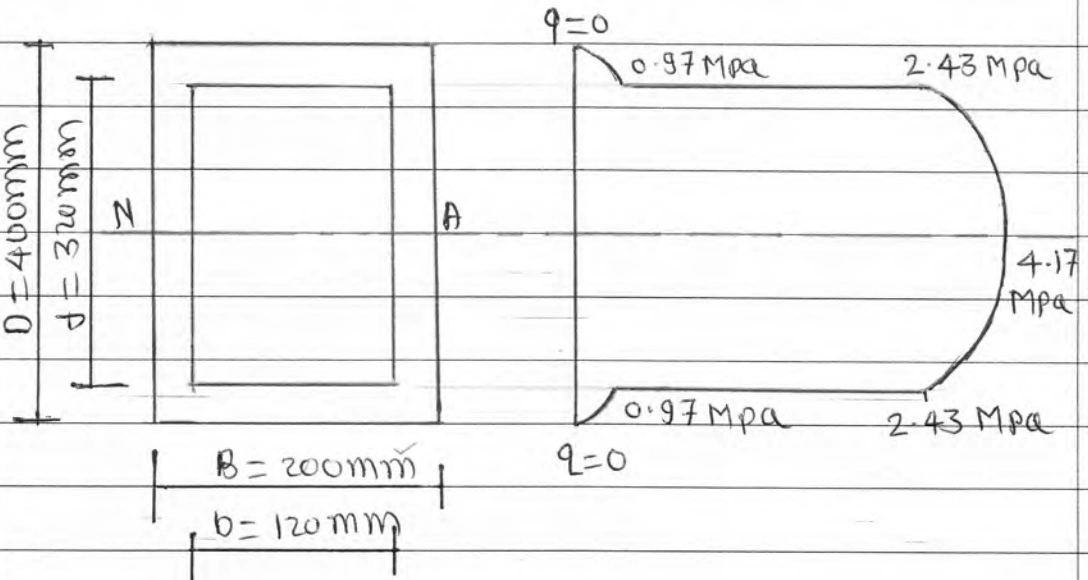
$= \frac{500 \times 8^2}{2}$

$= 16000 \ kN\text{-}m$

$= 16000 \times 10^6 \ N\text{-}mm$ ... 1m

as the beam is cantilever type, the tension zone will be above N.A & compression zone will be ~~above~~ below N.A.

Q.NO	SOLUTION	MARKS
	Now, $y_c = 137.06$ mm	
	& $y_t = 62.94$ mm.	... 1m
	& $M_{max} = 16000 \times 10^6$ N-mm.	
	& $I_{xx} = 26.7678 \times 10^6$ mm^4	... 2m
	Now using Bending Stress Equation.	
	$\frac{M}{I} = \frac{\delta_c}{y_c} = \frac{\delta_t}{y_t}$	
	$\therefore \frac{16000 \times 10^6}{26.7678 \times 10^6} = \frac{\delta_c}{137.06} = \frac{\delta_t}{62.94}$	
	$\therefore \delta_c = \frac{16000 \times 10^6 \times 137.06}{26.7678 \times 10^6}$	
	$= 81.92 \times 10^3$ N/mm^2	... 2m
	& $\delta_t = \frac{16000 \times 10^6 \times 62.94}{26.7678 \times 10^6}$	
	$= 37.62 \times 10^3$ N/mm^2	... 2m
		

Q .NO	SOLUTION	MARKS
Q-6 (a)	given data	
	$F = 100\ kN = 100 \times 10^3\ N$	
	$B \times D = 200\ mm \times 400\ mm$	
	$t = 40\ mm$	
	$b = (200-2t) = 200 - 2\times 40 = 120\ mm$	
	$d = (400-2t) = 400 - 2\times 40 = 320\ mm$	
	$b \times d = (120\ mm \times 320\ mm)$	
		01
	$I = I_{xx} = I_{NA} = \frac{BD^3}{12} - \frac{bd^3}{12}$	
	$= \frac{200 \times 400^3}{12} - \frac{120 \times 320^3}{12}$	
	$I = 738.986 \times 10^6\ mm^4$	01
	To find the ratio q_{max}/q_{avg}	

Q .NO	SOLUTION	MARKS
	q = shear stress at top & bottom layer = 0	
	q_1 = Shear stress at the junction of flange & web	
	$q_1 = \frac{F A_1 \bar{y}_1}{IB}$	
	$A_1 = 200 \times 40 = 8000\ mm^2$	
	$\bar{y}_1 = 160 + \frac{t}{2} = 160 + \frac{40}{2} = 180mm$	
	$q_1 = \frac{(100 \times 10^3 \times 8000 \times 180)}{738.986 \times 10^6 \times 200} = 0.97\ Mpa$	01
	q_1 suddenly increase to q_2	
	$\therefore q_2 = \frac{B}{2 \times t} \times q_1 = \frac{200}{(2 \times 40)} \times 0.97 = 2.43\ Mpa$	01
	$q_{max} = \frac{F \times [A_1 \bar{y}_1 + A_2 \bar{y}_2]}{I \times 2t}$	01
	$A_1 = 200 \times 40 = 8000mm^2$ $A_2 = 2[40 \times 160] = 12800mm^2$	
	$y_1 = 160 + t/2 = 160 + 40/2 = 180mm$	

Q .NO	SOLUTION	MARKS
	$y_2 = \frac{t}{2} = \frac{160}{2} = 80mm$	
	$q_{max} = \frac{100 \times 10^3 [8000 \times 180 + 12800 \times 80]}{738.986 \times 10^6 \times (2 \times 40)}$	
	$q_{max} = 4.167$ Mpa	01
	q_{avg} = Average shear stress = $\frac{F}{A}$	
	$A = [B \times D - b \times d]$ $A = [200 \times 400 - 120 \times 320]$	
	$A = 41600 \; mm^2$	
	$q_{avg} = \frac{100 \times 10^3}{41600}$	
	$q_{avg} = 2.40$ Mpa	01
	$\frac{q_{max}}{q_{avg}} = \frac{4.17}{2.40} = 1.74$	01

Q .NO	SOLUTION	MARKS
Q-6		
(b)	given data	
	$P = 800\,kN = 800 \times 10^3\,N$	
	$L = 4\,m = 4000\,mm$	
	$D = 200\,mm$	
	$d = ?$	
	$E = 2 \times 10^5\,N/mm^2$, $F.S = 4$	
	To find Internal diameter (d)	
	$L_e = L/2$ (both ends are fixed)	
	$L_e = \frac{4000}{2} = 2000\,mm$	01
	Safe load $= \frac{P_E}{F.S}$ $\therefore P.E = F.S \times$ Safe load	
	$P.E = 4 \times 800 \times 10^3 = 3200 \times 10^3\,N$	01
	But $P.E = \frac{\pi^2 EI}{(L_e)^2} = \frac{\pi^2 \times 2 \times 10^5 \times I}{(2000)^2}$	01
	$3200 \times 10^3 = \frac{\pi^2 \times 2 \times 10^5 \times I}{(2000)^2}$	01
	$\therefore I = \frac{3200 \times 10^3 \times (2000)^2}{\pi^2 \times 2 \times 10^5} = 6.48 \times 10^6\,mm^4$	01
	But $I = \frac{\pi}{64}(D^4 - d^4)$	01

Q .NO	SOLUTION	MARKS
	$\therefore 6.48 \times 10^6 = \frac{\pi}{64}(200^4 - d^4)$	
	$200^4 - d^4 = 132 \times 10^6 d^4$	
	$\therefore d^4 = 200^4 - 132 \times 10^6$	
	$d^4 = 1.468 \times 10^9$	
	$\therefore \boxed{d = 195.74\,mm}$	02

Q .NO	SOLUTION	MARKS
Q-6		
(c)	Since the elongation is known, the stress can be calculated by using the relation	
	$\delta L = \dfrac{\sigma L}{E}$	01
	$3 = \dfrac{\sigma \times 4000}{210 \times 10^3}$	
	$\sigma = 157.5\ N/mm^2$	01
	Now, in the case of impact load, the stress produced is given by	
	$\sigma = \dfrac{P}{A} + \sqrt{\left(\dfrac{P}{A}\right)^2 + \dfrac{2Eh}{L}\left(\dfrac{P}{A}\right)}$	01
	$\dfrac{P}{A} = x$	
	$157.5 = x + \sqrt{x^2 + \dfrac{2(210 \times 10^3) \times 15}{4000} \cdot x}$	01
	$157.5 = x + \sqrt{x^2 + 1575x}$	
	$(157.5 - x)^2 = x^2 + 1575x$	
	$24806.25 = 315x + 1575x$	
	$24806.25 = 1890x$	01
	$x = \dfrac{P}{A}$ (assumed) $\therefore \dfrac{P}{A} = 13.125$	
	$\therefore \dfrac{P}{800} = 13.125 \quad \therefore P = 800 \times 13.125$	02
	$P = 10500 N$	
	$P = 10.5 KN$	01