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

SUMMER – 14 EXAMINATIONS

Subject Code: 17311 **Model Answer** **Total Pages: 39**

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.

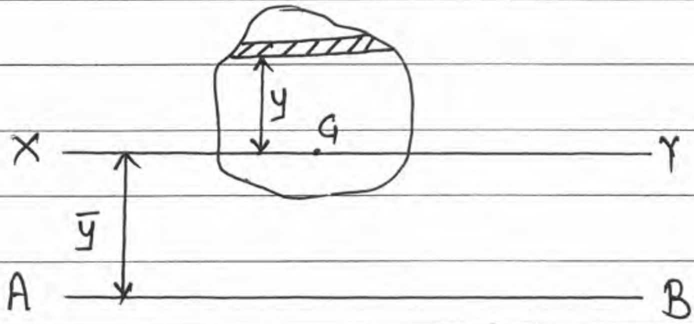
4) While assessing figures, examiners, may give credit for principle components indicated in the figure.

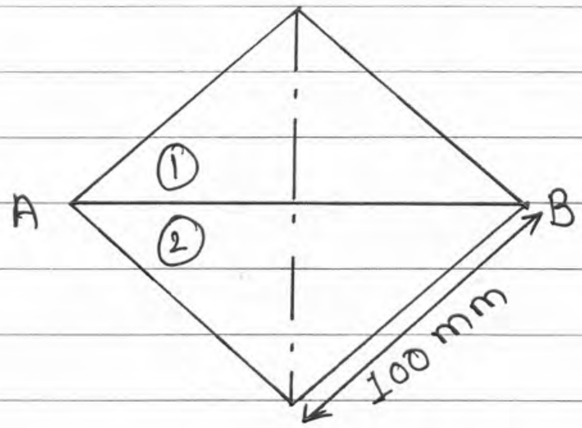
The figures drawn by candidate & model answer may vary. The examiner may give credit for any equivalent figure drawn.

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)	Attempt any six of the following.	
a)	Parallel axis theorem:-	
	The moment of Inertia of a lamina about any axis in the plane of the lamina is equal to the sum of the moment of inertia of that lamina about the centroidal axis parallel to the given axis and the product of the area of the lamina and square of the perpandicular distance between these two axis.	01
	$I_{AB} = I_G + A\bar{y}^2$	01
		
b)	Given data:	
	side of square = 100 mm	
	To find:	
	M.I. about its diagonal = ?	

Q .NO	SOLUTION	MARKS
Q 1 A) (b) cont.	soln :	
		
	$h = \frac{\text{Length of diagonal}}{2} = \frac{141.421}{2} = 70.71\,mm$	
	M.I. of square about diagonal AB	
	$I_{AB} = I_{AB_1} + I_{BB_2}$	
	$= \frac{bh^3}{12} + \frac{bh^3}{12} = \frac{bh^3}{6}$	01
	$= \frac{141.421 \times (141.421)^3}{6} = 66.67 \times 10^6\ mm^4$	01
c]	statement of Hooke's law:	
	For elastic materials, the stresses are proportional to strains upto certain limit called proportional limit.	02
	stress $\propto$ strain	
	$\therefore \frac{\text{stress}}{\text{strain}} = \text{constant}$	

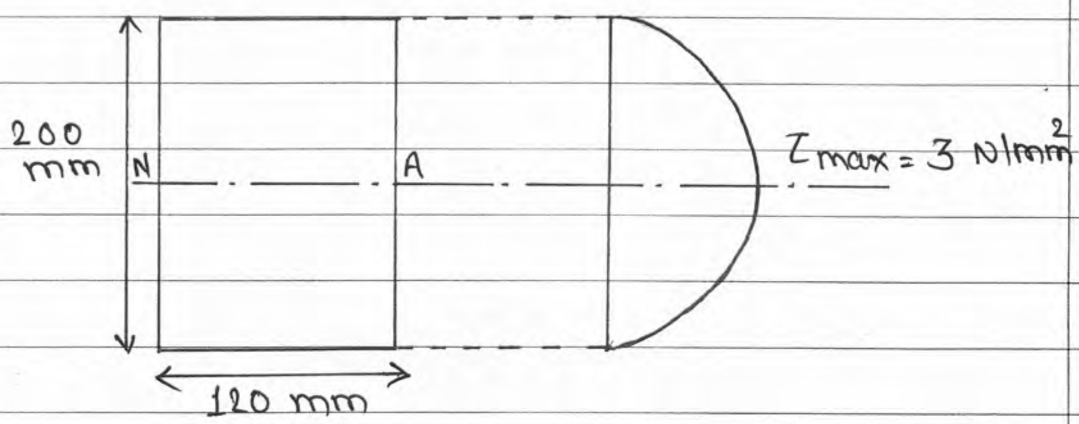
Q NO	SOLUTION	MARKS
Q 1(A) d]	Elastic limit :	
	A material is said to be elastic when it undergoes a deformation on the application of a loading such that the deformation disappears on the removal of the loading.	
	For every material the property of assuming or regaining it's previous shape and size is exhibited on the removal of the loading, when the intensity of stress is within a certain limit called the elastic limit.	02
e)	slenderness ratio:	
	The ratio of effective length to minimum radius of gyration is called as slenderness ratio.	01
	$\therefore \lambda = \frac{Le}{K}$	01
	where, λ = slenderness ratio	
	Le = effi. length of column	
	K = mini. radius of gyration	

Q .NO	SOLUTION	MARKS
Q.1 f)	Euler's formula :	
	$$P = \frac{\pi^2 EI}{l^2}$$	01
	where,	
	P - Critical load	
	E - Young's modulus of elasticity	
	I - moment of inertia of section	
	l - effective length of column	01
g)	Proof resilience :-	
	The maximum amount of strain energy which can be stored by a member or a body without exceeding the elastic limit is called proof resilience.	01
	$$U_{max} = \frac{\sigma^2}{2E} \cdot V$$	
	Modulus of resilience :-	
	Proof resilience per unit volume is called as modulus of resilience.	01
	$$\text{modulus of resilience} = \frac{\sigma^2}{2E}$$	

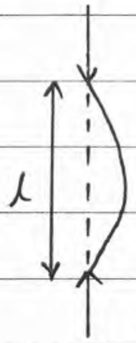
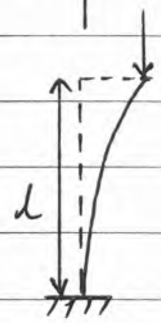
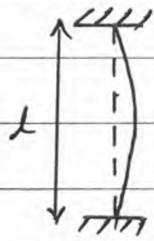
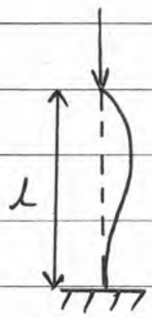
Q .NO	SOLUTION	MARKS
Q.1 h)	Given data:	
	$P = 60\ kN$	
	$\delta l = 0.6\ mm$	
	To find :	
	$U = ?$	
	Soln :	
	For gradually applied load,	
	$U = \frac{P}{2} \times \delta l$	01
	$U = \frac{60 \times 10^3}{2} \times 0.6$	
	$U = 18{,}000\ N\text{-}mm$	
	$U = 18\ N\text{-}m$	
	$U = 18\ J$	
	∴ strain energy stored = 18 J	01

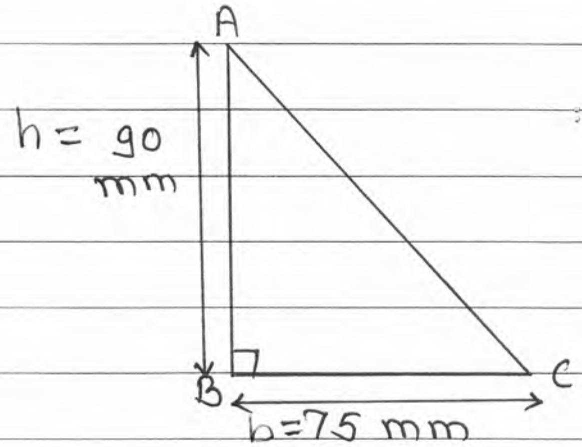
Q.NO	SOLUTION	MARKS
Q.1B]	Solve any two:	
a]	moment of resistance:	
	When section is subjected to external bending moment, compressive stresses are produced above neutral axis and tensile stresses are produced below neutral axis. The moment of couple formed by total compressive force (C) and total tensile force (T) is called as moment of resistance.	01
	Factors on which moment of resistance depends:	
	a) moment of inertia of section about neutral axis (I)	02
	b) Permissible bending stress (σ) of material and section	(For any two)
	c) section modulus (Z) of section	
	d) Distance of extreme fiber from neutral axis (Y)	
	(consider any two factors.)	
	Moment of resistance is produced due to internal stresses of section whereas bending moment is produced by external loading on beam.	01

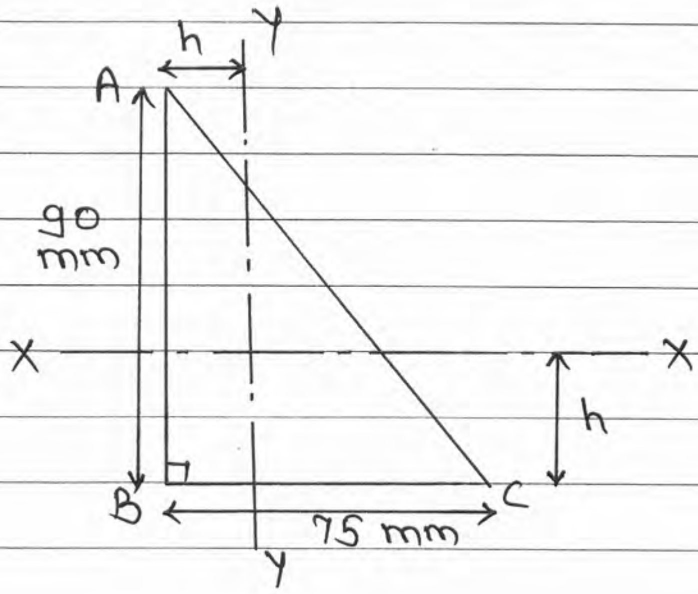
Q .NO	SOLUTION	MARKS
Q.1 b]	Given data:	
	$b = 120$ mm	
	$d = 200$ mm	
	$F = 48$ KN	
	To calculate:	
	$\tau_{max} = ?$	
	Soln:	
	$\tau_{av.} = \frac{F}{A}$	
	$= \frac{48 \times 10^3}{(120 \times 200)}$	
	$= 2$ N/mm^2	1
	For rectangular section, maxi. shear stress will be at neutral axis.	
	$\therefore \tau_{max} = 1.5\, \tau_{av.}$	1
	$= 1.5 \times 2$	
	$= 3$ N/mm^2	1

Q.NO	SOLUTION	MARKS
	shear stress distribution diagram:	
		1
	cross section stress distribution diagram	
Q.1 C]	Effective length :	
	The effective length of a given column with given end conditions is the length of an equivalent column of the same material and section with hinged ends having the value of the crippling load equal to that of the given column.	02

Q.NO	SOLUTION	MARKS
Q.1 c]	Different end conditions with sketch:	

End condition	Sketch	Eff. length	MARKS
i) When both ends of the column are pinned or hinged.		$Le = l$	$\frac{1}{2}$
ii) When one end is fixed and the other is free.		$Le = 2l$	$\frac{1}{2}$
iii) When both ends of column are fixed.		$Le = \frac{l}{2}$	$\frac{1}{2}$
iv) When one end of column is fixed and other end is pinned or hinged.		$Le = \frac{l}{\sqrt{2}}$	$\frac{1}{2}$

Q .NO	SOLUTION	MARKS
Q.2	Solve any two:	
a)	Given data:	
	Base of triangle (BC) = 75 mm	
	vertical side (AB) = 90 mm	
	$m\angle B = 90^\circ$	
	To find:	
	MI of triangle about sides AB and BC	
	Soln:	
		
	MI of triangle about side AB:	
	$I = \frac{hb^3}{12}$	2
	$I = \frac{90 \times (75)^3}{12}$	
	$I = 3.1640 \times 10^6 \ mm^4$	2

Q .NO	SOLUTION	MARKS
Q.2 a]	MI of triangle about side BC	
	$I = \frac{bh^3}{12}$	02
	$I = \frac{75 \times (90)^3}{12}$	
	$I = 4.5562 \times 10^6 \text{ mm}^4$	02
	OR	
	Note : Student can solve above problem by using parallel axis theorem. Examiner should consider any one solution for giving marks.	
	By using parallel axis theorem,	
		

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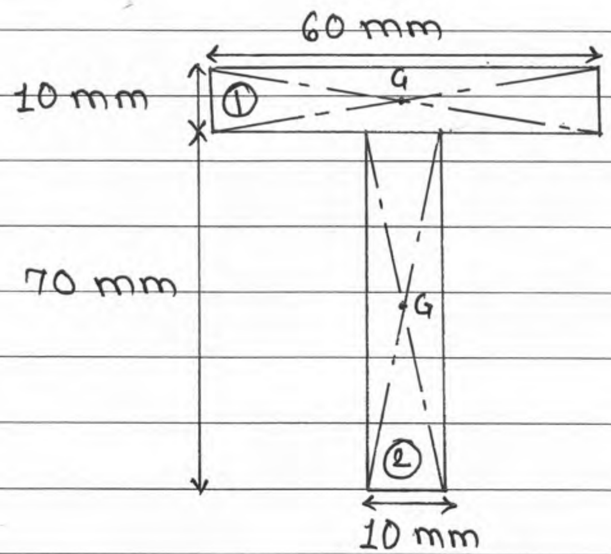
Q .NO	SOLUTION	MARKS
Q.2 a]	MI of triangle about side AB	
	$I_{AB} = I_{yy} + Ah^2$	1
	$= \frac{bh^3}{36} + \left(\frac{1}{2} \times b \times h\right) \times \left(\frac{h}{3}\right)^2$	1
	$= \frac{90 \times (75)^3}{36} + \left(\frac{1}{2} \times 90 \times 75\right) \times \left(\frac{75}{3}\right)^2$	
	$= 1.05468 \times 10^6 + 2.10937 \times 10^6$	
	$= 3.1640 \times 10^6\ mm^4$	02
	M.I. of triangle about side BC	
	$I_{BC} = I_{xx} + Ah^2$	1
	$= \frac{bh^3}{36} + \left(\frac{1}{2} \times b \times h\right) \times \left(\frac{h}{3}\right)^2$	1
	$= \frac{75 \times (90)^3}{36} + \left(\frac{1}{2} \times 75 \times 90\right) \times \left(\frac{90}{3}\right)^2$	

Q .NO	SOLUTION	MARKS
	$I = 1.51875 \times 10^6 + 0.004275 \times 10^6$	
	$I = 4.55625 \times 10^6 \ mm^4$	02
Q.2 b]		
	Given data:	
	Flange = 60 mm X 10 mm	
	Web = 10 mm x 70 mm	
	To calculate:	
	$I_{xx} = ?$	
	$I_{yy} = ?$	
	$I_p = ?$	
	Soln:	
	$y_1 = 70 + \frac{10}{2}$	
	$= 75 \ mm$	
	$y_2 = \frac{70}{2}$	
	$= 35 \ mm$	

Q .NO	SOLUTION	MARKS
Q.2 b]		



$\overline{X} = \frac{60}{2} = 30$ mm (due to symmetry @ Y-Y axis)

$\therefore x_1 = x_2 = 30$ mm

$A_1 = 60 \times 10 = 600 \text{ mm}^2$

$A_2 = 10 \times 70 = 700 \text{ mm}^2$

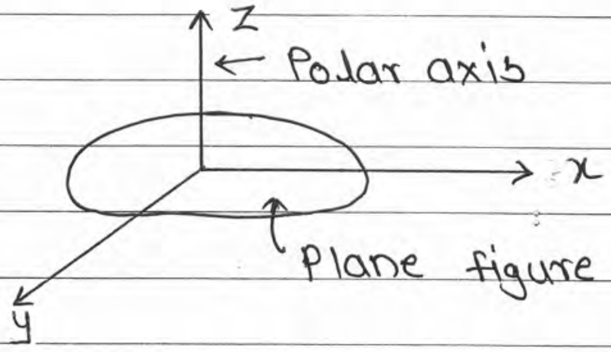
$$\overline{Y} = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2}$$

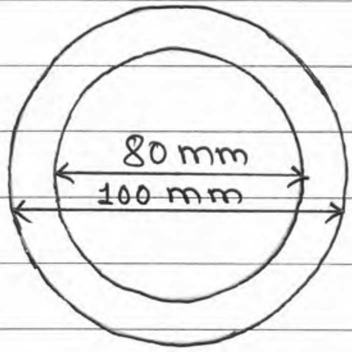
$$\overline{Y} = \frac{600 \times 75 + 700 \times 35}{600 + 700}$$

$\overline{Y} = 53.4615$ mm w.r.t. base — 01

Q .NO	SOLUTION	MARKS
Q.2 b]	To find M.I. about centroidal axis i.e. Ixx :	
	Applying parallel axis theorem, we get	
	$I_{xx} = [I_{G1} + A_1 h_1^2] + [I_{G2} + A_2 h_2^2]$	01
	$h_1 = \bar{y} - y_1$	
	$= 53.46 - 75$	
	$= -21.54$ mm	
	$h_2 = \bar{y} - y_2$	
	$= 53.46 - 35$	
	$= 18.46$ mm	
	$\therefore I_{xx} = [\frac{bh^3}{12} + A_1 h_1^2] + [\frac{bh^3}{12} + A_2 h_2^2]$	
	$I_{xx} = [\frac{60 \times (10)^3}{12} + 600 (-21.54)^2]$	
	$+ [\frac{10 \times (70)^3}{12} + 700 (18.46)^2]$	
	$I_{xx} = 283382.96 + 524373.453$	
	$I_{xx} = 807756.413 = 807.756 \times 10^3$ mm^4	
	$I_{xx} = 0.807756 \times 10^6$ mm^4	02

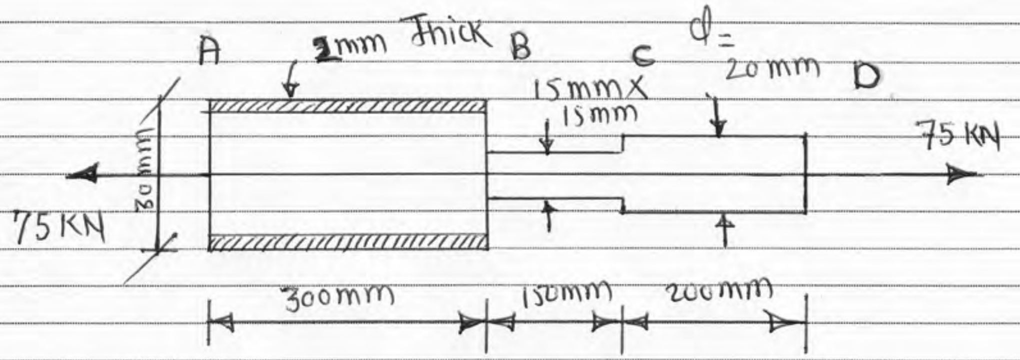
Q .NO	SOLUTION	MARKS
Q.2 b]	To find M.I. about centroidal axis I_{yy} :	
	$I_{yy} = I_{G1} + I_{G2}$	1
	$= \frac{db^3}{12} + \frac{db^3}{12}$	
	$= \frac{10 \times (60)^3}{12} + \frac{70 \times (10)^3}{12}$	
	$= 180 \times 10^3 + 5.8333 \times 10^3$	
	$= 185.8333 \times 10^3 \ mm^4$	1
	To find polar moment of inertia:	
	$I_p = I_{xx} + I_{yy}$	1
	$= 807.756 \times 10^3 + 185.833 \times 10^3$	
	$= 993.589 \times 10^3 \ mm^4$	1

Q .NO	SOLUTION	MARKS
Q.2C] i)	Perpendicular axis theorem:	
	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'.	
		
	$I_{zz} = I_{xx} + I_{yy}$	2
	Given data:	
	Hollow circular section.	
	External diameter = 100 mm	
	Internal diameter = 80 mm	

Q .NO	SOLUTION	MARKS
Q.2 c]		
	Polar moment of inertia of hollow circular section:	
	$I_p = \frac{\pi}{32}(D^4 - d^4)$	1
	$I_p = \frac{\pi}{32}((100)^4 - (80)^4)$	
	$I_p = 5.7962 \times 10^6 \ mm^4$	1
	ii) Given data:	
	$d = 10$ mm	
	$t = 8$ mm	
	$\tau = 80$ mpa	
	To calculate:	
	$P = ?$	

Q .NO	SOLUTION	MARKS
Q.2 C]	Soln:	
	Area resisting punching shear	
	$= \pi \times D \times t$	1
	$= \pi \times 10 \times 8$	
	$= 251.32 \ mm^2$	1
	Force required to punch the hole	
	P = stress x area resisting punching shear	1
	$P = 80 \times 251.32$	
	$P = 20.106 \ KN$	1

Q-3
(a)



1

$E_{AB} = 200$ Gpa $E_{BC} = 100$ Gpa $E_{CD} = 75$ Gpa

i) $A_{AB} = \frac{\pi}{4}\left(D_{outer}^2 - D_{inner}^2\right)$

$= \frac{\pi}{4}\left(30^2 - 26^2\right)$ 1

$A_{AB} = 175.93\ mm^2$

$A_{BC} = b \times d = 15 \times 15 = 225\ mm^2$ 1

$A_{CD} = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 20^2 = 314.15\ mm^2$ 1

ii) Deformation of each member

$\delta_{AB} = \frac{P \times L_{AB}}{A_{AB} \times E_{AB}} = \frac{75 \times 300}{175.93 \times 200} = 0.63945$ mm 1

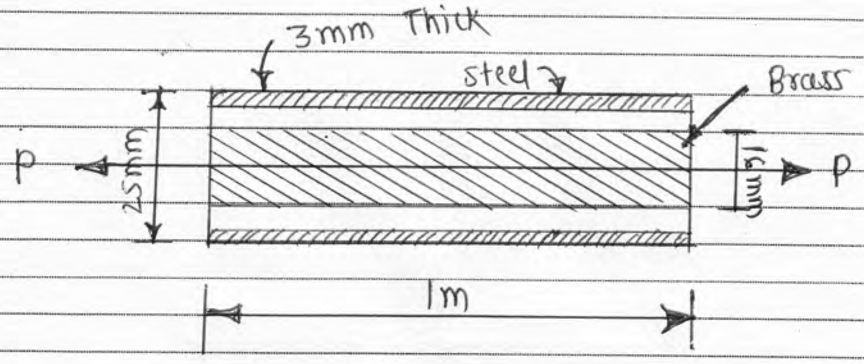
$\delta L_{BC} = \frac{P \times L_{BC}}{A_{BC} \times E_{BC}} = \frac{75 \times 150}{225 \times 100} = 0.5$ mm 1

$\delta L_{CD} = \frac{P \times L_{CD}}{A_{CD} \times E_{CD}} = \frac{75 \times 200}{314.15 \times 75} = 0.6366$ mm 1

$\delta L = \delta L_{AB} + \delta L_{BC} + \delta L_{CD} = 0.63945 + 0.5 + 0.6366$ 1

$\boxed{\delta L = 1.776\ mm}$

Q-3 (b)



$\sigma_s = 140\ \text{Mpa} = 140\ \text{N/mm}^2$

$L = 1\text{m} = 1000\text{mm}$

$E_s = 200\ \text{Gpa} = 200 \times 10^3\ \text{N/mm}^2$

$E_b = 100\ \text{Gpa} = 100 \times 10^3\ \text{N/mm}^2$

$d_{steel\ (outer)} = 25\text{mm}$, $d_{steel\ (inner)} = 19\text{ mm}$

$d_{brass} = 16\text{ mm}$

$$\frac{\sigma_s}{E_s} = \frac{\sigma_b}{E_b}$$ 1

$$\therefore \frac{\sigma_s}{E_s} \times E_b = \sigma_b$$

$$\therefore \sigma_b = \frac{140 \times 100 \times 10^3}{200 \times 10^3}$$

$$\boxed{\sigma_b = 70\ \text{Mpa}}$$ 1

$$P = P_{steel} + P_{brass}$$

$$P = \sigma_s \cdot A_s + \sigma_b \cdot A_b$$ 1

Q.3 b]

$P = 140 \times \left[\frac{\pi}{4} \times (25^2 - 19^2)\right] + 70 \times \frac{\pi}{4} \times 16^2$

$P = 140 \times 207.345 + 70 \times 201.06$

$P = 29.0283 \times 10^3 + 14.074 \times 10^3$

$\boxed{P = 43.1023 \times 10^3 \ N}$ 1

$\boxed{P = 43.1023 \ KN}$

$P_{steel} = \sigma_s \cdot A_s = 140 \times 207.345 = 29.0283 \times 10^3 \ N$

$\boxed{P_{steel} = 29.0283 \ KN}$ 1

$P_{brass} = \sigma_b \cdot A_b = 70 \times 201.06 = 14.074 \times 10^3 \ N$

$\boxed{P_{brass} = 14.074 \ KN}$ 1

Deformation in each metal

$\delta L_{steel} = \left(\frac{PL}{A \cdot E}\right)_{steel} = \frac{29.0283 \times 10^3 \times 1000}{207.345 \times 200 \times 10^3}$

$\boxed{\delta L_{steel} = 0.700 \ mm}$ 1

$\delta L_{brass} = \left(\frac{P \cdot L}{A \cdot E}\right)_{brass} = \frac{14.074 \times 10^3 \times 1000}{201.06 \times 100 \times 10^3}$

1

$\boxed{\delta L_{brass} = 0.700 \ mm}$

Q-3

(c) i) Relation betn E & G

$$E = 2G(1+\mu) \quad \text{--- i)}$$ 2

ii) Relation betn E & K

$$E = 3K(1-2\mu) \quad \text{--- ii)}$$ 2

from eqn i)

$$1+\mu = \frac{E}{2G}$$

$$\therefore \boxed{\mu = \frac{E}{2G} - 1}$$

Substituting the value of 'μ' in eqn ii)

$$E = 3K\left[1 - 2\left(\frac{E}{2G} - 1\right)\right]$$

$$E = 3K\left[1 - \frac{E}{G} + 2\right] = 3K\left[3 - \frac{E}{G}\right]$$

$$E = 3K\left(\frac{3G-E}{G}\right)$$

$$\boxed{EG = 3K(3G-E)}$$

$$\therefore \boxed{EG = 9KG - 3KE} \quad \text{---- iii)}$$

$$\therefore 9KG = EG + 3KE$$ 04

$$\therefore 9KG = E(G+3K) \quad \therefore \boxed{E = \frac{9KG}{G+3K}}$$

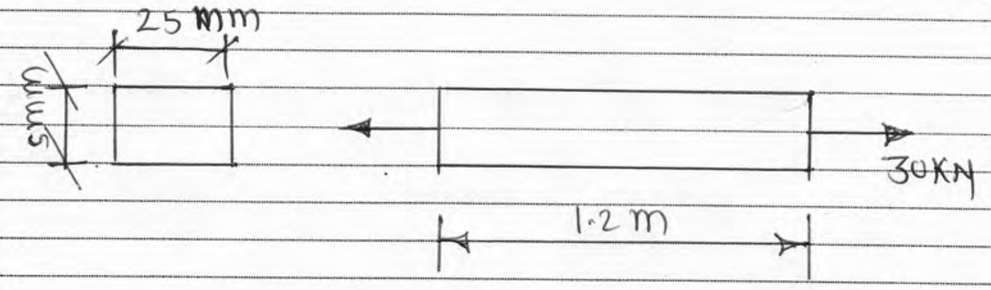
or from eqn iii)

$$3KE = 9GK - EG \quad \therefore \boxed{G = \frac{3EK}{9K-E}}$$

or from eqn iii)

$$EG = K(9G-3E) \quad \therefore \boxed{K = \frac{EG}{3(3G-E)}}$$

Q-4
(a)



$E = 190\ Gpa \qquad \mu = 0.24$

i) To find the change of length

$$\delta L = \frac{P \cdot L}{A \cdot E} = \frac{30 \times 10^3 \times 1200}{25 \times 5 \times 190 \times 10^3}$$

$$\boxed{\delta L = 1.515\,mm}$$ 1

ii) To find change in thickness (δt) & width (δb)

linear strain $(e) = \frac{\delta L}{L}$

$$e = \frac{1.515}{1200} = 1.263 \times 10^{-3}$$ 1

lateral strain $= -\mu \times e$

$= -0.24 \times 1.263 \times 10^{-3}$

$$\boxed{\text{lateral strain} = -3.0315 \times 10^{-4}}$$ 1

iii) lateral strain $= \frac{\delta t}{t}$ 1/2

$-3.0315 \times 10^{-4} \times 5 = \delta t$

$$\therefore \boxed{\delta t = -1.515 \times 10^{-3}\,mm}$$ 1

simily

lateral strain $= \frac{\delta b}{b}$ $\frac{1}{2}$

$\therefore \delta b = -3.0315 \times 10^{-4} \times 25$

$\therefore \boxed{\delta b = -7.578 \times 10^{-3}\ mm}$ 1

we have

$\frac{\delta v}{v} = e(1-2\mu)$ 1

$\delta v = v.e\ (1-2\mu)$

$\delta v = 5 \times 25 \times 1200 \times 1.263 \times 10^{-3} (1 - 2 \times 0.24)$

$\boxed{\delta v = 98.51\ mm^3}$ 1

Q-4 (b) let

$d = 30\ mm$

$L = 1m = 1000mm$

$E = 200\ Gpa$

$\alpha = 11.5 \times 10^{-6} / °c$

i) $\sigma = E\alpha t = 200 \times 11.5 \times 10^{-6} \times 50$ 1

$\boxed{\sigma = 0.115\ KN/mm^2}$ (compressive) 2

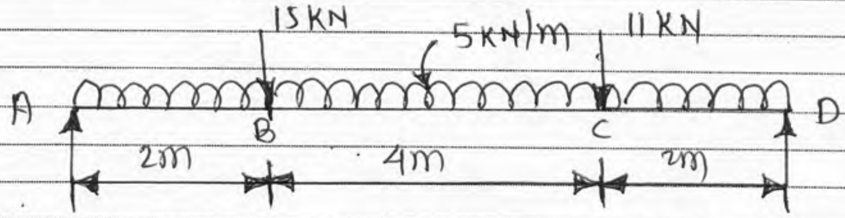
ii) strain (e) $= \frac{L\alpha t - d}{L}$ 01

$e = \frac{1000 \times 50 \times 11.5 \times 10^{-6} - 0.12}{1000} = 4.55 \times 10^{-4}$ 01

iii) $\sigma = E \times e = 200 \times 4.55 \times 10^{-4}$ 1

$\boxed{\sigma = 0.091\ KN/mm^2}$ (compressive) 2

Q-4 (c)



i) $\Sigma F_y = R_A - 15 - 11 - 5 \times 8 \times R_D$

$R_A + R_D = 66$ — i)

$\Sigma M_A = R_D \times 8 + 11 \times 6 + 5 \times 8 \times 8/2 + 15 \times 2$

$0 = 8 R_D + 66 + 160 + 30$

$8 R_D = 256$

$\boxed{R_D = 32 \text{ KN}}$

$R_A + R_D = 66$

$R_A = 66 - R_D$

$\boxed{R_A = 34 \text{ KN}}$ 01 (For Reaction calculations)

ii) S.F. calculation (starting from left end D)

$F_D = -32$ KN

$F_{CR} = -32 + 5 \times 2$ $F_{CR} = -22$ KN → $\frac{1}{2}$

$F_{CL} = -22 + 11 = -11$ KN → $\frac{1}{2}$

$F_{BR} = -11 + 5 \times 4 = +9$ KN → $\frac{1}{2}$

$F_{BL} = 9 + 15 = 24$ KN → $\frac{1}{2}$

$F_A = 24 + 5 \times 2 = 34$ KN

iii) To Locate point of contrashear or zero shear

$F_{pcs} = -32 + 5 \times x + 11$

$-5x = -21$ $\therefore 5x = 21$ 1

$\therefore \boxed{x = 4.2}$ from D

iv) B.M. Calculation

$M_D = 0$ KN-m

$M_C = 32\times2 - 5\times2\times 2/2 = 54$ KN-m $\frac{1}{2}$

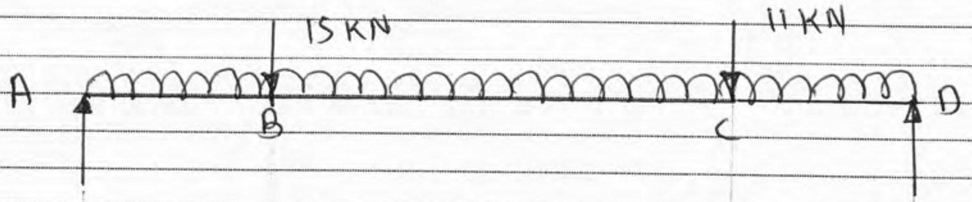
$M_B = 32\times6 - 11\times4 - 5\times6\times 6/2 = 58$ KN-m $\frac{1}{2}$

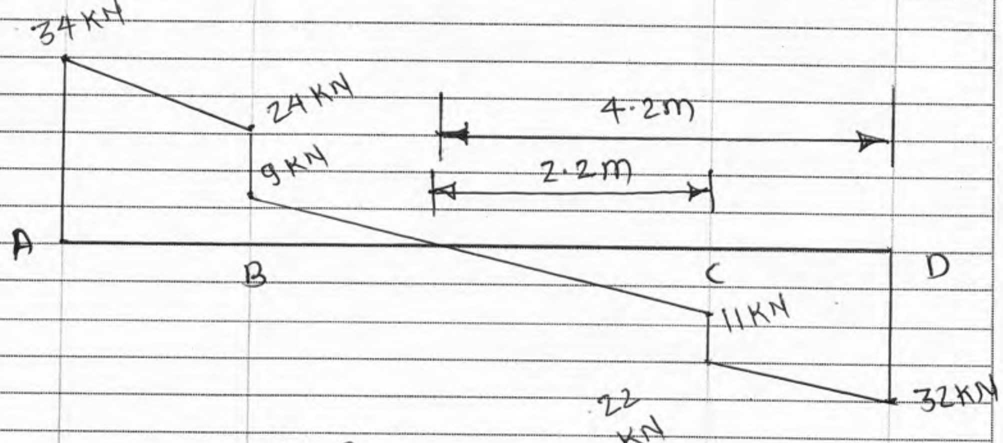
$M_A = 0$ KN-m

$M_{max} = 32\times4.2 - 5\times4.2\times 4.2/2 - 11\times2.2$

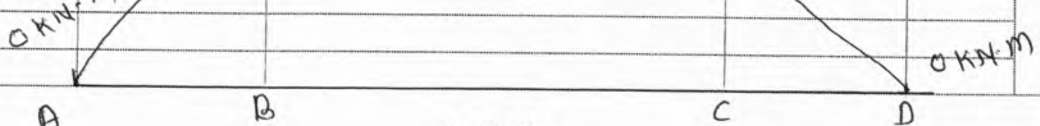
$= 134.4 - 44.1 - 24.2$

$\boxed{M_{max} = 66.1 \text{ KN-m}}$ 1

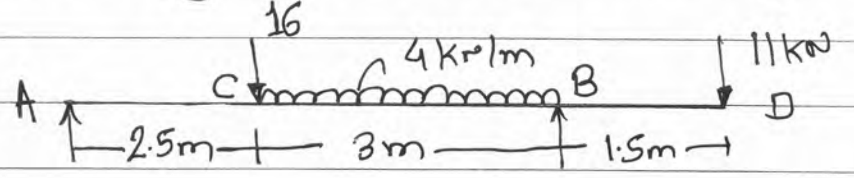
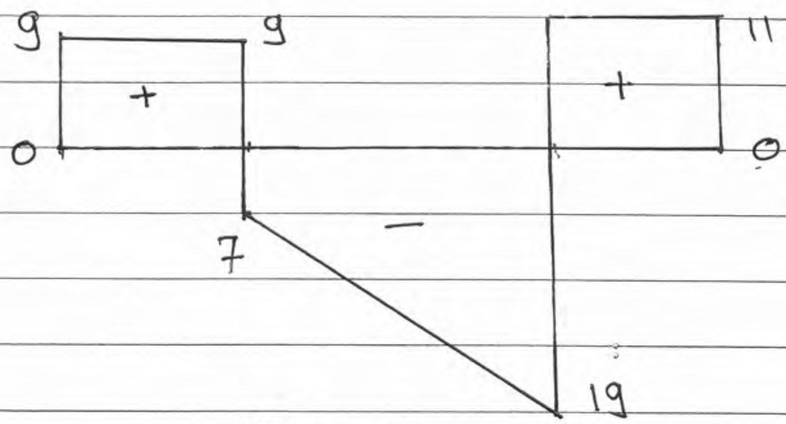
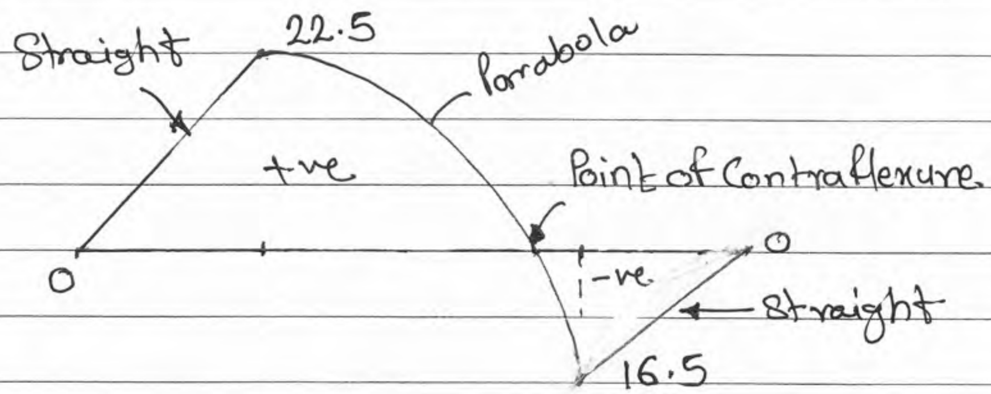




S.F.D 1

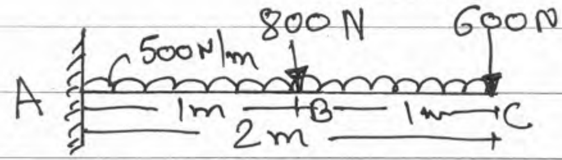


B.M.D 1

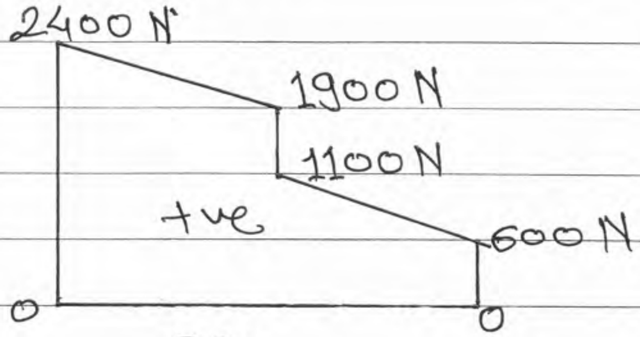
Q .NO	SOLUTION	MARKS
Q.5	Solve any two of the following:	16
a)		
	$R_A = 9$ kN $\quad R_B = 30$ kN	
		— 1m
	SFD	
		— 1m
	BMD	
	① calculation of Reaction	
	∴ $R_A = 9$ KN, $R_B = 30$ KN	1 M

Q .NO	SOLUTION	MARKS
Q.5 a]	SF calculation: (↑ -ve, ↓ +ve)	
	SF @ D (R) = 0	
	(L) = 11 kN	
	SF @ B (R) = 11 kN	
	(L) = 11 − 30 = −19 kN.	
	SF @ C (R) = −19 + (4×3) = −7 kN.	2m
	(L) = −7 + 16 = 9 kN.	
	SF @ A (R) = 9 kN	
	(L) = 9 − 9 = 0 kN.	
	BM calculation: ↺ -ve, (↻ +ve)	
	BM @ D = 0	
	BM @ B = −11×1.5 = −16.5 kN-m	1 M
	BM @ C = −(11×4.5) + (30×3) − (4×3×$\frac{3}{2}$)	
	= 22.5 kN-m	1 M
	BM @ A = 0	
	Location of Point of Contraflexure:	
	Let assume 'x' be the distance of point of contraflexure from support 'B'.	
	∴ BM @ x = 0 = −(11×(1.5+x)) + (30×x) − (4×x×$\frac{x}{2}$) = 0	
	∴ x = 0.967 m from support B	1m

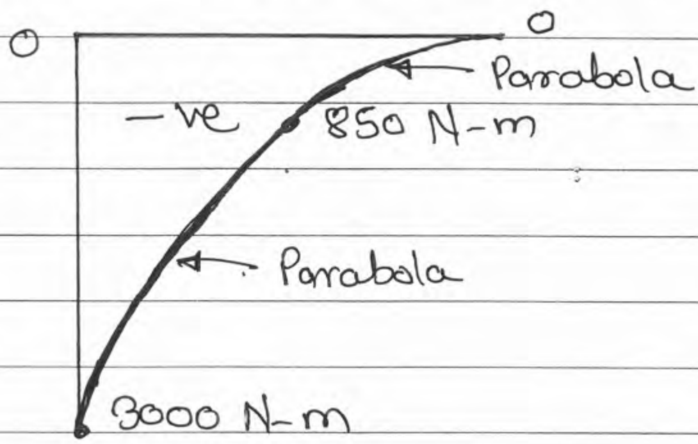
Q .NO	SOLUTION	MARKS
Q.5(b)	i) State the relation between SF & BM. How it is used to locate the position of maximum BM.?	
	→ Relation:	
	Let S_x & M_x be the SF & BM on a section at ~~~~ st 'x' from any one support.	
	$\therefore \quad S_x = \frac{dM_x}{dx}$	2m
	Thus the rate of increase of bending moment with respect to 'x' on any section at a distance 'x' from left end of the beam, is equal to shear force at the section.	
	For locating the section of zero shear force, shear force equation for the respective zone shall be equated to zero.	
	& thus the corrosponding point where the shear force changes the sign, should shows the position of maximum Bending Moment.	2m

Q .NO	SOLUTION	MARKS
Q.5)(b) ii)		

↑ $R_A = 2400$



SFD — 1m



— 1m

BMD

Sf calculation: (↑-ve, ↓+ve)

Sf@ C (R) = 0

(L) = 600 N

Sf@ B (R) = 600 + (500×1) = 1100 N

(L) = 1100 + 800 = 1900 N — 1m

Sf@ A (R) = 600 + (500×2) + 800

= 2400

(L) = 2400 − 2400 = 0

Q.NO	SOLUTION	MARKS

BM calculation ; (↺ -ve ; ↻ +ve)

BM @ C = 0

BM @ B = $-(600 \times 1) - (500 \times 1 \times \frac{1}{2})$

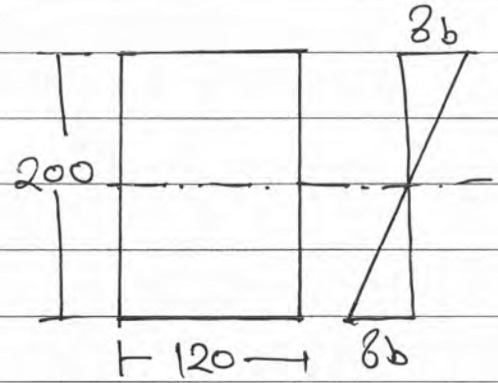
$= -850$ N-m — $\frac{1}{2}$ M

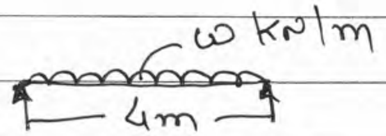
BM @ A(R) = $-(600 \times 2) - (500 \times 2 \times \frac{2}{2})$

$-(800 \times 1)$

$= -3000$ N-m — $\frac{1}{2}$ M

Q.5) c)





→ $\sigma_b = 80$ N/mm² (Given)

Using Bending Equation

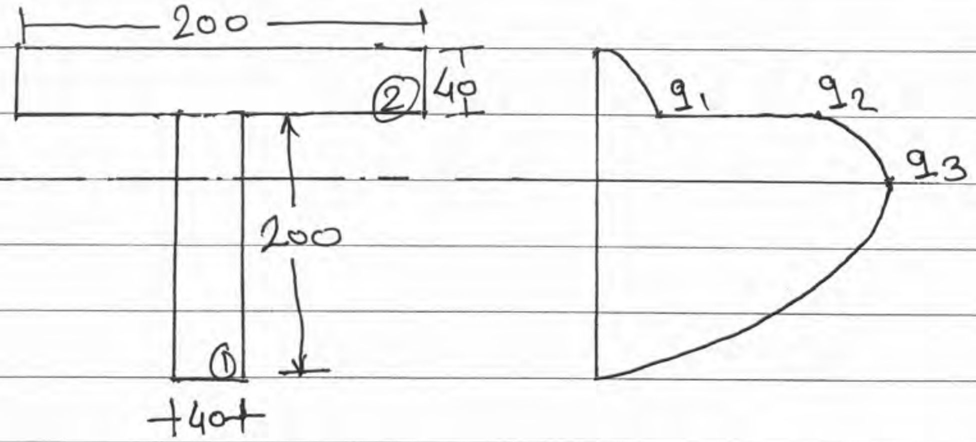
$$\frac{M}{I} = \frac{\sigma_b}{y}$$

$\therefore M = \frac{wl^2}{8} = \frac{w \times 4^2}{8} = 2w$ kN-m — 1M

$= 2 \times 10^6 \times w$ N-mm. — 1M

Q .NO	SOLUTION	MARKS
Q.5 c]	$I = \frac{bd^3}{12} = \frac{120 \times 200^3}{12} = 80 \times 10^6\ mm^4$ —	2m
	$y = \frac{200}{2} = 100\ mm.$ —	1m
	$\therefore \frac{M}{I} = \frac{\sigma}{y}$ —	1m
	$\therefore \frac{2 \times 10^6\, w}{80 \times 10^6} = \frac{80}{100}$	
	$\therefore w = 32\ N/mm$	
	$w = 32\ kN/m.$ —	2m

Q .NO	SOLUTION	MARKS
Q-6)	Solve any two of the following	16
a)		



→ Using $\tau = \dfrac{SA\bar{y}}{Ib}$

$a_1 = a_2 = 200 \times 40 = 8000 \text{ mm}^2$

$y_1 = \dfrac{200}{2} = 100 \text{ mm}$

$y_2 = 200 + \dfrac{40}{2} = 220 \text{ mm}$

$\therefore \bar{y} = \dfrac{y_1A_1 + y_2A_2}{A_1 + A_2} = \dfrac{(100 \times 8000) + (220 \times 8000)}{8000 + 8000}$

$= 160$ mm from bottom — 1m

$\therefore h_1 = \bar{y} - y_1 = 160 - 100 = 60 \text{ mm}$

$h_2 = y_2 - \bar{y} = 220 - 160 = 60 \text{ mm}$

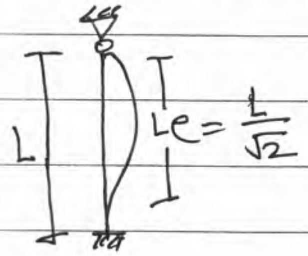
$\therefore I_{xx_1} = \dfrac{40 \times 200^3}{12} + (8000 \times 60^2)$

$= 55.467 \times 10^6 \text{ mm}^4$

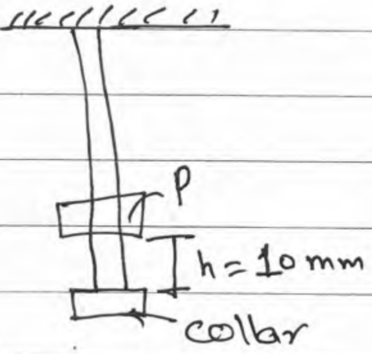
Q .NO	SOLUTION	MARKS
Q.6 a]	$I_{xx2} = \frac{200 \times 40^3}{12} + (8000 \times 60^2)$	
	$= 29.867 \times 10^6\ mm^4$	
	$\therefore I_{xx} = 55.467 \times 10^6 + 29.867 \times 10^6$	
	$= 85.334 \times 10^6\ mm^4$ —	1 m
	$\therefore$ Shear stress at bottom of flange	
	$q_1 = \frac{SA\bar{y}}{Ib}$	
	$= \frac{75 \times 10^3 \times (200 \times 40) \times 60}{85.334 \times 10^6 \times 200}$	
	$= 2.109\ N/mm^2$ —	2 m
	$\therefore$ Shear stress at Junction	
	$q_2 = \frac{SA\bar{y}}{Ib}$	
	$= \frac{75 \times 10^3 \times (200 \times 40) \times 60}{85.334 \times 10^6 \times 40}$	
	$= 10.5647\ N/mm^2$ —	2m
	& Shear Stress at neutral axis	
	$q_3 = \frac{75 \times 10^3 \times (160 \times 40) \times 80}{85.334 \times 10^6 \times 40}$	

$= 11.25\ N/mm^2$ — 2m

Q .NO	SOLUTION	MARKS
Q.6(b)	Using Rankine's formula.	
	$P = \dfrac{\sigma_c A}{1 + a\left(\dfrac{L_e}{r_{min}}\right)^2}$	
	$\rightarrow$ $D = 100$ mm, $d = 80$ mm.	
	$L = 4$ m	
	$L_e = \dfrac{L}{\sqrt{2}} = \dfrac{4000}{\sqrt{2}} = 2828.43$ mm	1m
	$a = \dfrac{1}{7500}$	
	$\sigma_c = 320$ N/mm^2	
	$r_{min} = \sqrt{\dfrac{I_{min}}{A}}$	
	$\because I_{min} = \dfrac{\pi}{64}(100^4 - 80^4)$	
	$= 2.898 \times 10^6$ mm^4	1m
	$A = \dfrac{\pi}{4}(100^2 - 80^2)$	
	$= 2.827 \times 10^3$ mm^2	1m
	$\therefore r_{min} = \sqrt{\dfrac{2.898 \times 10^6}{2.827 \times 10^3}}$	
	$r_{min} = 32$ mm	1m



Q .NO	SOLUTION	MARKS
Q.6 b]	$\therefore \; P = \dfrac{\sigma_c \cdot A}{1 + a\,(le/r_{min})^2}$	1m
	$= \dfrac{320 \times 2827.43}{1 + \left(\dfrac{1}{7500} \times \left(\dfrac{2828.43}{32}\right)^2\right)}$	
	$P = 443.156 \times 10^3$ N	
	$P = 443.156$ kN	1m
	$\therefore$ Safe Load $= \dfrac{P}{FOS}$	1m
	$= \dfrac{443.156}{2.5}$	
	$\boxed{\text{Safe Load} = 177.26 \text{ kN}}$	1m

Q .NO	SOLUTION	MARKS
Q.6(C)		
→	Given :	
	$h = 10\,mm$	
	$A = 600\,mm^2$	
	$L = 2500\,mm$	
	$E = 200 \times 10^3\,N/mm^2$	
	&	
	$\delta l = 2.5\,mm$	
	Find: σ_{max} & P	
→	$\therefore \delta l = \frac{\sigma_{max} \cdot L}{E}$	1m
	$\therefore 2.5 = \frac{\sigma_{max} \times 2500}{200 \times 10^3}$	
	$\therefore \sigma_{max} = 200\,N/mm^2$	2m
	Also $\sigma_{max} = \frac{P}{A} + \sqrt{\frac{2PEh}{AL} + \frac{P^2}{A^2}}$	1m
	consider $\frac{P}{A} = x$	
	$\therefore 200 = x + \sqrt{\frac{2 \times 200 \times 10^3 \times 10 \times x}{2500} + x^2}$	
	$\therefore$	
	$\therefore 200 - x = \sqrt{1600x + x^2}$	

Q .NO	SOLUTION	MARKS
Q.6 c]	Squaring on both side	
	$(200-x)^2 = 1600x + x^2$	
	$200^2 - 2\times 200\times x + \cancel{x^2} = 1600x + \cancel{x^2}$	
	$\therefore 200^2 = 1600x + 400x$	
	$\therefore x = \frac{200^2}{2000}$	
	$\therefore x = 20$ —	2m
	So $\frac{P}{A} = 20$	
	$\therefore P = 20 \times 600$	
	$\therefore P = 12000$ N	
	$\boxed{\therefore P = 12 kN}$ —	2m