



WINTER – 14 EXAMINATIONS

Subject Code: 17304

Model Answer

Total Pages: 50

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 assess 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.

Important notes to examiners

- 1) In Q. 6 C) the value of power transmitted is given is 20kN but it should be 20KW. The examiner may consider the same while assessing this question.
- 2) In Q. 6 e) the problem is on design of shaft diameter, but value of relationship between external diameter (D) and internal diameter(d) , value of modulus of rigidity (G) is not given in problem.

Therefore Two solutions are possible. Examiner should consider any one for giving proportionate marks

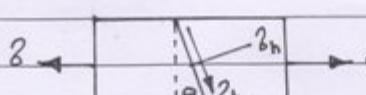
Solution 1

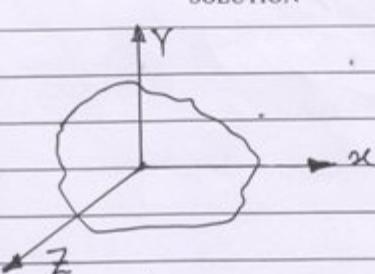
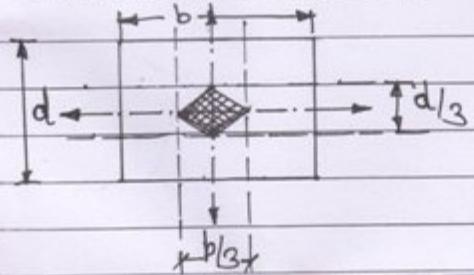
- I) Student may assume suitable relationship between D & d with value of modulus of rigidity (G) to find external diameter D, by using strength criteria and stiffness criteria.

Solution 2

- II) Student may assume only Value of modulus of rigidity (G) and find external diameter D, by using directly torsional formula.



Q.NO	SOLUTION	MARKS
Q.1 A)	Attempt any SIX of the following	$2 \times 6 = 12$
a)	Ans : Malleability - This is the property of material which allows it to expand in all directions without rupture.	- 1M
	Names : i) Steel iv) Gold (Any Two) ii) copper v) Silver iii) Aluminium.	- 0.5M
b)	Ans :	
		
	Equation of tangential Stress on an inclined plane :	
	$\sigma_t = \frac{F}{2} \sin \theta$	- 2M
c)	Mutually Perpendicular axis theorem : It states that "the moment of inertia of a plane section about an axis perpendicular to the section 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 centroid."	1M

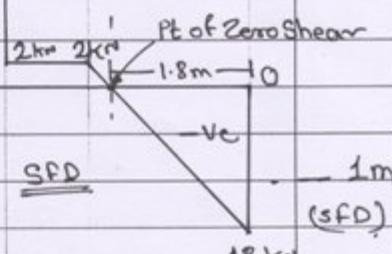
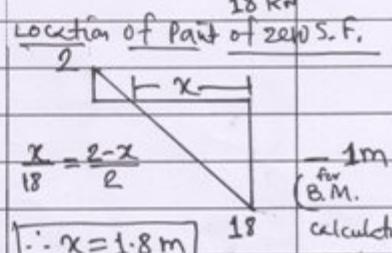
Q.NO	SOLUTION	MARKS
1 (c) cont.		
	$I_{zz} = I_{xx} + I_{yy}$	- 1M
	<p>This theorem is also called as polar axis theorem.</p>	
d) Ans:	Middle Third Rule with diagram.	
		- 1m
	<p>"In case of rectangular section, when any external load is applied within the middle one third part of section, then no tensile stresses are produced anywhere in the section."</p>	- 1M

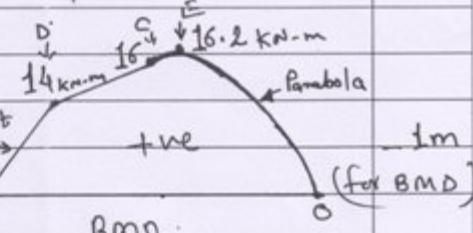
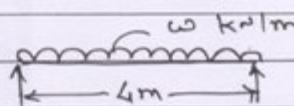


Q.NO	SOLUTION	MARKS
1) e)	four assumptions made in the theory of Pure Torsion : i) The material is homogeneous and isotropic.	Any four
	ii) The twist along the shaft is uniform.	four
	iii) Radial lines remain radial even after applying torsional moment.	-2M ($\frac{1}{2}$ for each)
	iv) The stresses are within the elastic limit, i.e. shear stress is proportional to shear strain.	
	v) Cross-sections which are plane before applying twisting moment remain plane even after the application of twisting moment i.e. no warping takes place.	
f)	Lateral Strain : "The strain which is set in the perpendicular direction to the applied force is called as lateral strain." — 1m Mathematically, it is the ratio of change in lateral dimension to the original dimension	
	$e_{lat} = \frac{\Delta b}{b} \text{ or } \frac{\Delta t}{t} \text{ or } \frac{\Delta d}{d}$	

Q.NO	SOLUTION	MARKS
1 f)	Longitudinal strain : cont. The strain which is set along the direction of the applied force is called as longitudinal strain.	
	Mathematically it is the ratio of change in length to the original length in the direction of force.	1m
	$\epsilon_{\text{long}} = \frac{\Delta L}{L}$	
g)	Distinguish :	
	In a thin cylindrical shell, when subjected to an internal pressure,	
1)	The longitudinal stress is equal to half the circumferential stress.	- 1M.
2)	Circumferential stress acts along the circumference and longitudinal stress acts along the length of shell - 1m	
h)	Core of section : It is the central limited area of section, when any external load acts within it, then no tension is produced at anywhere in the section.	1M
*	The value of diameter of core of section for circular section is $d/8$ and $1M$. d for on either side from centre of section.	

Q.NO	SOLUTION	MARKS
Q.1 B)	Attempt any two of the following:	4x2=8
a)	Given : i) $A = 20 \times 20 = 400 \text{ mm}^2$ ii) $\sigma = 50 \text{ MPa}$ iii) $\delta L = 1.2 \text{ mm}$ iv) $L = 3 \text{ m} = 3000 \text{ mm}$	
	Find : i) $P = ?$ ii) $E = ?$	
	Soln :	
	$P = 2 \times A = 50 \times 400$ $\therefore P = 20,000 \text{ N}$ $\boxed{P = 20 \text{ KN}}$	— 2 M
	$E = \frac{\sigma}{\epsilon}$	
	$\therefore \epsilon = \frac{\delta L}{L} = \frac{1.2}{3000} = 4 \times 10^{-4}$	
	$E = \frac{\sigma}{\epsilon} = \frac{50}{4 \times 10^{-4}} = 125000 \text{ N/mm}^2$ $\boxed{E = 125 \times 10^3 \text{ N/mm}^2}$	— 2 M
[or]	$\sigma = \frac{PL}{AE}$	OR
	$E = \frac{PL}{A \cdot \delta L} = \frac{20 \times 10^3 \times 3000}{400 \times 1.2} = 125 \times 10^3 \text{ N/mm}^2$	2 M

Q.NO	SOLUTION	MARKS
1(B) b)	A) Support Reactions: i) $\Sigma F_y = 0$ $\therefore R_A + R_B = 12 + (10 \times 2)$ $R_A + R_B = 32$ ii) $\Sigma M @ A = 0$ $\therefore (R_B \times 4) - (10 \times 2 \times \frac{2+2}{2}) - (12 \times 1) = 0$ $\therefore R_B = 18 \text{ kN}$ $\therefore R_A = 32 - 18 = 14 \text{ kN}$	- 1m
B) Shear force calculation:	i) $SF @ BC(R) = -9 \text{ kN}$ ii) $SF @ BC(L) = -18 \text{ kN} \quad 14 \text{ kN} \quad 14 \text{ kN}$ iii) $SF @ CC(R) = -18 + (10 \times 2) = 2 \text{ kN}$ iv) $SF @ DC(R) = 2 \text{ kN}$ v) $SF @ D(L) = 2 + 12 = 14 \text{ kN}$ vi) $SF @ AC(R) = 14 \text{ kN}$ vii) $SF @ A(L) = 14 - 14 = 0$	- 1m
C) Bending Moment Calculation:	i) $BM @ B = 0$ ii) $BM @ E = (18 \times 1.8) - (10 \times 1.8 \times \frac{1.8}{2}) = 16.2 \text{ kN-m}$ iii) $BM @ C = (18 \times 2) - (10 \times 2 \times \frac{2}{2}) = 16 \text{ kN-m}$	 

Q.NO	SOLUTION	MARKS
1 (B)	iv) $BM @ D =$ $b = (8 \times 3) - (10 \times 2 \times (1 + \frac{2}{2}))$ cont. $= 14 \text{ kNm}$	
		
	v) $BM @ A = 0$	
c)	Given: i) $b = 120 \text{ mm}$ ii) $d = 300 \text{ mm}$ iii) $L = 4 \text{ m} = 4000 \text{ mm}$ iv) $8b = 120 \text{ MPa}$	
	Find: $w = ?$	
		
	Using flexural formula let w is udl in N/m .	
	$\frac{M}{I} = \frac{8b}{y}$	
	$M = \frac{w l^2}{8} = \frac{4^2 w}{8} = 2w \text{ N-m}$	
	$= 2w \times 10^3 \text{ N-mm}$	- 1/2 m
	$I = \frac{bd^3}{12} = \frac{120 \times 300^3}{12} = 270 \times 10^6 \text{ mm}^4$	- 1m



Q.NO.	SOLUTION	MARKS
1(B)	$\frac{2}{3}b = 120 \text{ N/mm}^2$	
C cont.	$y = \frac{300}{2} = 150 \text{ mm}$	- $\frac{1}{2}\text{m}$
	$\therefore \frac{2 \times 10^3 \omega}{270 \times 10^6} = \frac{120}{150}$	- 1m
	$\therefore \omega = \frac{120 \times 270 \times 10^6}{150 \times 2 \times 10^3}$	
	$\omega = 108000 \text{ N/m}$	- 1m
	$\boxed{\therefore \omega = 108 \text{ kNm}}$	
Q.2	Attempt any four of the following	4x4=16
a)	Composite Section: If two or more members of different materials are connected together and are subjected to the loads, then the combination is called composite section.	- 1m
i)	Modular Ratio: It is defined as the ratio of moduli of the two different materials.	- 1m



Q.NO	SOLUTION	MARKS
2 (a) ii)	Rankine's Formula :	
	$P_R = \frac{2cA}{1 + a \left[\frac{L_e}{K} \right]^2}$	- 1m
	∴ Symbols Used :	
	P_R = Rankine's crippling load	
	$2c$ = Ultimate crushing stress for the column material.	
	A = Area of cross-section	
	$a = \frac{2c}{\pi^2 E}$ = Rankine's constant	
	L_e = Effective length of column which depends upon the column end conditions.	- 1m
b)	Effective length of Column :	
i)	Both end hinged $L_e = L$	- 1m
ii)	Both end fixed $L_e = \frac{L}{2}$	- 1m
iii)	One end fixed and other end hinged.	
	$L_e = \frac{L}{\sqrt{2}}$	- 1m
iv)	One end fixed and other end free.	
	$L_e = 2L$	- 1m



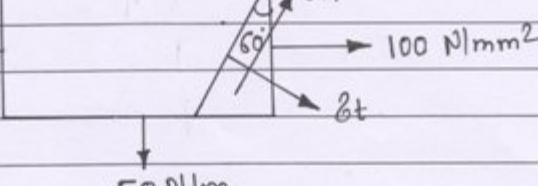
Q.NO.	SOLUTION	MARKS
2 c)	Given: i) $E = 2.8k$ Find : i) $\mu = ?$ ii) $\frac{E}{G} = ?$	
	soln: Using $E = 3k(1-2\mu)$ $2.8k = 3k(1-2\mu)$	1m
	$\therefore 2.8 = 3(1-2\mu)$ $\therefore 2.8 = 3 - 6\mu$ $\therefore 2.8 - 3 = -6\mu$ $\therefore \frac{0.2}{6} = \mu$	
	$\therefore \mu = 0.0333$	1m
	Now, Using $E = 2G(1+\mu)$	1m
	$\therefore \frac{E}{G} = 2(1+0.033)$	
	$\therefore \frac{E}{G} = 2.066$	1m

Q.NO	SOLUTION	MARKS
2 d)	Given: i) $d = 40\text{mm}$ ii) $t = 4\text{mm} \therefore D = 40 + 8 = 48\text{mm}$ iii) $P = 120 \times 10^3 \text{N}$ iv) $E_s = 2.1 \times 10^5 \text{N/mm}^2$ v) $E_c = 0.14 \times 10^5 \text{N/mm}^2$	
	Find:	
	i) $\sigma_c = ?$ ii) $\sigma_s = ?$	
	Soln:	
	$A_s = \frac{\pi}{4} (D^2 - d^2)$ $= \frac{\pi}{4} (48^2 - 40^2)$ $= 552.92 \text{ mm}^2$ $A_c = \frac{\pi}{4} d^2$ $= \frac{\pi}{4} 40^2$ $= 1256.63 \text{ mm}^2$	- 1/2 m
	$\sigma_s = \frac{E_s \sigma_c}{E_c}$ $\sigma_s = \frac{2.1 \times 10^5}{0.14 \times 10^5} \sigma_c$	- 1/2 m

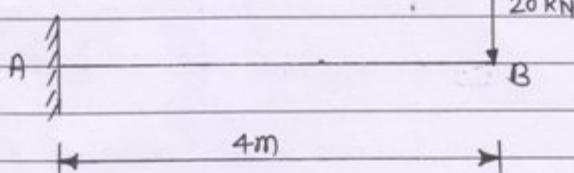
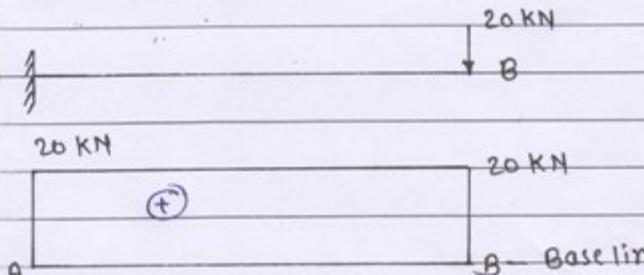
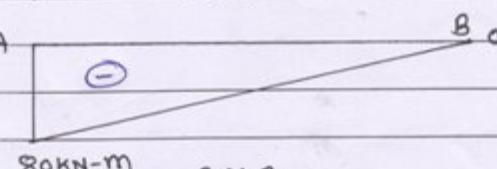


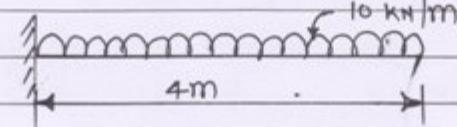
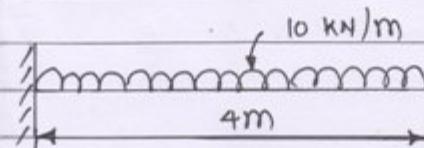
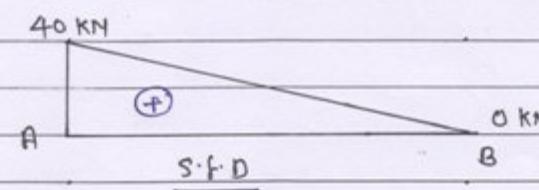
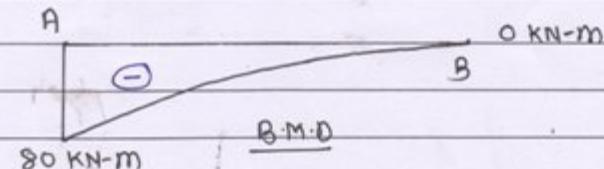
Q.NO	SOLUTION	MARKS
2 d cond.	$\sigma_s = 15 \sigma_c$	- $\frac{1}{2}$ m
	$R = \sigma_s A_s + \sigma_c A_c$	- $\frac{1}{2}$ m
	$120 \times 10^3 = 15 \sigma_c \times 552.92 + \sigma_c \times 1256.63$	
	$120 \times 10^3 = 9550.43 \sigma_c$	
	$\therefore \sigma_c = \frac{120 \times 10^3}{9550.43}$	
	$\sigma_c = 12.56 \text{ N/mm}^2$	- 1 m
	$\therefore \sigma_s = 15 \sigma_c = 15 \times 12.56$	
	$\therefore \sigma_s = 188.47 \text{ N/mm}^2$	- $\frac{1}{2}$ m
e)	Given : i) $\sigma_x = 100 \text{ N/mm}^2$ (Tensile) ii) $\sigma_y = 50 \text{ N/mm}^2$ (Tensile) iii) $\theta = 60^\circ$	
	Find : i) σ_n = normal stresses on inclined plane ii) σ_t = tangential stress on inclined plane	
	Soln : i) Normal stress on inclined plane	
	$\sigma_n = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y \cos 2\theta}{2}$ - 1m	



Q.NO	SOLUTION 50 N/mm ²	MARKS
2 e cont.		
		
	$\therefore B_n = \frac{100 + 50}{2} + \frac{100 - 50}{2} \cos 2 \times 60^\circ$ $= 75 - 12.5$	
	$B_n = 62.5 \text{ N/mm}^2$	1M
	$B_t = \frac{B_x - B_y \sin 2\theta}{2}$ $= \frac{100 - 50}{2} \sin 2 \times 60^\circ$	1M
	$B_t = 21.65 \text{ N/mm}^2$	1M

Q.NO	SOLUTION	MARKS
2 f)	Given: i) $d = 1m = 1000 \text{ mm}$ ii) $t = 10 \text{ mm}$ iii) $h = 200 \text{ m} = 200 \times 10^3 \text{ mm}$ iv) $\gamma_w = 10 \times 10^3 \text{ N/m}^3$	
	Find: i) Hoop stress (σ_c) = ? ii) Longitudinal stress (σ_L) = ?	
	Soln: i) Maximum water pressure $\rho = \gamma_w \times h = \frac{10 \times 10^3 \times 200 \times 10^3}{(10^3)^3}$ $= \frac{2000 \times 10^3}{10^6}$ $\rho = 2 \text{ N/mm}^2$	
	Now, $\sigma_c = \text{Hoop Stress} = \frac{\rho d}{2t} = \frac{1}{2} \text{ N/mm}^2$ $= \frac{2 \times 1000}{2 \times 10}$ $\boxed{\sigma_c = 100 \text{ N/mm}^2}$	1m
	$\sigma_L = \frac{1}{2} \sigma_c = \frac{\rho d}{4t} = \frac{1}{2} \text{ N/mm}^2$ $= \frac{1}{2} \times 100$ $\boxed{\sigma_L = 50 \text{ N/mm}^2}$	1m

Q.NO.	SOLUTION	MARKS
Q-3 (a) i>	 <p>Shear force calculation</p> <p>i> S.F at B = 20 kN</p> <p>ii> S.F at A = 20 kN</p>	0 M
	Bending moment calculation	
	<p>i> B.M at B = 0 KN-m</p> <p>ii> B.M at A = $-20 \times 4 = -80$ KN-m</p>	0 M
	 <p>S.F.D</p> <p>Baseline</p>	0 M
	 <p>B.M.D</p>	0 M

Q.NO	SOLUTION	MARKS
Q.3 ii>		
a.		
Cont..		
i>	s.f calculation	
	S.F at B = 0	
	S.F at A = $10 \times 4 = 40 \text{ kN}$	0 M
ii>	B.M. calculation	
	B.M at B = 0 KN-m	
	B.M at A = $-(10 \times 4) \times \frac{4}{2} = -80 \text{ KN-m}$	0 M
		
		0 M
		0 M



Q.NO	SOLUTION	MARKS
Q.3 b)	<p>i) To find reaction (Support reaction)</p> $\sum F_y = 0$ $R_A + R_B = 20 + 10 \times 8$ $R_A + R_B = 100 \quad \text{--- (1)}$ $\sum M_A = 0$ $-R_B \times 4 + 10 \times 8 \times \frac{1}{2} + 20 \times 1 = 0$ $-R_B \times 4 + 80 \times 2 + 20 = 0$ $-4R_B + 160 + 20 = 0$ $R_B = \frac{180}{4}$ $R_B = 45 \text{ KN} \quad \therefore R_A = 55 \text{ KN}$	
ii) S.F. calculation	a) S.F. at C = 0	
	b) S.F. at A(L) = $-10 \times 2 = -20 \text{ kN}$	
	c) S.F. at A(R) = $-20 + 55 = 35 \text{ kN}$	
	d) S.F. at D(L) = $35 - 10 \times 1 = 25 \text{ kN}$	
	e) S.F. at D(R) = $25 - 20 = 5 \text{ kN}$	0 M



Q NO	SOLUTION	MARKS
Q.3		
b.	f) S.F. at B(l) = $S - 10 \times 3 = -25 \text{ KN}$	
Cont.	g) S.F. at B(R) = $-25 + 45 = 20 \text{ KN}$	
	i) S.F. at E = $20 - 10 \times 2 = 0 \text{ KN}$.	
	iii) B.M. calculation	
a)	B.M. at C = 0 KN-m	
b)	B.M. at A = $-10 \times 2 \times 1 = -20 \text{ KN-m}$	
c)	B.M. at D = $-10 \times 3 \times 1.5 + 55 \times 1$ = 10 KN-m	
d)	B.M. at B = $-10 \times 6 \times 3 + 55 \times 4 - 20 \times 3$ = -20 KN-m	
e)	B.M. at E = 0 KN-m	0 M
	iv) point of zero shear $\frac{5}{x} = \frac{25}{(3-x)}$ $5(3-x) = 25x$ $15 - 5x = 25x$ $15 = 30x$ $x = 0.5$	0 M



Q.NO	SOLUTION	MARKS
Q 3 c)	<p>Diagram showing a beam A-B. At support A, there is a spring. At point C, which is 4m from A, there is a uniformly distributed load of 15 kN/m over a 4m length, and a concentrated downward force of 120 kN at point C. The total length of the beam is 6m, with 2m from C to support B.</p>	
i) To find reaction (support reaction)		
$\sum M_A = 0$		
$R_B \times 6 - 120 \times 4 - 15 \times 4 \times \frac{4}{2} = 0$		
$R_B \times 6 - 480 - 120 = 0$		
$6 R_B - 600 = 0$		
$R_B = 100 \text{ kN}$		
$\sum F_y = 0$		
$R_A + R_B = 120 + 60$		
$R_A + R_B = 180 \quad \text{put } R_B = 100 \text{ kN}$		
$\therefore R_A = 80 \text{ kN}$		
ii) S.F calculation		
a) S.F at A = 80 kN		
b) S.F at C _b = $80 - 15 \times 4 = 20 \text{ kN}$		
c) S.F at C _A = $80 - 15 \times 4 - 120 = -100 \text{ kN}$		
d) S.F at B = -100 kN.	01M	

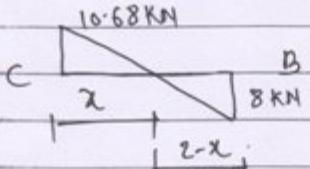


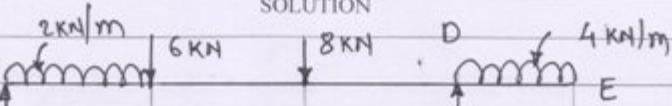
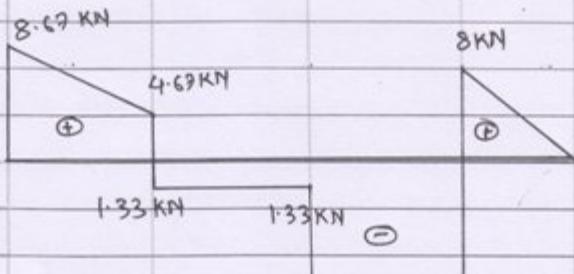
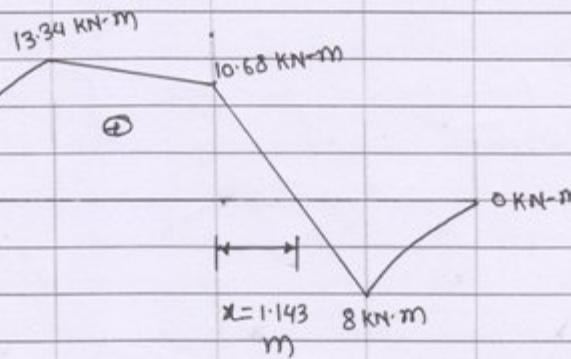
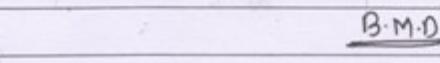
Q.NO.	SOLUTION	MARKS
Q.3. iii) B.M calculation		
C	a) $M_A = 0 \text{ KN-m}$	
Contd-	b) $M_C = 80 \times 4 - 15 \times 4 \times \frac{4}{2}$ $M_C = 320 - 120$ $M_C = 200 \text{ KN-m}$	01M
		01M
		01M
	<u>B.M.D.</u>	



Q.NO.	SOLUTION	MARKS
d)	<p>Diagram of a beam A-E with supports at A and D. Span AB is 2m, BC is 2m, CD is 2m, and DE is 2m. A downward force of $2\text{KN}/\text{m}$ acts on segment AB, a downward force of 6KN acts at point B, and a downward force of 8KN acts at point C. A downward force of $4\text{KN}/\text{m}$ acts on segment DE. The beam is fixed at A and has an upward reaction R_A at A and an upward reaction R_D at D.</p>	
i)	<p>To find support reaction</p> $\sum H = 0$ $R_A + R_D - 4 - 6 - 8 - 8 = 0$ $R_A + R_D = 26 \quad \textcircled{1}$ $\sum M_A = 0$ $-6R_D + 4 \times 2 \times 7 + 8 \times 4 + 6 \times 2 + 2 \times 2 = 0$ $R_D = 17.33 \text{ KN}$ $\therefore R_A = 26 - 17.33$ $R_A = 8.67 \text{ KN}$	
ii)	<p>S.F calculation</p> <p>a) S.F at A = 8.67 KN</p> <p>b) S.F at B(L) = $8.67 - 2 \times 2 = 4.67 \text{ KN}$</p> <p>c) S.F at B(R) = $4.67 - 6 = -1.33$</p> <p>d) S.F at C(L) = $-1.33 - 8 = -9.33 \text{ KN}$</p> <p>e) S.F at D(L) = $-9.33 + 17.33 = 8 \text{ KN}$</p> <p>f) S.F at E = 0 KN</p>	01 M



Q.NO	SOLUTION	MARKS
Q.3	iii) B.M calculation	
d.	a) B.M at A = 0 KN·m	
Cont..	b) B.M at B = $8.67 \times 2 - 2 \times 2 \times 1 = 13.34 \text{ KN}\cdot\text{m}$	
	c) B.M at C = $8.67 \times 4 - 2 \times 2 \times 3 - 6 \times 2 = 10.68 \text{ KN}\cdot\text{m}$	
	d) B.M at D = $-4 \times 2 \times 1 = -8 \text{ KN}\cdot\text{m}$	
	e) B.M at E = 0 KN·m	01.M
iv)	point of contraflexure	
	 <p>let x be the point of contraflexure</p>	
	$\frac{x}{10.68} = \frac{2-x}{8}$	
	$8x = 10.68(2-x)$	
	$8x = 21.36 - 10.68x$	
	$18.68x = 21.36$	
	$x = \frac{21.36}{18.68}$	
	$\therefore x = 1.143 \text{ m}$	

Q.NO	SOLUTION	MARKS
Q.3.d Cont..		
		01 M
		01 M
		

Q.NO	SOLUTION	MARKS
Q.3. e		
	i) S.F calculation	
	a) S.F at B = -3 kN	
	b) S.F at A = $-3 + (2 \times 4) = -3 + 8 = 5 \text{ kN}$ 01 M	
	* Location of zero Shear force.	
	$\frac{3}{x} = \frac{5}{4-x}$	
	$3(4-x) = 5x$	
	$12 - 3x = 5x$	
	$12 = 8x$	
	$x = 1.5 \text{ m}$	
	ii) B.M. calculation	01 M
	a) B.M at B = 0 kN-m	
	b) B.M at C = Max B.M.	
	$(3 \times 1.5) - (2 \times 1.5) \times 1.5 / 2 = 2.25 \text{ kN-m}$	01 M
	c) B.M at A = 0 kN-m	01 M
	For B.M.D	



Q.NO.	SOLUTION	MARKS
Q.3F	<p>finding moment of Inertia @ centroidal axis</p> <p>i) $I_G = I_{xx} = I_{yy}$</p> $I_G = \frac{1}{12} [bd^3 - bd^3]$ $= \frac{1}{12} [120 \times 120^3 - 80 \times 80^3]$ $= \frac{1}{12} [207.36 \times 10^6 - 4.096 \times 10^6]$ $I_G = 13.867 \times 10^6 \text{ mm}^4$	01M
ii)	$h = \frac{120}{2} = 60 \text{ mm}$	
iii)	using parallel axis theorem	
	$I_{AB} = I_G + Ah^2$	



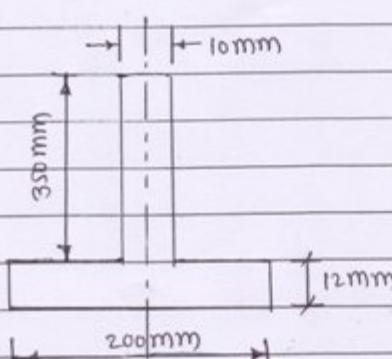
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(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

26 | 50

Page No: _____ / N

Subject Code: 17304

Q.NO	SOLUTION	MARKS
Q.3.F.	$\therefore I_G = I_{xx} = I_{yy} = I$	
Cont..	$I_G = 13.867 \times 10^6 \text{ mm}^4$	
iv)	$A = [(120 \times 120) - (80 \times 80)]$ $A = 8000 \text{ mm}^2$	
v)	$I_{AB} = I_G + A h^2$ $= 13.867 \times 10^6 + 8000 \times 60^2$ $I_{AB} = 42.667 \times 10^6 \text{ mm}^4$	LM LM

Q.NO	SOLUTION	MARKS
Q-4		
(a)	i) Moment of inertia (I) Moment of inertia of section is defined as the product of area of a section and the square of the distance between the centroid of section and reference axis.	2 M
	ii) Radius of Gyration (K) it is defined as the distance at which the area 'A' is supposed to be concentrated to give the same moment of inertia	2 M
	$I = A K^2$ $K = \sqrt{\frac{I}{A}}$ where K is Radius of gyration	
b)		

Q.NO	SOLUTION	MARKS
Q.4.b.	Find area of each figure	
i>	$A_1 = 350 \times 10 = 3500 \text{ mm}^2$	
Cont.	$A_2 = 200 \times 12 = 2400 \text{ mm}^2$	
	Total Area = $A_1 + A_2$ $= 3500 + 2400$ $= 5900 \text{ mm}^2$	
ii>	To find \bar{x} & \bar{y} Given section is symmetrical @ YX axis	
	$\therefore \bar{x} = \frac{200}{2} = 100 \text{ mm}$	1M
iii)	\bar{y} To find \bar{y}	
	$\bar{y}_1 = 12 + \frac{350}{2} = 187 \text{ mm}$	
	$\bar{y}_2 = \frac{6}{2} = 3 \text{ mm}$	
	$\therefore \bar{y} = \frac{A_1 \bar{y}_1 + A_2 \bar{y}_2}{A_1 + A_2}$	
	$\bar{y} = \frac{3500 \times 187 + 2400 \times 3}{3500 + 2400}$	
	$\bar{y} = \frac{654500 + 14400}{5900}$	
	$\boxed{\bar{y} = 113.37 \text{ mm}}$	1M



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(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

29 | 50

Subject Code: 17304

Page No: ___ / N

Q.NO	SOLUTION	MARKS
Q.4.b Cont.	To find I_{xx} $I_{xx} = I_{xx_1} + I_{x_2 x_2}$	
	$I_{xx} = [I_{G_1} + A_1 h_1^2] + [I_{G_2} + A_2 h_2^2]$	10
	$= \left[\frac{10 \times 350^3}{12} + 3500(187 - 113.37)^2 \right] +$	
	$\left[\frac{200 \times 12^3}{12} + 2400(113.37 - 6)^2 \right]$	10
	$I_{xx} = 82.40 \times 10^6 \text{ mm}^4$	2M.



Q.NO	SOLUTION	MARKS
Q.4(c)		
	i) To find M.I w.r.t diameter	
	Moment of Inertia @ centroidal axis	
	$\therefore I_G = I_{xx} = I_{yy}$	
	$I_G = \frac{\pi}{64} (D^4 - d^4)$	
	$= \frac{\pi}{64} (220^4 - 110^4)$	
	$= 107803272 \text{ mm}^4$	
	$I_G = 10.78 \times 10^7 \text{ mm}^4$	01 M
	ii) $h = \frac{D}{2} = \frac{220}{2} = 110 \text{ mm}$	1/2 M
	iii) $A = \frac{\pi}{4} (D^2 - d^2) = \frac{\pi}{4} (220^2 - 110^2)$	1/2 M
	$A = 28509.9532 \text{ mm}^2 = 28.51 \times 10^3 \text{ mm}^2$	
	iv) apply parallel axis theorem	
	$I_{tangent} = I_G + Ah^2$	
	$= 107803272 + 28509.9532 \times 110^2$	
	$= 452773706 \text{ mm}^4$	
	$= 45.27 \times 10^7 \text{ mm}^4$	01 M



Q.NO	SOLUTION	MARKS
Q.4.c.	v) polar moment of inertia	
Cont..	$I_p = I_{xx} + I_{yy} \therefore I_G = I_{xx} = I_{yy}$ $\therefore I_{pp} = I_{xx} + I_{yy}$	
	$I_p = 107803272 + 107803272$ = 56006544	
	$I_{polar} = 215.60 \times 10^6 \text{ mm}^4$	01 M
d>		
(1) finding Area	$A_1 = A_3 = 50 \times 10 = 500 \text{ mm}^2$ $A_2 = (200 - 10 - 10) \times 10 = 180 \times 10 = 1800 \text{ mm}^2$ $A = A_1 + A_2 = 500 + 1800 + 500 = 2800 \text{ mm}^2$ $+ A_3$	
(2) Distance of the centroid from the left face		
	$x_1 = x_3 = \frac{50}{2} = 25 \text{ mm}$	
	$x_2 = \frac{10}{2} = 5 \text{ mm}$	

Q.NO	SOLUTION	MARKS
Q.4.d.	Distr' of the vertical centroidal axis from the left face	
Cont-		
	$\bar{x} = \frac{A_1x_1 + A_2x_2 + A_3x_3}{A_1 + A_2 + A_3}$ $= \frac{500 \times 25 + 1800 \times 5 + 500 \times 25}{2800}$ $= 12.14 \text{ mm}$	0 M
	$\therefore I_{xx} = M.I \text{ of ABCD} - M.I \text{ of PQRS}$ $= \frac{50 \times 200^3}{12} - \frac{(50-10) \times 180^3}{12}$ $= 13.89 \times 10^6 \text{ mm}^4$	0 M
	To find I_{yy}	
	$I_{yy} = I_{yy1} + I_{yy2} + I_{yy3}$	
	$I_{yy1} = I_{G1} + A_1h_1^2$	
	$I_{G1} = \frac{10 \times 50^3}{12} = 104166.67 \text{ mm}^4$	
	$h_1 = \frac{50}{2} - \bar{x} = 25 - 12.4 = 12.6 \text{ mm}$	
	$I_{yy1} = 104166.67 + 500 \times (12.6)^2 = 183546.67 \text{ mm}^4$	0 M



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$$33 \overline{)50}$$

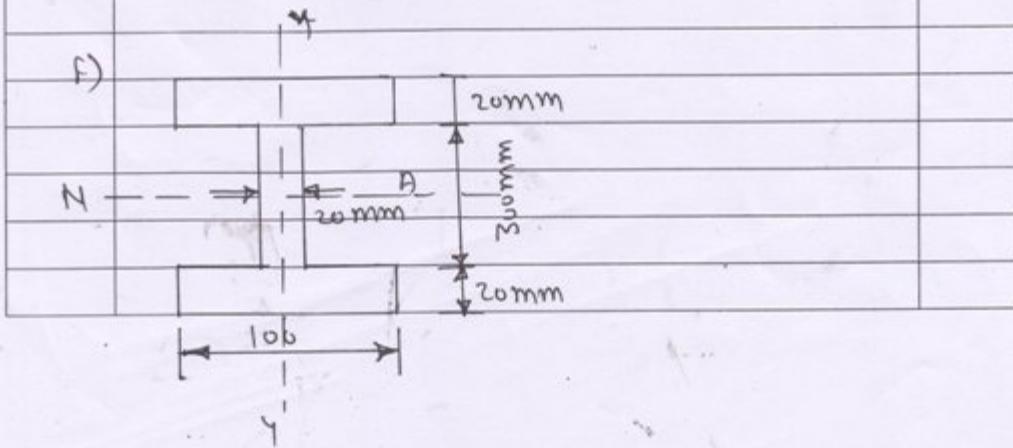
Subject Code: 17304

Page No: _____ / N

Q.NO	SOLUTION	MARKS
Q.4.d. Cont.	$I_{44_2} = I_{G_2} + A_2 h_2^2$ $I_{G_2} = \frac{180 \times 10^3}{12} = 15000 \text{ mm}^4$ $h_2 = 12.14 - \frac{10}{2} = 7.14 \text{ mm}$ $I_{44_2} = 15000 + 1800 \times 7.14^2$ $= 106763.28 \text{ mm}^4$ $I_{44_1} = I_{44_3} = 183546.67 \text{ mm}^4$ $I_{44} = I_{44_1} + I_{44_2} + I_{44_3}$ $= 183546.67 + 106763.28 + 183546.67$ $I_{44} = 47.38 \times 10^4 \text{ mm}^4$	01 M



Q.NO	SOLUTION	MARKS
Q.4.e)	State four assumption made in pure bending	
i>	The material of the beam is homogeneous and Isotropic	4 M (Any four)
ii>	Transverse section of the beam which is plane before bending will remain plane after bending	
iii>	The beam is stressed well upto proportional limit such that it must obey's Hook's law	
iv>	the value of Young's modulus is same in tension & in compression	
v>	The elastic limit is not exceeded.	
vi>	The beam initially straight & unstressed.	
vii>	Each longitudinal fiber is free to expand or contract independently from every other layer	
viii>	The resultant force across transverse section of beam is zero	
ix>	The deformation of the section due to shear force is neglected.	



Q.NO	SOLUTION	MARKS
Q-4 (F)	a) shear Stress at the bottom layer = 0 cont. b) q_1 = Shear Stress at the Junction of flange and web	
	$I = \frac{1}{12} (BH^3 - b h^3) = \frac{1}{12} (100 \times 340^3 - 80 \times 300^3)$ $I = 1.47 \times 10^8 \text{ mm}^4$	
i>	shear stress at junction in flange	
	$q_1 = \frac{FA\bar{y}}{I_B} = \frac{100 \times 10^3 \times 100 \times 20 \times (150 + \frac{20}{2})}{1.47 \times 10^8 \times 100}$ $q_1 = 2.169 \text{ N/mm}^2$	0.1 M
ii>	shear stress at junction (in web)	
	$\therefore q_1$ suddenly increases to q_2 $q_2 = \frac{B}{t} \times q_1 = \frac{100}{20} \times 2.169 = 10.845 \text{ N/mm}^2$	0.1 M
iii>	$q_{max} = \frac{FA\bar{y}}{I_B}$ (for additional part)	
	$A\bar{y} = A_1\bar{y}_1 + A_2\bar{y}_2$ $A\bar{y} = 100 \times 20 \times 160 + 150 \times 20 \times 75$ $A\bar{y} = 545 \times 10^3 \text{ mm}^3$	1/2 M
	$q_{max} = \frac{100 \times 10^3 \times 545 \times 10^3}{1.47 \times 10^8 \times 20}$ $q_{max} = 18.53 \text{ N/mm}^2$	1/2 M



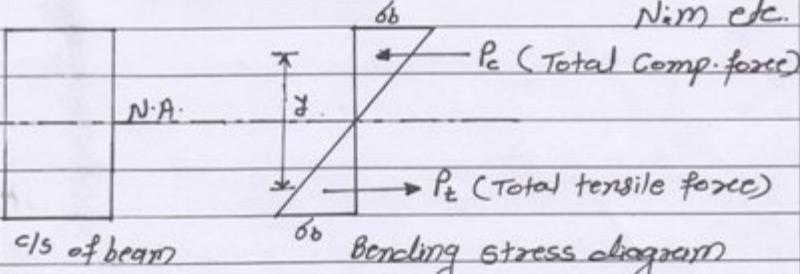
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(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)**

$$36 \overline{)50}$$

Subject Code: 17304

Page No: ___/N

Q.NO	SOLUTION	MARKS
Q.4-f. Cont.	<p>$q_{max} = 18.49 \text{ N/mm}^2$</p>	

Q.NO.	SOLUTION	MARKS
Q5 a>	<p>i) Moment of Resistance :-(MR)</p> <p>The resistance offered by the moment of couple due to two equal and opposite forces to the bending moment (M) induced due to external forces is called as moment of resistance. It is given by product of section modulus and allowable bending stress.</p>	02
	$M \cdot R = Z \times \sigma_b$ <p style="text-align: right;">S.I. unit N-mm; N-m etc.</p>  <p>Bending stress diagram</p>	



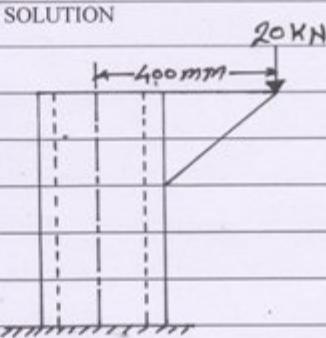
Subject Code: 17304

Page No: ___ / N

Q.NO.	SOLUTION	MARKS
Q5 b>	<p>Given</p>	
	$\sigma_{max} = \frac{P}{A} + \frac{M}{Z_{yy}}$	0.1 M
	$Z_{yy} = \frac{d(b^2)}{6}$	
	$Z_{yy} = \frac{100 \times 200^2}{6}$	0.1 M
	$\sigma_{max} = \frac{60 \times 10^3}{200 \times 100} + \frac{60 \times 10^3 \times 40}{100 \times 200^2}$	for z
	$\therefore \sigma_{max} = 3 + 3.6 = 6.6 \text{ MPa}$	0.1 M
	$\sigma_{min} = -0.6 \text{ MPa}$ -ve sign indicate tensile stress.
		0.1 M

Subject Code: 17304

Page No: ___ / N

Q.NO	SOLUTION	MARKS
Q5 c>	Given	
		
	D - 250 mm	
	d - 200 mm	
	P - 20 kN	
	e - 400 mm	
	$\sigma_{max} - ?$	
	$\sigma_{min} - ?$	
1) $\sigma_{max} = \text{Direct stress}(\sigma_d) + \text{Bending stress}(\sigma_b)$		
$\sigma_{max} = \frac{P}{A} + \frac{M}{Z}$ 01 M		
$M = P \times e = 20 \times 10^3 \times 400 = 8 \times 10^6 \text{ N-mm}$		
$Z = \frac{\pi}{320} (D^4 - d^4) = 905.66 \times 10^3 \text{ mm}^3$ 01 M		
$A = \frac{\pi}{4} (D^2 - d^2) = 17671.45 \text{ mm}^2$		
$\therefore \sigma_{max} = \frac{20 \times 10^3}{17671.45} + \frac{8 \times 10^6}{905.66 \times 10^3}$		
$= 1.13 + 8.83$		
$\boxed{\sigma_{max} = 9.96 \text{ N/mm}^2} \dots (\text{Comp})$ 01 M		
2) $\sigma_{min} = \text{Direct stress}(\sigma_d) - \text{Bending stress}(\sigma_b)$		
$= 1.13 - 8.83$		
$\boxed{\sigma_{min} = -7.70 \text{ N/mm}^2} \dots -\text{ve sign indicate } 01 \text{ M tensile stress.}$		



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4
40/50

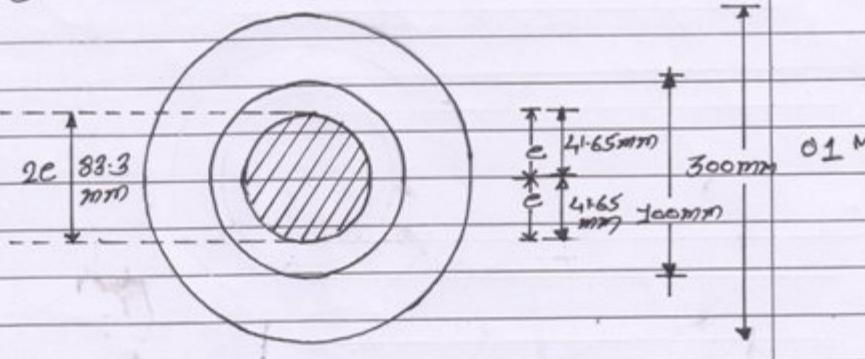
Subject Code: 17304

Page No: ___ / N

Q.NO	SOLUTION	MARKS
Q5 d)	Given, $P = 4 \text{ kN}$; $c = 200 \text{ mm}$; $b = 60 \text{ mm}$; $t = 20 \text{ mm}$	
1)	$\sigma_{\max} = \sigma_o + \sigma_b = \frac{P}{A} + \frac{M}{Z}$.	01 M
	$\sigma_{\max} = \frac{P}{A} + \frac{P \cdot c}{Z}$. $Z = \frac{\frac{t}{6} b^2}{6}$	01 (for Z)
	$= \frac{4 \times 10^3}{60 \times 20} + \frac{4 \times 10^3 \times 200}{20 \times 60^2}$	
	$\sigma_{\max} = 3.33 + 66.67$	
	$\therefore \boxed{\sigma_{\max} = 70 \text{ N/mm}^2}$(Comp)	01 M
2)	$\sigma_{\min} = \sigma_o - \sigma_b$ $= 3.33 - 66.67$	
	$\boxed{\sigma_{\min} = -63.34 \text{ N/mm}^2}$(Tensile)	01 M
Q5 e)	Given, $P = 80 \text{ kN}$; $b = 120 \text{ mm}$; $t = 40 \text{ mm}$ $c = \frac{b}{3} = \frac{120}{3} = 40 \text{ mm}$.	
1)	$\sigma_{\max} = \sigma_o + \sigma_b$ $= \frac{P}{A} + \frac{M}{Z}$	01 M
	$\sigma_{\max} = \frac{P}{A} + \frac{P \cdot c}{Z}$	

Subject Code: 17304

Page No: ___ / N

Q.NO.	SOLUTION	MARKS
Q5c> Cont...	$Z = \frac{t b^2}{6} = \frac{40 \times 120^2}{6} = 96 \times 10^3 \text{ mm}^3$	01 M
	$\therefore \sigma_{\max} = \frac{80 \times 10^3}{120 \times 40} + \frac{80 \times 10^3 \times 40}{96 \times 10^3}$ $= 16.67 + 33.33$	
	$\therefore \boxed{\sigma_{\max} = 50 \text{ N/mm}^2} \quad \dots \text{(Comp)}$	01 M
	$\sigma_{\min} = 60 - 6b$ $= 16.67 - 33.33$	
	$\boxed{\sigma_{\min} = -16.66 \text{ N/mm}^2} \quad \dots \dots \text{VC sign indicate tensile stress.}$	01 M
Q5f> Given	$D = 100 \text{ mm}; d = 100 \text{ mm.}$	
		01 M



Subject Code: 17304

Page No: ___ / N

Q.NO.	SOLUTION	MARKS
Q5 #> Cont...	1) Limit of eccentricity (e).	
	$e \leq \frac{Z}{A}$	01 M
	$Z = \frac{\pi}{32D} (D^4 - d^4) = \frac{\pi}{32 \times 300} (300^4 - 100^4)$	
	$Z = 2.617 \times 10^6 \text{ mm}^3$	
	$A = \frac{\pi}{4} (D^2 - d^2) = \frac{\pi}{4} (300^2 - 100^2)$	
	$A = 62.83 \times 10^3 \text{ mm}^2$	
	$\therefore e \leq \frac{2.617 \times 10^6}{62.83 \times 10^3} \leq 41.65 \text{ mm}$	01 M
	$\therefore e = 41.65 \text{ mm}$	1/2 M
	$\therefore 2e = 83.30 \text{ mm}$	1/2 M
	For hollow circular section having $D=300\text{mm}$ and $d=100\text{mm}$ the core of section is Circular of Diameter $2e$ i.e. 83.30 mm .	

Q.NO	SOLUTION	MARKS
Q6) a)	Given $D = 80\text{ mm}$, for hollow $D = 1.5d$; $d = \frac{2}{3}D$	
	1) Torque from Solid shaft	
	$T_{\text{solid}} = \frac{\pi}{16} D^3 \cdot C = \frac{\pi}{16} (80)^3 \cdot C$	
	$T_{\text{solid}} = 100.53 \times 10^3 \cdot C \dots \dots (i)$	01 M
	2) Torque from hollow shaft	
	$T_h = \frac{\pi}{16D} (D^4 - d^4) \cdot C \quad \dots \dots d = \frac{2}{3}D$	
	$= \frac{\pi}{16D} [D^4 - (\frac{2}{3}D)^4] \cdot C$	
	$= \frac{\pi}{16} \times 0.802 D^3 \cdot C$	
	$T_h = 0.1574 D^3 \cdot C \dots \dots (ii)$	01 M
	3) Equating eqn (i) & (ii)	
	$100.53 \times 10^3 \cdot C = 0.1574 D^3 \cdot C$	
	$\therefore D = 86.11 \text{ mm}$	1/2 M
	$\therefore d = \frac{2}{3}D \quad d = 57.40 \text{ mm}$	1/2 M

Q.NO	SOLUTION	MARKS
Q6 a) Cont....	<p>⇒ Percentage Saving in the material</p> $= \frac{A_s - A_h}{A_s} \times 100$ $= \left[\frac{\pi}{4} (80)^2 - \frac{\pi}{4} (86.11^2 - 57.4^2) \right] \times 100$ $\frac{\pi}{4} (80)^2$	
	$\% \text{ Saving} = 35.64 \%$	01 M
Q6 b)	<p>Given. $l = 3m$, $d = 75mm$, $F = 2 \text{ kN}$, $R = 0.6m$</p> $G = 90 \text{ GN/m}^2 = 90 \times 10^3 \text{ N/mm}^2$	
	<p>⇒ Using Torsional formula</p> $\frac{T}{I_p} = \frac{G\theta}{L}$ $\therefore \theta = \frac{TL}{I_p \cdot G}$	01 M
	$T = F \times R = 2 \times 0.6 = 1.2 \text{ kN} \cdot m = 1.2 \times 10^6 \text{ N} \cdot \text{mm}$ $I_p = \frac{\pi}{32} (d)^4 = \frac{\pi}{32} (75)^4 = 3.106 \times 10^6 \text{ mm}^4$	01 M
	$\therefore \theta = \frac{1.2 \times 10^6 \times 3000}{3.106 \times 10^6 \times 90 \times 10^3}$	
	$\theta = 0.01287 \text{ rad} \quad \text{or} \quad \theta = 0.737^\circ$	01 M



Q.NO	SOLUTION	MARKS
Q6 c>	Given, Power $P = 20 \text{ kW}$; $N = 2 \text{ Revolution/sec}$ $\tau = 40 \text{ MN/m}^2 = 40 \text{ N/mm}^2$; $T_{\max} = 1.4 T_{\text{mean}}$	
1>	Power Transmitted by shaft $P = 2\pi N T_{\text{mean}}$ $20 \times 10^3 = 2 \times \pi \times 2 T_{\text{mean}}$ $\therefore T_{\text{mean}} = 1.59 \times 10^3 \text{ N-mm}$ $T_{\text{mean}} = 1.59 \times 10^6 \text{ N-mm}$	01 M
2>	$T_{\max} = 1.4 \times 1.59 \times 10^6$ $T_{\max} = 2.226 \times 10^6 \text{ N-mm}$	01 M
Using Torsional formula		
	$\frac{T}{I_p} = \frac{\tau}{R}$	01 M
	$I_p = \frac{\pi}{32} D^4$; $R = D/2$	
	$\frac{2.226 \times 10^6}{\frac{\pi}{32} D^4} = \frac{40}{D/2}$	
	$32 \times 2.226 \times 10^6 = D^3$ $\pi \times 2 \times 40$	
	$\therefore D = 65.68 \text{ mm}$	01 M

* Note:- The value of Power is printed in Q.Paper as 20 kN but it is taken as 20 kW in above problem. Examiner should consider the same.



Subject Code: 17304

Q.NO	SOLUTION	MARKS
A-6(d)	given $D = 100\text{mm}$, $\theta = 2.25^\circ = 0.04299 \text{ rad}$ $L = 6\text{m}$ $G = 80 \text{ KN/mm}^2$	
	1) using Torsional formula	
	$\frac{T}{I_p} = \frac{G\theta}{L}$	1M
	$T = \frac{G \cdot \theta \cdot I_p}{L}$	
	$I_p = \frac{\pi}{32} (D^4) = \frac{\pi}{32} \times 100^4 = 9.817 \times 10^6 \text{ mm}^4$	1M
	$T = \frac{80 \times 10^3 \times 0.04299 \times 9.817 \times 10^6}{6000}$	
	$T = 6.28 \times 10^6 \text{ N-mm}$	2M

Subject Code: 17304

Page No: ___ / N

Q.NO	SOLUTION	MARKS
Q-6 (e)	<u>solution ①</u> Two solutions are possible in this Problem. * In this problem relationship between external diameter with internal diameter is not given * So student can assume the same. * • assume $G = 80 \text{ Gpa}$ & $d = 0.75 D$	
	<u>Case solution ①</u> $\tau = 63 \text{ MPa}$ $R = D/2$ $T = 62 \times 10^6 \text{ N-mm} \quad \& \quad J = \frac{\pi}{32} (D^4 - d^4)$	
	$\therefore J = \frac{\pi}{32} ((D^4 - (0.75D)^4))$	
	$\therefore J = 0.06711029 D^4$	$\frac{1}{2} \text{ M}$
i>	Diameter based on Strength criteria	
	$\frac{\tau}{R} = \frac{T}{J}$ $\frac{63}{D/2} = \frac{62 \times 10^6}{0.06711029 D^4}$	$\frac{1}{2} \text{ M}$
	$\therefore 4.2279 D^4 = 0.5 D \times 62 \times 10^6$	
	$\therefore D^3 = \frac{31 \times 10^6}{4.228}$	
	$\therefore D = 194.22 \text{ mm}$	1 M

Q.NO	SOLUTION	MARKS
ii>	diameter based on stiffness criteria	
	$\frac{T}{J} = \frac{G \cdot \Theta}{L}$	$\frac{1}{2} M$
	$\frac{62 \times 10^6}{0.06311029 D^4} = \frac{80 \times 10^3 \times 0.024434}{3000}$	
	$62 \times 10^6 \times 3000 = 0.06311029 D^4 \times 80 \times 10^3 \times 0.024434$	
	$\therefore 62 \times 10^6 \times 3000 = 131.181 D^4$	
	$\therefore D^4 = 14178882.61$	
	$\therefore D = 194.048 \text{ mm}$	01
	from above two criteria min. diameter = 194.23 mm	$\frac{1}{2} M$
Q-6 (e)	other alternate solution-2	
a)	maximum Torque = 62 kNm	
b)	shear stress = 63 MPa	
c)	Length of shaft = 3m	
d)	$\Theta = 1.4^\circ$	
e)	assuming $G = 80 \text{ GPa}$	
f)	$R = D/2$	



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49/50

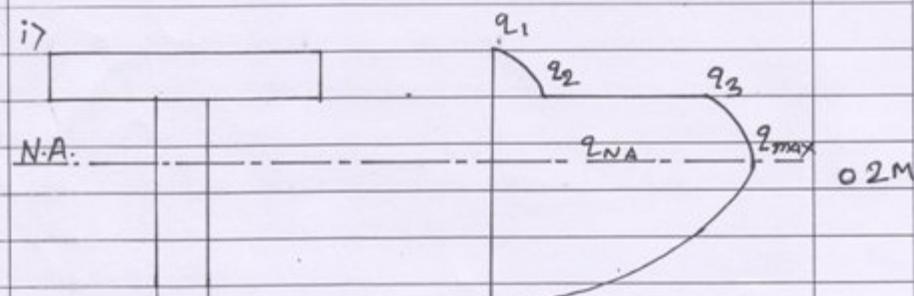
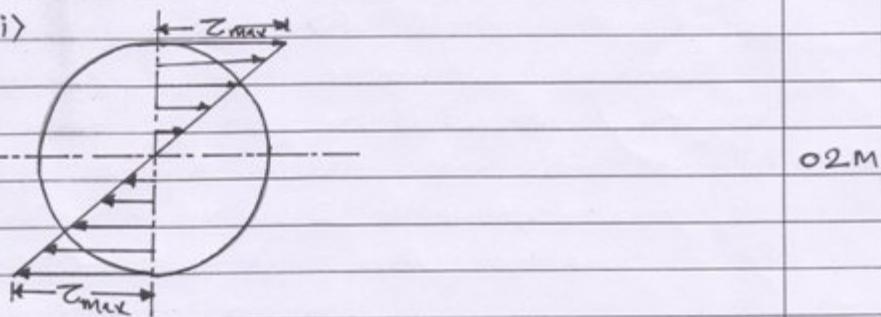
Subject Code: 17304

Page No: ___ / N

Q.NO	SOLUTION	MARKS
	External diameter of shaft	→
	$T_{max} = \frac{G \cdot O}{R}$	1M
	$63 = \frac{80 \times 10^3 \times 0.024434}{D/2}$	
	$63 \times 3000 = 0.5 D \times 80 \times 10^3 \times 0.024434$	
	$189000 = 977.36 D$	
	$D = 193.38 \text{ mm}$	3M

Subject Code: 17304

Page No: ___ / N

Q.NO	SOLUTION	MARKS
Q6 f) i)		
	<p>T-Section Shear stress distribution diagram</p>	
ii)		02M
	<p>Circular shaft</p> <p>$\tau \rightarrow$ Intensity of shear stress. at outer fibre.</p>	