MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

SUMMER – 15 EXAMINATIONS

Subject Code: 17311 **Model Answer- Mechanics of Structure** **Total Pages: 01 / 30**

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 access 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.

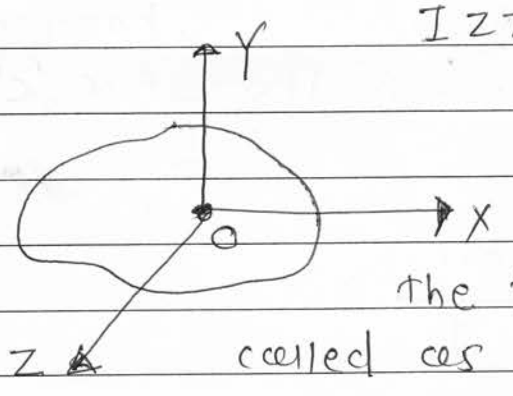
5) The figures drawn by candidate & model answer may vary. The examiner may give credit for any equivalent figure drawn.

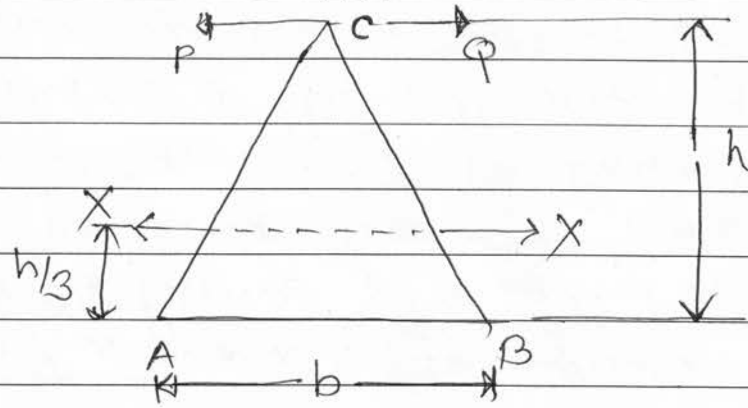
5) Credit may be given step wise for numerical problems. In some cases, the assumed contact values may vary and there may be some difference in the candidate's answers and model answer.

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.

Important notes to examiner

Q .NO	SOLUTION	MARKS
1. A		
a)	Perpendicular Axis theorem	
	Statement - if I_{xx} and I_{yy} are the moment's of inertia of a plane section about the two mutually perpendicular axes meeting at 'O', then the moment of inertia, I_{zz} about the third axis ZZ ⊥er to plane and passing through the intersection of X-X and Y-Y is given by	01M
	$I_{ZZ} = I_{xx} + I_{yy}$	
		
	The third axis ZZ is called as Polar Axis.	
	i.e. $I_{zz} = I_p$	
	$\boxed{I_p = I_{xx} + I_{yy}}$	01M
	where I_p = polar moment of Inertia	
b)	consider a triangular section ABC of base b & hight 'h' as shown in fig.	

Q .NO	SOLUTION	MARKS
Q.1) A)		
b)	counti.... the centre of Gravity of triangle will be at a distance of $h/3$ from the base AB.	
		
	M. I. of triangle about the horizontal Axis PQ Passing through it's apex 'C' is given by	
	$$I_{PQ} = \frac{b \cdot h^3}{4}$$	02M
c)	* Ductility :- it is the Property of material to undergo a considerable deformation under tension without rupture. or	01M
	* it is the property of material due to which it can be drawn into thin wires.	
	* malleability :- it is the Property of a material by virtue of which it get's Permanently deformed by compression without rupture. or	01M

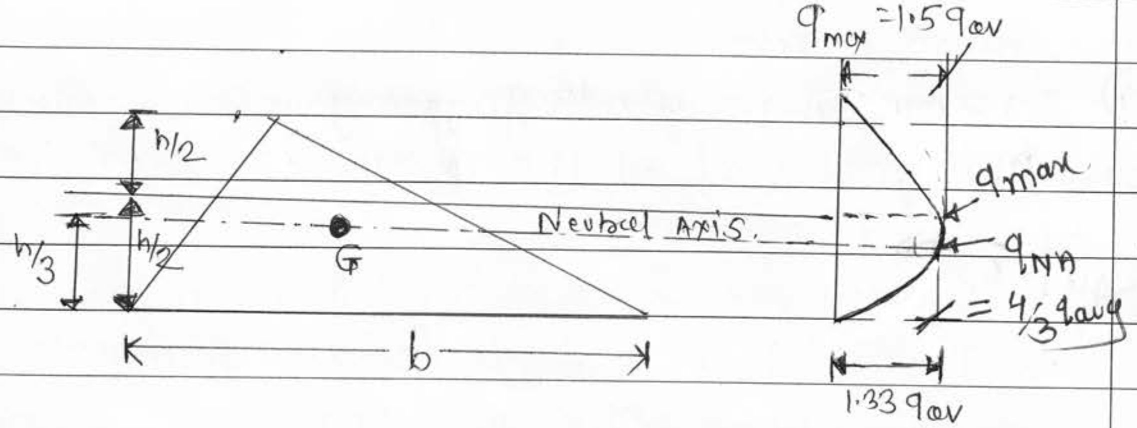
* it is the property of a material due to which it can be drawn into thin sheets.

Q.NO	SOLUTION		MARKS
Q.1 A)			
d)	nominal Breaking stress	Actual Breaking stress	
	(i) it is the ratio of load at Breaking Point. To the original cross-sectional Area.	(i) it is the ratio of load at Breaking Pt. To the reduced cross-sectional area at fracture.	01M
	(ii) nominal breaking stress is less than ultimate stress.	(ii) Actual breaking stress is higher than ultimate stress.	01M
(e)	end conditions of column.		
	1) Both end hinged $L = 2L$		(½M for each)
	2) Both end fixed $L = \frac{L}{2}$		
	3) one end fixed and other end hinged		$L = L/\sqrt{2}$
	4) one end fixed and other end free		$L = 2L$
f)	(i) if $y = 0$, but $\frac{\partial y}{\partial x} \neq 0$ then column end is hinged		01M
	(ii) if $y \neq 0$, $\frac{\partial y}{\partial x} \neq 0$ then column end is free.		01M

Q .NO	SOLUTION	MARKS
Q. 1 A)		
(g)	Proof resilience. (U_{max})	
	The maximum amount of strain energy which can be stored by a member or a body without exceeding the elastic limit is called as proof resilience.	01M
	$$\boxed{U_{max} = \frac{\sigma^2}{2E} \cdot V}$$	01M
	where σ = stress produced at elastic limit E = modulus of elasticity V = Volume of body.	

	Gradual load	Sudden load	
(h)			
(1)	Stress produced is $\sigma = \frac{P}{A}$	(1) Stress produced is $\sigma = \frac{2P}{A}$	01M
(2)	Stress due to gradual load is lesser than sudden load	(2) Stress due to sudden load is higher than the gradual load.	01M

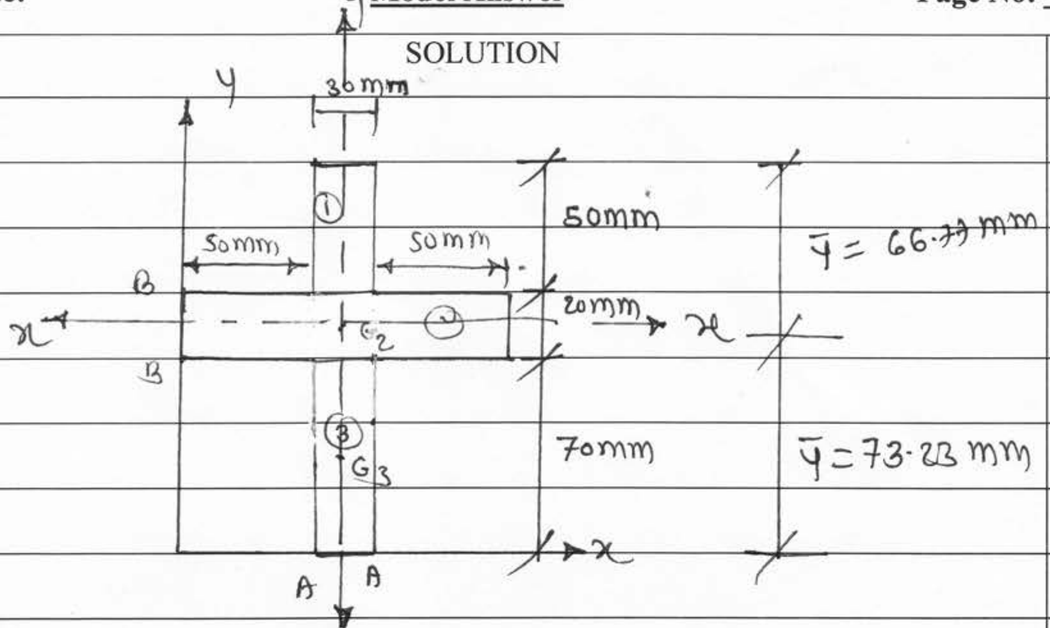
Q.NO	SOLUTION	MARKS
Q-1(B) a)	Assumption in bending Theory	
	i) The elastic limit is not exceeded.	(½M for Any Four)
	ii) The beam intially straight and unstressed.	
	iii) each longitudinal fiber is free to expand or contract independently from every other layer.	
	iv) The resultant force accross transverse section of the beam is zero.	
	v) The deformation of the section due to shear force is neglected	
	vi) The materical of the beam is homogeneous and isotropic.	
	vii) Transverse section of the beam which is plane before bending will remain's plane after the bending.	
	viii) the beam is stressed well upto proportional limit such that it must obeys Hooke's law.	
	ix) the value of young's modulus (E) is same in tension and in compression.	
ii)	Bending eq^n $\frac{M}{I} = \frac{\sigma_b}{y} = \frac{E}{R}$	01M
	where M = Bend. moment = M_r	
	I = M.I. of sect^n about the N.A. passing through the centroid of section.	
	$I = I_{NA} = I_{xx}$	01M
	σ_b = Bending stress in layer at a dist. 'y' from N-A.	

Q .NO	SOLUTION	MARKS
1 (B) (ii) cont…	count….	
	y = Distance of the layer from the N-A of the beam cross-section	
	E = modulus of elasticity of beam material	
	R = Radius of curvature of bent up beam.	
(b)		02M
	consider a triangular section of base b and hight h as shown in fig the N.A. Passes through the centroid 'G' at a dist. h/3 from the base,	
	$$q_{av} = \frac{S}{A} = \frac{S}{\frac{1}{2}bh}$$	½M
	$$q_{NA} = \frac{4}{3} q_{av}$$	½M
	the max. shear stress occur at a distance h/2 from the base.	
	$$\boxed{q_{max} = 1.59 q_{av}}$$	1M

Q.NO	SOLUTION	MARKS
Q-1-B (c)	i) short column When the ratio of effective length to the least lateral dimension's of the column is less than 12, then it is called a short column. or When the ratio of effective length to the least radius of gyration is less than 45, then it is called short column.	02M
	ii) long column. When the ratio of effective length to the least radius of gyration is greater than 45 then it is called a long column.	02M

Q .NO	SOLUTION	MARKS

Q-2(a)



i) Area calculation

$A_1 = 30 \times 50 = 1500\,mm^2$

$A_2 = 130 \times 20 = 2600\,mm^2$

$A_3 = 70 \times 30 = 2100\,mm^2$ — ½M

ii) Distance of centroid from the base AA

$y_1 = 70 + 20 + 50/2 = 115\,mm$

$y_2 = 70 + 20/2 = 70 + 10 = 80\,mm$

$y_3 = 70/2 = 35\,mm$

$$\bar{y} = \frac{1500 \times 115 + 2600 \times 80 + 2100 \times 35}{1500 + 2600 + 2100}$$

$\boxed{\bar{y} = 73.23\,mm}$ — 01M

iii) To find I_{xx}

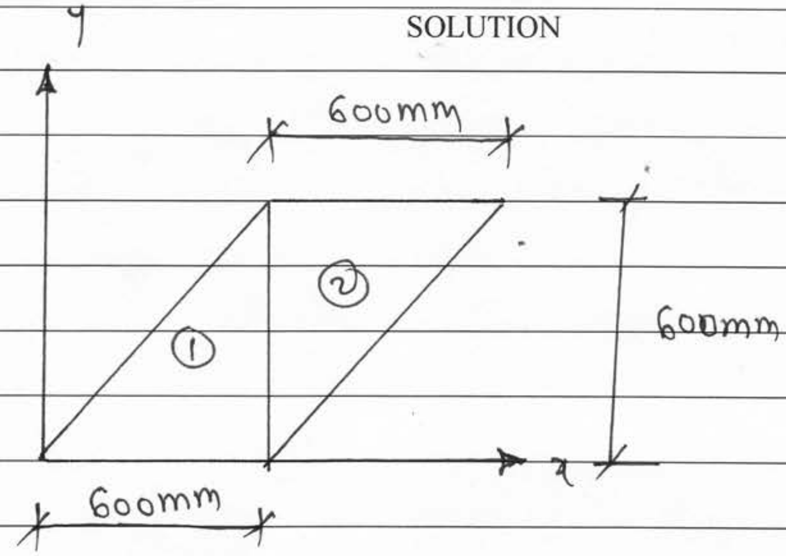
$I_{G_1} = \frac{30 \times 50^3}{12} = 312.5 \times 10^3\,mm^4$ — ½M

$h_1 = 66.77 - \frac{50}{2} = 41.77$ $\boxed{h_1 = 41.77\,mm}$ — ½M

$I_{xx_1} = I_{G_1} + A_1 h_1^2 = 312.5 \times 10^3 + 1500 \times (41.77)^2$

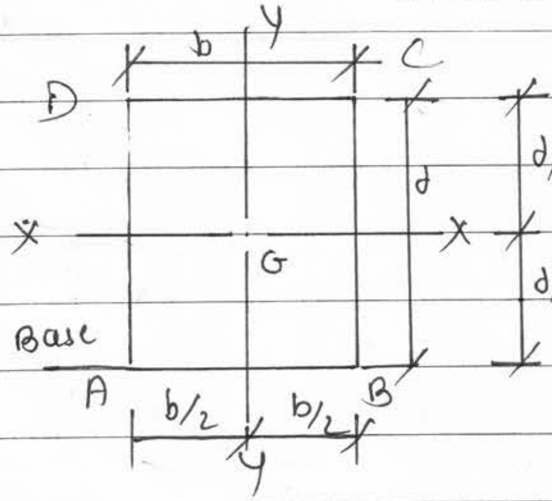
$\boxed{I_{xx1} = 2.929 \times 10^6\,mm^4}$ — 01M

Q .NO	SOLUTION	MARKS
	$I_{G_2} = \dfrac{130 \times 20^3}{12} = 86.67 \times 10^3 \ mm^4$	1/2 M
	$h_2 = 66.77 - \left(50 + \dfrac{20}{2}\right)$	
	$h_2 = 6.77 \ mm$	1/2 M
	$I_{xx_2} = I_{G_2} + A_2 h_2^2$	
	$= 86.67 \times 10^3 + 2600 \times (6.77)^2$	
	$I_{xx_2} = 205.84 \times 10^3 \ mm^4$	01 M
	$I_{G_3} = \dfrac{30 \times 70^3}{12} = 875.5 \times 10^3 \ mm^4$	1/2 M
	$h_3 = 73.23 - 70/2 = 38.23 \ mm$	1/2 M
	$I_{xx_3} = I_G + A_3 h_3^2 = 875.5 \times 10^3 + 2100 \times (38.23)^2$	
	$I_{xx_3} = 3.9447 \times 10^6 \ mm^4$	01 M
	Now	
	$I_{xx} = I_{xx_1} + I_{xx_2} + I_{xx_3}$	
	$= 2.929 \times 10^6 + 86.67 \times 10^3 + 3.9447 \times 10^6$	
	$I_{xx} = 6.96 \times 10^6 \ mm^4$	1/2 M

Q .NO	SOLUTION	MARKS
Q-2 (b)		
	∴ i) Area calculation	
	$A_1 = \frac{600 \times 600}{2} = 180000 \text{ mm}^2$	
	$A_2 = 180000 \text{ mm}^2$	½ M
	$x_1 = \frac{2}{3} \times 600 = 400 \text{ mm}$ $\quad y = \frac{600}{3} = 200 \text{ mm}$	½ M
	$x_2 = 600 + \frac{600}{3} = 800 \text{ mm}$ $\quad y_2 = \frac{2}{3} \times 600 = 400 \text{ mm}$	½ M
	$\bar{x} = \frac{A_1 x_1 + A_2 x_2}{A_1 + A_2} = \frac{180000 \times 400 + 180000 \times 800}{180000 + 180000}$	
	$\bar{x} = 600 \text{ mm}$	½ M
	$\bar{y} = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2}$	½ M
	$\bar{y} = \frac{180000 \times 200 + 180000 \times 400}{180000 + 180000}$	
	$\bar{y} = 300 \text{ mm}$	½ M
	ii) M.I @ x-x axis	
	$h_1 = \bar{y} - y_1 = 300 - 200 = 100 \text{ mm}$	½ M
	$h_2 = y_2 - \bar{y} = 400 - 300 = 100 \text{ mm}$	½ M

Q.NO	SOLUTION	MARKS
Q-2 (b) Cont.	$I_{xx} = [I_{G1} + A_1 h_1^2] + [I_{G2} + A_2 h_2^2]$	
	$= \left[\frac{600 \times 600^3}{12} + 180000 \times 100^2\right] +$	01 M
	$\left[\frac{600 \times 600^3}{12} + 180000 \times 100^2\right]$	
	$I_{xx} = 2.52 \times 10^{10}\ mm^4$	01 M
	iii) M.I @ y-y - axis	
	I_{yy} = M.I of triangle ① @ base + M.I of Triangle ② @ base	
	$I_{yy} = \frac{bh^3}{12} + \frac{bh^3}{12}$	01 M
	$I_{yy} = \frac{bh^3}{6}$	
	$I_{yy} = \frac{600 \times 600^3}{6}$	
	$\boxed{I_{yy} = 2.16 \times 10^{10}\ mm^4}$	01 M

Q .NO	SOLUTION	MARKS
Q-2 (c)	i)	



$A = b \times d$

$h = d/2$

i) let $I_{AB} = I_{Base} = I_G + Ah^2$ — ½M

$= \frac{bd^3}{12} + b \times d \times \left(\frac{d}{2}\right)^2$ — ½M

$= \frac{bd^3}{12} + bd\frac{d^2}{4}$

$= \frac{bd^3}{12} + \frac{bd^3}{4}$

$= \frac{bd^3}{12} + \frac{3bd^3}{12}$

$= \frac{4bd^3}{12}$

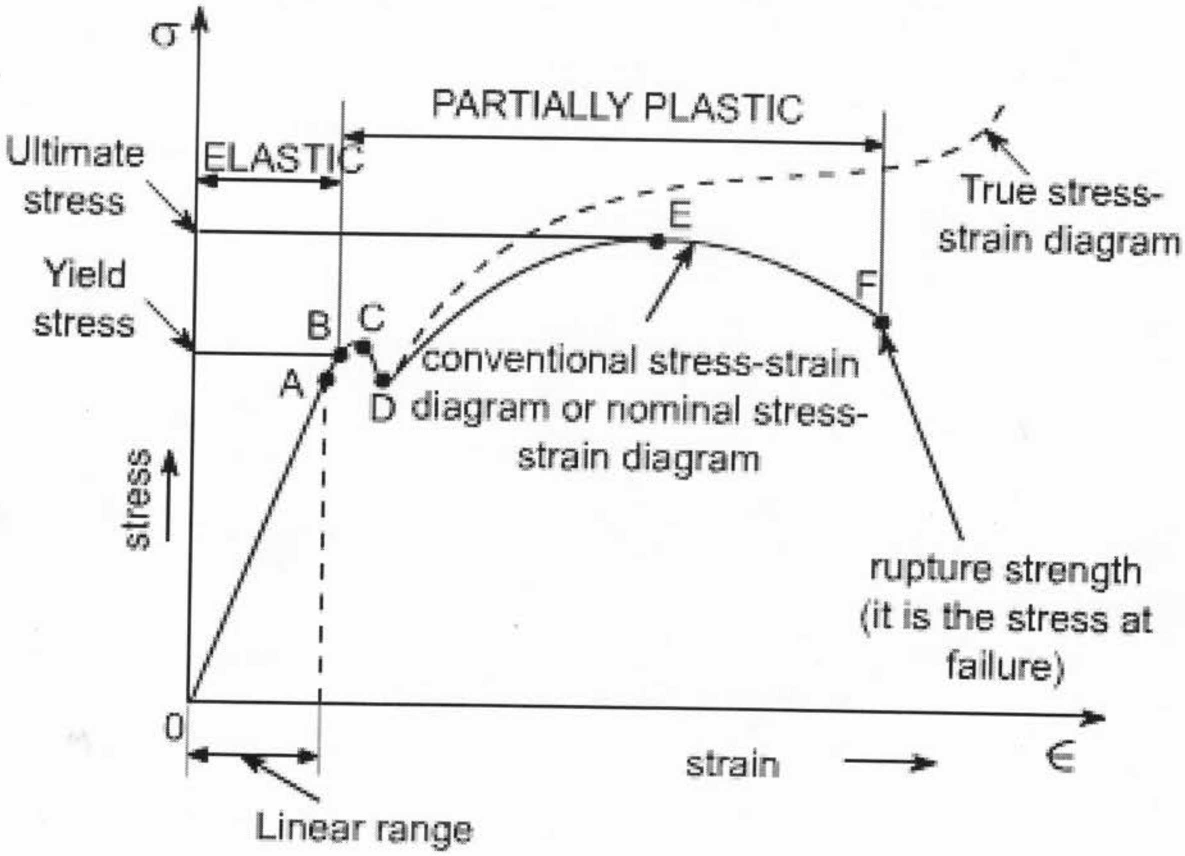
$\boxed{I_{Base} = \frac{bd^3}{3}}$ — 01M

ii) Moment of inertia from side AD

let $I_{AD} = I_{side} = I_G + Ah^2$ — ½M

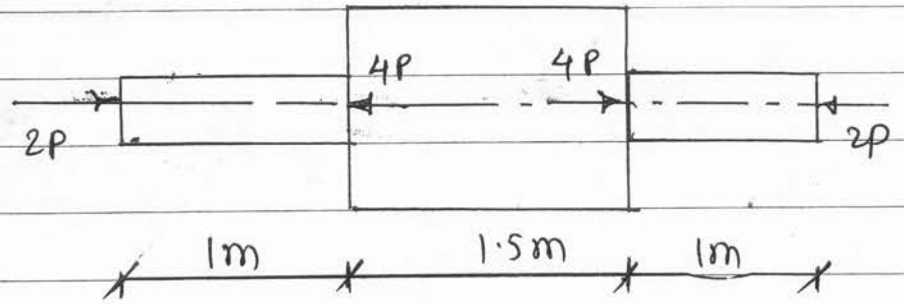
$= \frac{db^3}{12} + b \times d \times \left(\frac{b}{2}\right)^2$ — ½M

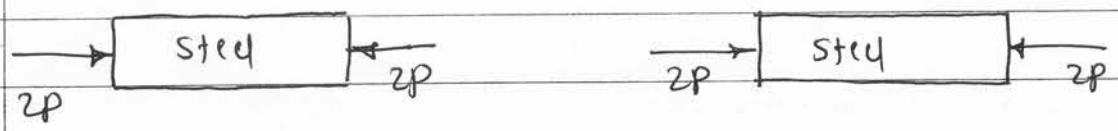
$\boxed{I_{AD} = \frac{db^3}{3}}$ — 01M

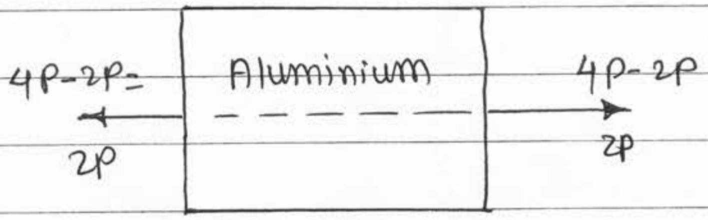
Q .NO	SOLUTION	MARKS
Q-2-c-ii)	Draw stress-strain curve for mild steel unoer tensile loading showing Important points on it.	04 M
		04 M

Q .NO	SOLUTION	MARKS

Q-3 (a)







01M

→ given data

i) $A_{steel} = 75\ mm^2$ ii) $A_{Al} = 300 mm^2$

$\delta L = 2mm$

$\delta L = \delta L_1 + \delta L_2 + \delta L_3$ 01M

$$\delta L = \left(\frac{P.L}{A.E}\right)_{steel} + \left(\frac{P.L}{A.E}\right)_{Al} + \left(\frac{P.L}{A.E}\right)_{steel}$$ 01M

$$2 = \frac{-2P \times 1000}{75 \times 20 \times 10^4} + \frac{2P \times 1500}{300 \times 7 \times 10^4} - \frac{2P \times 1000}{75 \times 20 \times 10^4}$$ 01M

$$2 = \frac{-2000P}{15 \times 10^6} + \frac{3000P}{21 \times 10^6} - \frac{2000P}{15 \times 10^6}$$ 01M

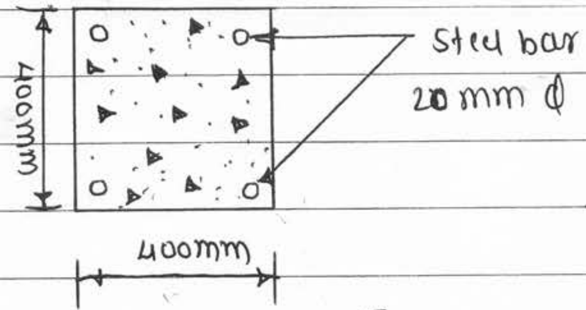
$$2 = -1.3333 \times 10^{-4} + 1.4286 \times 10^{-4} - 1.3333 \times 10^{-4}$$ 01M

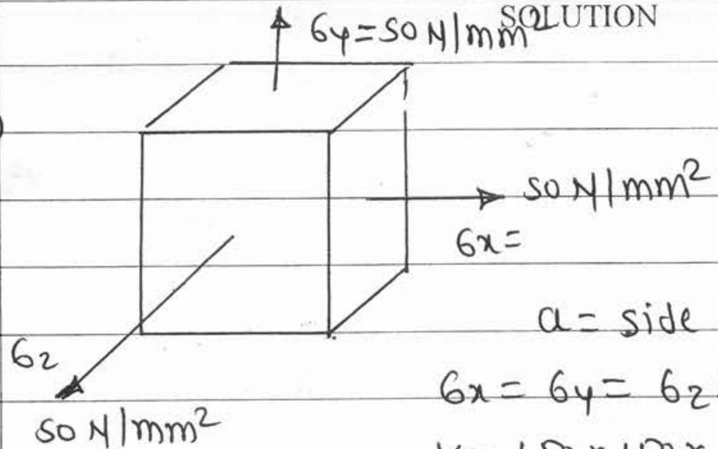
$$2 = -1.238 \times 10^{-4} P$$

$$\therefore P = -\frac{2}{1.238 \times 10^{-4}}$$ 01M

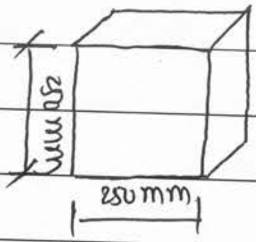
$$\boxed{\begin{aligned} P &= -16.15 \times 10^3\ N \\ P &= 16.15\ KN \end{aligned}}$$

(-ve sign indicate P is compressive in nature 01M

Q .NO	SOLUTION	MARKS
Q-3 (b)		
	given $P = 500\,KN$ $\frac{E_s}{E_c} = 13.33$	
ANS →	i) Total area $= 400 \times 400 = 160000\,mm^2$	½M
	ii) Area of steel $= 4 \times \frac{\pi}{4} \times 20^2 = 1256.63\,mm^2$	½M
	iii) Area of concrete = Total area − Area of steel	
	$= 160000 - 1256.63$	
	$= 158.74 \times 10^3\,mm^2$	½M
	iv) $\frac{\sigma_s}{\sigma_c} = \frac{E_s}{E_c} = m$	
	$\frac{\sigma_s}{\sigma_c} = 13.33$ $\boxed{\sigma_s = 13.33\,\sigma_c}$	½M
	v) $P = P_s + P_c$	
	$= \sigma_s A_s + \sigma_c A_c$	01M
	$= 13.33\,\sigma_c \times 1256.63 + \sigma_c \times 158.74 \times 10^3$	01M
	$= 16.75087 \times 10^3\,\sigma_c + 158.74 \times 10^3\,\sigma_c$	
	$500 \times 10^3 = 175.49 \times 10^3\,\sigma_c$	01M
	$\sigma_c = \frac{500 \times 10^3}{175.49 \times 10^3}$	01M
	$\boxed{\sigma_c = 2.849\,N/mm^2}$	01M
	$\sigma_s = 13.33 \times 2.849$	
	$\boxed{\sigma_s = 37.979\,N/mm^2}$	01M

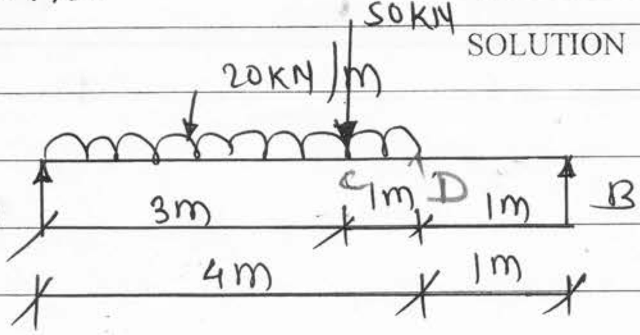
Q .NO	SOLUTION	MARKS
Q-3 (c)		
	a = side of cube = 150 mm	
	$\sigma_x = \sigma_y = \sigma_z = 50\ N/mm^2$	
	$V = 150 \times 150 \times 150 = 3.375 \times 10^6\ mm^3$	
	$E = 2 \times 10^5\ N/mm^2$ & $\mu = 0.33$	
	$\frac{\delta v}{V} = \frac{\sigma_x + \sigma_y + \sigma_z}{E}(1-2\mu)$	01M
	$\frac{\delta v}{V} = \frac{50+50+50}{2 \times 10^5}(1 - 2 \times 0.33)$	01M
	$\frac{\delta v}{V} = \frac{150 \times (0.34)}{2 \times 10^5}$	01M
	$\frac{\delta v}{V} = 2.55 \times 10^{-4}$	01M
	$\delta v = (2.55 \times 10^{-4}) \times (3.375 \times 10^6)$	
	$\boxed{\delta v = 860.625\ mm^3}$	01M
	$E = 3K(1-2\mu)$	01M
	$2 \times 10^5 = 3K(1 - 2 \times 0.33)$	01M
	$\boxed{K = 196.078 \times 10^3\ N/mm^2}$	01M
	<u>or</u>	
	$K = \frac{\sigma}{\delta v / v} = \frac{50}{\frac{860.625}{(150)^3}}$	
	$\boxed{K = 196.078 \times 10^3\ N/mm^2}$	

Q .NO	SOLUTION	MARKS
Q-4 (a)	given data	
	$L = 1m = 1000\,mm$	
	$P = 9\,KN$	
	$t = 20^\circ c$	
	$d = 12\,mm \quad E = 200\,KN/mm^2 \quad \alpha = 16 \times 10^{-6} /^\circ c$	
	i) stress due to external load (σ_1)	
	$\sigma_1 = \frac{P}{A} = \frac{9 \times 10^3}{\frac{\pi}{4} \times 12^2} = 79.579\ N/mm^2$	01 M formula 01 M calculation 01 M ANS
	ii) stress due to Temperature	
	$\sigma_2 = E\alpha t$	01 M
	$= 200 \times 10^3 \times 16 \times 10^{-6} \times 20$	01 M
	$= 64\ N/mm^2$	01 M
	iii) Total stresses (resultant stresses)	
	residual stress $= 79.579 + 64$	
	$\boxed{\sigma = 143.579\ N/mm^2}$	02M

Q .NO	SOLUTION	MARKS
Q-4 (b)	 a = side of cube = 250 mm $\delta V = 5200\ mm^3$ $\mu = \frac{1}{m} = 0.25$	
	$\sigma_x = \sigma_y = \sigma_z = \frac{3.8 \times 10^6}{250 \times 250} = 60.8\ N/mm^2$	01M
	$\frac{\delta V}{V} = \frac{\sigma_x + \sigma_y + \sigma_z}{E}(1 - 2\mu)$	01M
	$\sigma_x = \sigma_y = \sigma_z = \sigma$ $\frac{\delta V}{V} = \frac{3\sigma}{E}(1 - 2\mu)$	01M
	$\frac{5200}{(250)^3} = \frac{3 \times 60.8}{E}(1 - 2 \times 0.25)$	01M
	$3.328 \times 10^{-4} = \frac{182.4}{E} \times (0.5)$	
	$3.328 \times 10^{-4} = \frac{91.2}{E}$	
	$E = \frac{91.2}{3.328 \times 10^{-4}}$	01M
	$\boxed{E = 274.038 \times 10^3\ N/mm^2}$	01M
	$E = 3K(1 - 2\mu)$	01M
	$K = \frac{E}{3(1 - 2\mu)} = \frac{274.038 \times 10^3}{3(1 - 2 \times 0.25)}$	
	$\boxed{K = 182.692 \times 10^3\ N/mm^2}$	01M

Q .NO	SOLUTION	MARKS

Q-4 (c)



Step-I) To find the reaction

$\Sigma F_y = R_A - 50 - 20 \times 4 + R_B$

$\Sigma F_y = R_A - 50 - 80 + R_B$

$\Sigma F_y = R_A + R_B - 130$

$R_A + R_B = 130$ ——— (1)

$\Sigma M_A = 0$

$-R_B \times 5 + 50 \times 3 + 20 \times 4 \times 4/2 = 0$

$-R_B \times 5 + 150 + 20 \times 4 \times 2 = 0$

$-R_B \times 5 + 150 + 160 = 0$

$R_B \times 5 = 310$

$\boxed{R_B = 62\,KN}$ $\therefore$ $\boxed{R_A = 68\,KN}$ — 01M

Step-II To calculate shear force

i) $SF_B = -62\,KN$

ii) $SF_D = -62\,KN$

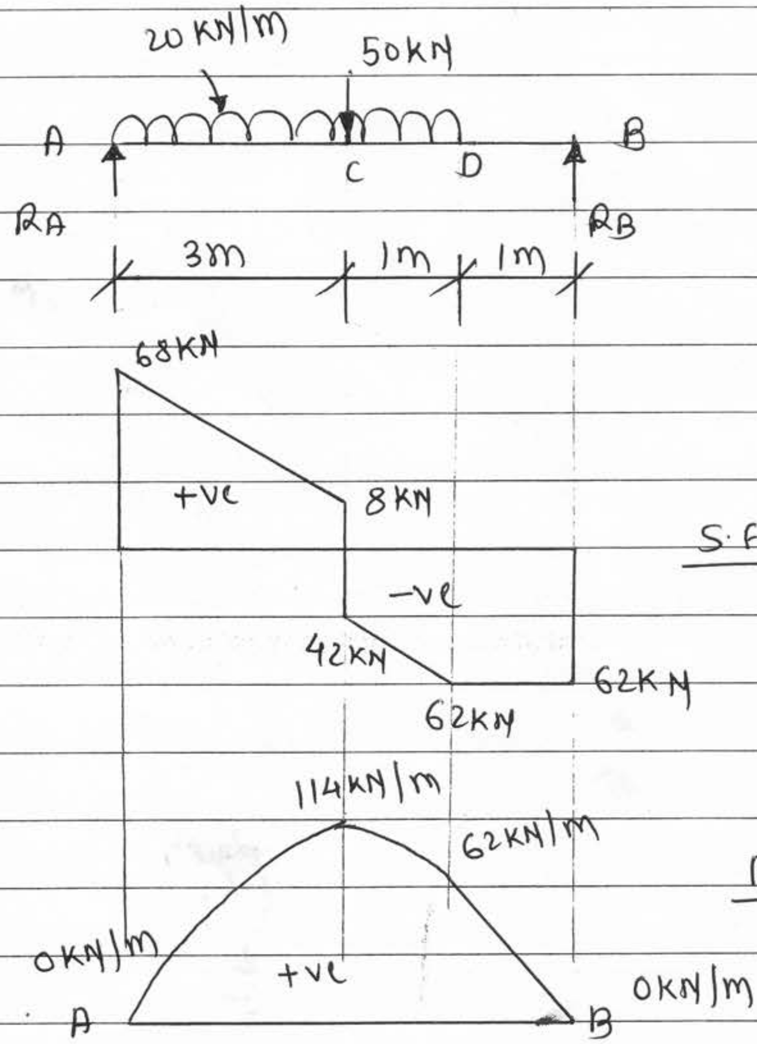
iii) $SF_{CR} = -62 + 20 \times 1 = -42\,KN$

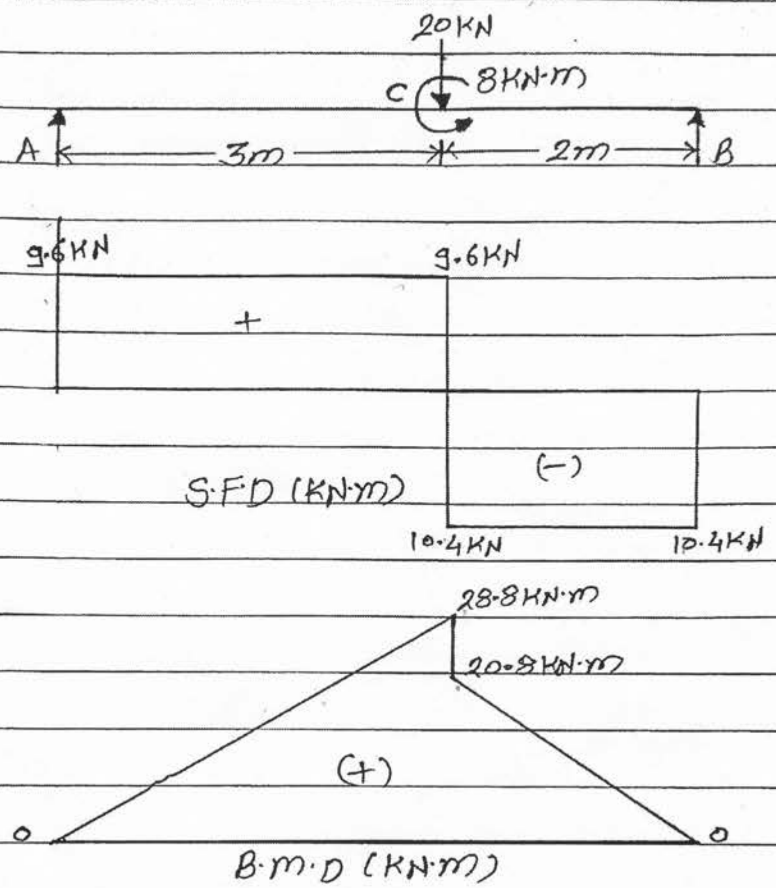
iv) $SF_{CL} = -42 + 50 = 8\,KN$

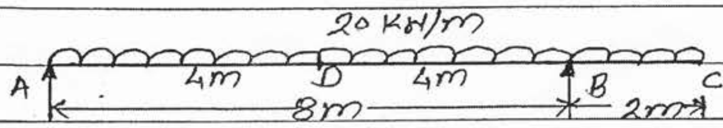
$SF_A = 8 + (20 \times 3)$

$SF_A = 8 + 60$ — 02M

v) $SF_A = 68\,KN$

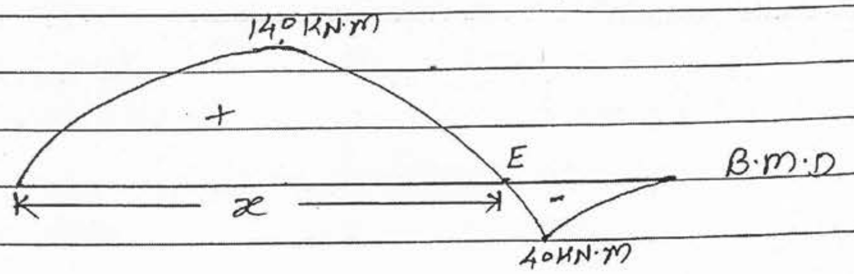
Q .NO	SOLUTION	MARKS
	Step-III> B.M calculation.	
	i> $M_A = 0$	
	ii> $M_B = 0$	
	iii> $M_C = 62 \times 2 - (20 \times 1 \times \frac{1}{2})$	
	$M_C = 114$ KN/m	01M
	iv) $M_D = 62 \times 1 = 62$ KN/m	
	Step-IV) S.F.D & B.M.D	
		
	S.F.D	02M
	B.M.D	02M

Q.NO	SOLUTION	MARKS
Q5 a)		2M 2M
	1) Support reactions	
	a) $\Sigma F_y = 0$; $R_A + R_B = 20$ KN.	
	b) $\Sigma M@A = 0$; $(20 \times 3) - 8 - R_B \times 5 = 0$	
	$52 = 5R_B$	
	$\therefore R_B = 10.4$ KN	1M
	$\therefore R_A = 9.6$ KN	
	2) S.F. Calculation	
	i) S.F. at just left of A = 0	
	ii) SF at just right of A = R_A = 9.6 KN	
	iii) S.F at just left of C = 9.6 KN	

Q.NO	SOLUTION	MARKS
Q5 a) Cont...	iv) S.F at just right of C = 9.6 − 20 = −10.4 KN	
	v) S.F at just left of B = −10.4 KN	2M
	vi) S.F at just right of B = −10.4 + R_B = 0 KN.	
	3) B.M. Calculation.	
	i) B.M at A = B.M at B = 0 KN·m .... S.S. end	
	ii) B.m at just left of C	
	M_{CL} = $R_A \times 3$ = 9.6×3 = 28.8 KN·m	1M
	iii) B.m at just right of C	
	M_{CR} = $R_A \times 3 - 8$ = $9.6 \times 3 - 8$ = 20.8 KN·m	
Q5 b)	i)	
		
	1) Support reactions	
	a) $\Sigma F_y = 0$; $R_A + R_B$ = 20×10 = 200 KN.	
	b) $\Sigma M@A = 0$; (20×10×5) − 8 R_B = 0	
	∴ R_B = 125 KN.	1M
	∴ R_A = 75 KN	
	2) B.M. Calculation	
	$M_A = M_C = 0$	
	M_D = $R_A \times 4 - 20 \times 4 \times 2$ = 75×4 − 20×4×2 = 140 KN·m	1M
	M_B = $R_A \times 8 - 20 \times 8 \times 4$ = 75×8 − 20×8×4 = −40 KN·m	

Q.NO	SOLUTION	MARKS

Q5b i) Cont...



3) To Locate point of Contraflexure (E).

Let x be the distance of E from A. — 1m

$\Sigma M_E = 0$

$\therefore M_x = R_A \cdot x - 20 \times x \cdot \frac{x}{2} = 75x - 10x^2$

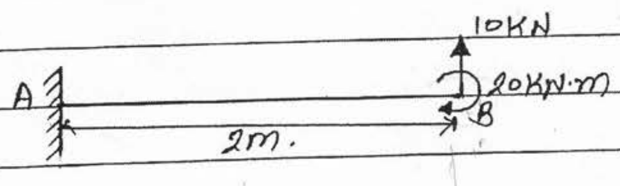
Equating M_x to the zero we have.

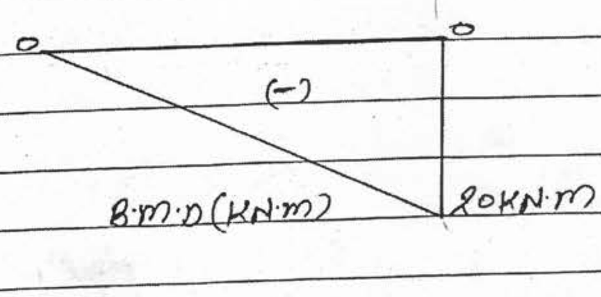
$75x - 10x^2 = 0$

$75 - 10x = 0$

$x = 7.5\,m.$ $(0 < x < 8)$ point E lies between A & B. — 1m

Q5b ii)



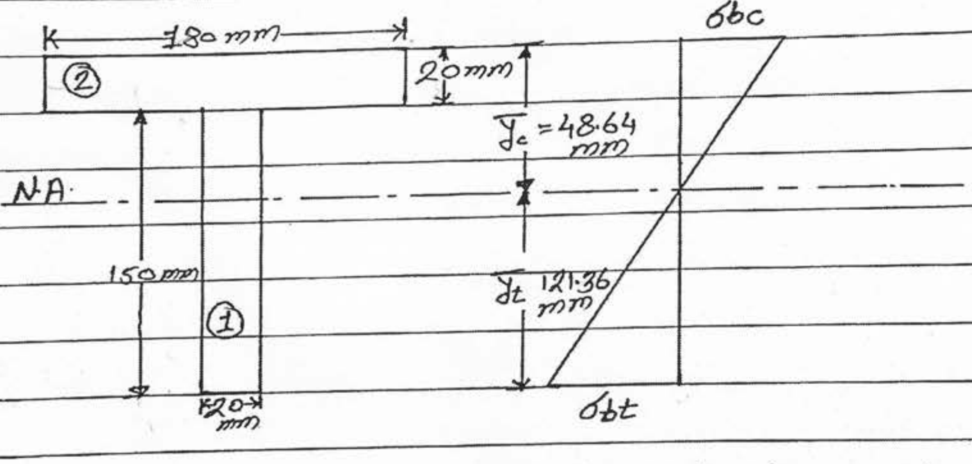
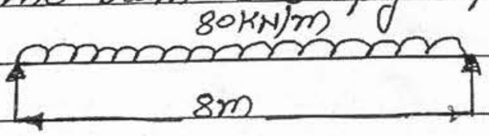


1m

1) Support reaction

$\Sigma F_y = 0$; $R_A + 10 = 0$

$R_A = -10\,KN$ $\therefore R_A = 10\,KN (\downarrow)$ — 1m

Q .NO	SOLUTION	MARKS
Q5b ii) Cont...	$\Sigma M@A = 0$	
	$M_A + 10 \times 2 - 20 = 0$	
	$M_A = 0$ kN·m.	
	2) B.M. Calculation.	
	i) B.M at A = $M_A = 0$ kN·m.	
	ii) B.M at left of B	
	$M_{BL} = -M_A - R_A \times 2 = -10 \times 2 = -20$ kN·m	2M
	iii) B.M at right of B.	
	$M_{BR} = -M_A - R_A \times 2 + 20 = 0$ kN·m.	
Q5 c)		
	Since nothing is mensioned about the type of beam Assume the beam as simply supported beam.	
		
	1) Maximum B.M	
	$M_{max} = \frac{wl^2}{8} = \frac{80 \times 8^2}{8} = 640$ kN·m	2M

Q.NO	SOLUTION	MARKS
Q5 c) Cont...	2) M. I. of section	
	i) Position of N.A.	
	$\bar{y}_t = \frac{a_1y_1+a_2y_2}{a_1+a_2} = \frac{(150\times20\times75)+(180\times20\times160)}{(150\times20)+(180\times20)}$	1 M
	$\bar{y}_t = 121.36$ mm.	1 M
	$\therefore \bar{y}_c = 170 - 121.36 = 48.64$ mm.	
	$I_{xx} = \left[\frac{20\times150^3}{12} + 150\times20(121.36-75)^2\right] + \left[\frac{180\times20^3}{12} + 180\times20(121.36-160)^2\right]$	1 M
	$I_{xx} = 12.07\times10^6 + 5.49\times10^6$	
	$I_{xx} = 17.56\times10^6$ mm^4	1 M
	3) Maximum Bending stress	
	Now using Bending stress equation	
	$\frac{M}{I} = \frac{\sigma_b}{y}$	1 M
	$\therefore \sigma_{bt} = \frac{M}{I}\cdot\bar{y}_t$	
	$\sigma_{bt} = \frac{640\times10^6}{17.56\times10^6}\times121.36 = 4423.14$ N/mm^2 (Tensile)	1 M

Q.NO	SOLUTION	MARKS
Q6 a)		
→	Given. $b = 230mm$, $S = 120KN$, $\tau_{max} = 3.13\ N/mm^2$	
	1) Average shear stress (τ_{avg})	
	$\tau_{avg} = \frac{S}{c/s\ Area} = \frac{120\times10^3}{230\times d} = \frac{521.74}{d}$	1M
	2) For rectangular section,	
	$\tau_{max} = \frac{3}{2}\cdot\tau_{avg}$	1M
	$3.13 = \frac{3}{2}\times\frac{521.74}{d}$	
	$\therefore d = \frac{3}{2}\times\frac{521.74}{3.13} = 250.03mm.$	2M
	3) Minimum radius of gyration r_{min}	
	$r_{min} = \sqrt{\frac{I_{min}}{A}}$	1M
	$I_{xx} = \frac{bd^3}{12} = \frac{230\times250.03^3}{12} = 299.58\times10^6 mm^4$	1M
	$I_{yy} = \frac{db^3}{12} = \frac{250.03\times230^3}{12} = 253.50\times10^6 mm^4$	1M
	$\therefore I_{min} = I_{yy} = 253.50\times10^6 mm^4$	
	$\therefore r_{min} = \sqrt{\frac{253.50\times10^6}{230\times250.03}} = 66.395\ mm.$	1M

Q.NO	SOLUTION	MARKS
Q6 b)		
→	Given, $D = 200\ mm$, $d = 150\ mm$, $L = 5\ m$	
	$f_c = 550\ N/mm^2$, $a = \left(\frac{1}{1600}\right)$.	
	i) Rankines crippling load	
	$P_R = \dfrac{f_c \cdot A_c}{1 + a\left(\frac{L_e}{r_{min}}\right)^2}$	1M
	Area of column $A_c = \frac{\pi}{4}(D^2 - d^2)$	
	$= \frac{\pi}{4}(200^2 - 150^2)$	
	$A = 13744.46\ mm^2$	
	Minimum radius of gyration	
	$r_{min} = \sqrt{\dfrac{I_{min}}{A}} = \sqrt{\dfrac{\frac{\pi}{64}(200^4 - 150^4)}{13744.46}} = 62.5\ mm$	1M
	OR	
	$r_{min} = \sqrt{\dfrac{D^2 + d^2}{16}} = \sqrt{\dfrac{200^2 + 150^2}{16}} = 62.5\ mm.$	
	Case-I - Both ends are fixed.	
	Effective length $L_e = \frac{L}{2} = \frac{5}{2} = 2.5\ m.$	½M
	$\therefore P_R = \dfrac{550 \times 13744.46}{1 + \frac{1}{1600}\left(\frac{2500}{62.5}\right)^2}$	
	$P_R = 3779.72\ KN.$	1M

Q.NO	SOLUTION	MARKS
Q6b) Cont...	Case - II One end is fixed & other free	
	Effective length $L_e = 2L = 2\times 5 = 10m$.	½M
	$\therefore P_R = \dfrac{550\times 13744.46}{1+\frac{1}{1600}\left(\frac{10000}{62.5}\right)^2} = \dfrac{7559.45\times10^3}{17}$	
	$P_R = 444.67\ KN$	1M
	Case - III - One end is fixed & other is hinged	
	Effective length $L_e = \dfrac{L}{\sqrt{2}} = \dfrac{5}{\sqrt{2}} = 3.535m$.	½M
	$\therefore P_R = \dfrac{550\times 13744.46}{1+\frac{1}{1600}\left(\frac{3535}{62.5}\right)^2}$	
	$P_R = 2520.32\ KN$	1M
	Case - IV - Both ends are hinged	
	Effective length $L_e = L = 5m$.	½M
	$\therefore P_R = \dfrac{550\times 13744.46}{1+\frac{1}{1600}\left(\frac{5000}{62.5}\right)^2}$	
	$P_R = 1511.89\ KN$	1M

Q.NO	SOLUTION	MARKS
Q6 c)		
→	Given, $D = 25mm$, $L = 1500mm$, $P = 30KN$	
	$E = 2.1 \times 10^5 \ N/mm^2$	
	1) Area of rod $A = \frac{\pi}{4} D^2 = \frac{\pi}{4}(25)^2$	
	$A = 490.87 \ mm^2$	½ m
	2) Volume of rod $V = A \times L = 490.87 \times 1500$	
	$V = 736305 \ mm^3$	½ m
	$V = 736.305 \times 10^{-6} \ m^3$	
	3) Stress for suddenly applied load	
	$\sigma = \frac{2P}{A} = \frac{2 \times 30 \times 10^3}{490.87} = 122.23 \ N/mm^2$	1 m
	4) Strain energy stored	
	$U = \frac{\sigma^2}{2E} \cdot V = \frac{122.23^2}{2 \times 2.1 \times 10^5} \times 736305$	1 m
	$U = 26191.72 \ N.mm = 26.19 \ N.m$ or Joule	1 m
	5) modulus of resilience $= \frac{U}{V} = \frac{26.19}{736.305 \times 10^{-6}}$	1 m
	$= 35569.5$ Joule/m^3	1 m
	6) Change in Length (δL)	
	$\delta L = \frac{\sigma L}{E} = \frac{122.23 \times 1500}{2.1 \times 10^5}$	1 m
	$\delta L = 0.873 \ mm$	1 m