Modified

CBCS SCHEME

USN | | | | | | | | | |

18ME32

Third Semester B.E. Degree Examination, Feb./Mar. 2022
Mechanics of Materials

Time: 3 hrs. Max. Marks: 100

Note: ***Answer any FIVE full questions, choosing ONE full question from each module.***

Module-1

1 a. Define i) Poisson's ratio ii) Stress iii) Percentage Reduction in area iv) Toughness. **(04 Marks)**

b. Derive the relationship between Modulus of Rigidity and Modulus of elasticity. **(06 Marks)**

c. A stepped bar is subjected to an external loading as shown in Fig. Q1(c). Calculate the change in the length of bar. Take E = 200GPa for steel , E = 70 GPA for Aluminum and E = 100 GPa for copper. **(10 Marks)**

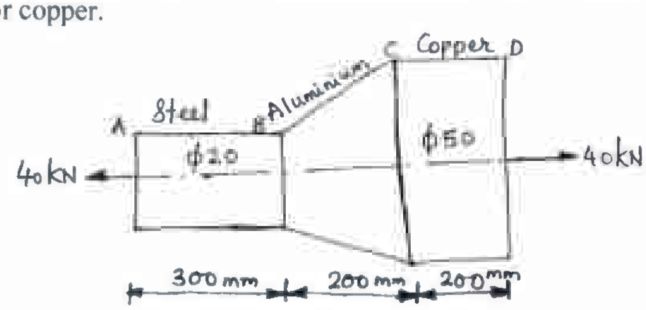


Fig. Q1(c)

OR

2 a. Draw Stress – Strain diagram for mild steel subjected to tension and indicate salient points on the diagram. **(06 Marks)**

b. A composite section comprises of a steel tube 10cm internal diameter and 12cm external diameter fitted inside a brass tube of 14cm internal diameter and 16cm external diameter. The assembly is subjected to a compressive load of 500kN. Find the load carried by each tube and change in the length of tubes. The length of tube is 150cm. Take E_S = 200 GPa and E_b = 100 GPa. **(08 Marks)**

c. The bronze bar 3m long with 320mm^2 cross sectional area is placed between two rigid walls. At -20°C there is a gap Δ = 2.5mm as shown in Fig. Q2(c). Find the magnitude and the type of stress induced in the bar when it is heated to a temperature 60°C. Take E = 80GPa and $\alpha_B = 18 \times 10^{-6}$/°C. **(06 Marks)**

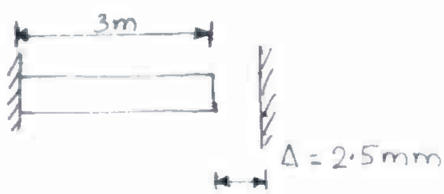


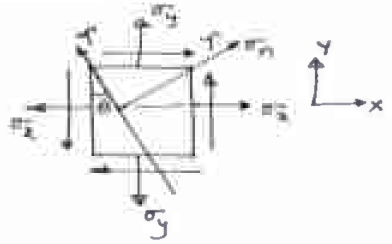
Fig. Q2(c)

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-2

3 a. Derive the expression for normal stress and tangential stress on a plane inclined at θ° to the vertical axis in a biaxial stress system with shear stress as shown in Fig.Q3(a). Also find Resultant stress and Angle of Obliquity. **(10 Marks)**

Fig. Q3(a)



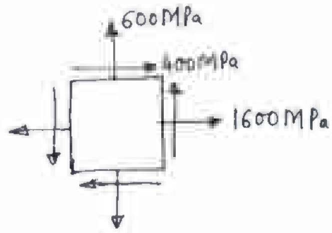
b. The state of stress at a point in a strained material as shown in Fig. Q3(b). Determine

i) The principal stresses and principal planes.

ii) Maximum shear stress and plane on which it is acting. Also find the normal stress on the maximum shear plane.

iii) Sketch the element aligned with planes of principal stresses and planes of maximum shear. **(10 Marks)**

Fig. Q3(b)



OR

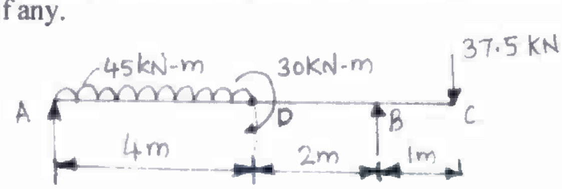
4 a. A thin cylinder of 75mm internal diameter and 250mm long has 2.5mm thick walls. The cylinder is subjected to an internal pressure of $7MN/m^2$. Determine the change in internal diameter and change in length and change in volume of cylinder. Also compute the Hoop stress and Longitudinal stress and maximum shear stress. Take E = 200GPa and μ = 0.3. **(10 Marks)**

b. A thick cylinder with internal diameter 80mm and external diameter 120mm is subjected to an external pressure of $40kN/m^2$, when the internal pressure is $120kN/m^2$. Calculate the circumferential stress at external and internal surfaces of the cylinder. Plot the variation of circumferential stress and radial pressure on the thickness of the cylinder. **(10 Marks)**

Module-3

5 Draw Shear force and Bending moment diagrams for the beam shown in Fig. Q5. Locate the point of contra flexure if any. **(20 Marks)**

Fig. Q5



OR

6 a. A simply supported of beam span 5m has a cross section of 150mm × 250mm. If the permissible stress is $20N/mm^2$. Find

i) Maximum intensity of uniformly distributed load it can carry.

ii) Maximum concentrated load P applied at 2m from one end it can carry. **(10 Marks)**

b. The cross section of a beam is a T section (Fig. Q6(b)) 150mm × 100mm × 15mm with 150mm horizontal. Find the maximum intensity of shear stress and sketch the shear stress distribution across the section if it has to resist a shear force of 90kN. **(10 Marks)**

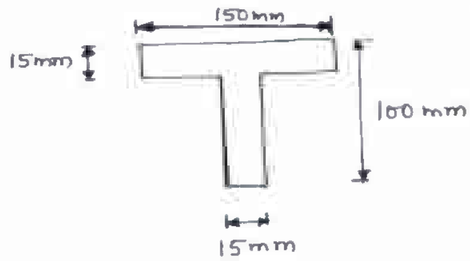


Fig. Q6(b)

Module-4

7 a. Derive the torsional equation for a circular shaft with usual notations. State the assumptions made. **(10 Marks)**

b. A solid circular shaft is subjected to a bending moment of 10kN-m and a torque of 15kN-m. The yield stress of the material in simple tension is 250MPa and E = 200GPa. If factor of safety is 3. Determine the maximum diameter of the shaft using Maximum Principal Stress theory and Maximum Shear Stress theory. **(10 Marks)**

OR

8 a. Write a note on :
i) Maximum Principal Stress theory ii) Maximum Shear Stress theory. **(08 Marks)**

b. A solid circular shaft is required to transmit 300kW at 120 rpm. The shear stress in the material is not to exceed $80 N/mm^2$. Find the diameter required. If the shaft is replaced by a hollow one whose internal diameter is 0.6 times its external diameter. The length material and maximum shear stress being same. Calculate the percentage saving in weight, that could be obtained. **(12 Marks)**

Module-5

9 a. Explain Castigliano's theorem I with its applications and Castigliano's theorem II. **(10 Marks)**

b. A hallow cast iron column whose outside diameter is 200mm and thickness of 20mm is 4.5m long and is fixed at both ends. Calculate the safe load by Rankine formula using factor of safety 2.5. Find the ratio of Euler's to Rankine's loads. Take $E = 1 \times 10^5 N/mm^2$ and Rankine constant = $\frac{1}{1600}$ for both ends fixed and $\sigma_c = 550 N/mm^2$. **(10 Marks)**

OR

10 a. Derive an expression for a critical load in a column subjected to compressive load. When one end is fixed and other end is free. **(10 Marks)**

b. Calculate the strain energy stored in a bar shown in Fig. Q10(b), subjected to a gradually applied axial load of 80kN. Compare this value with what obtained in uniform bar of same length and having the same volume, when subjected to the same load. $E = 2 \times 10^5 N/mm^2$. **(10 Marks)**

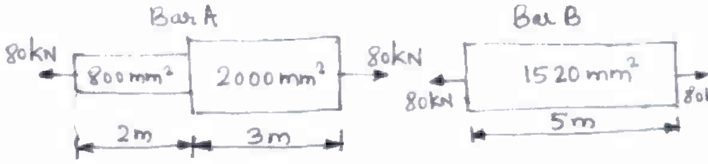


Fig. Q10(b)

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Re: Sir, Regarding Modification of Scheme and Solutions

"Dr M S Govinde Gowda" <msggowda1964@gmail.com>

May 24, 2022 3:04 PM

To: boe@vtu.ac.in

Dear Sir,
PFA for Corrected and Approved scheme and solution of 18ME32-Mechanics of Materials for your kind notice and further needful from your end.
Further to mention with regard to Q5 which was claimed as out of syllabus that the most of the BOE members as well the subject experts have expressed that the couple is also a kind of load and also it needs to be taught (even though not mentioned) since this concept is very essential in other subjects like Design-1 and -2, FEM etc. Hence it need not be considered as out of syllabus.
With regards
......

Dr. M.S.Govinde Gowda
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On Wed, May 18, 2022 at 4:21 PM <boe@vtu.ac.in> wrote:

" APPROVED "
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Visvesvaraya Technological University
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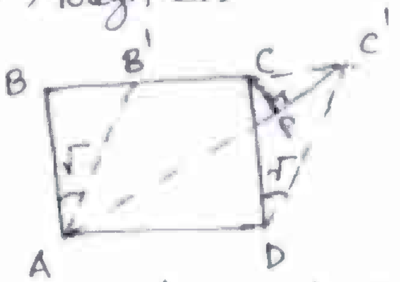
20121 3225881

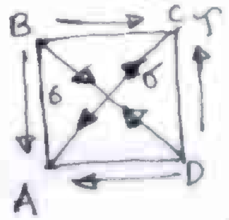
Scheme & Solutions

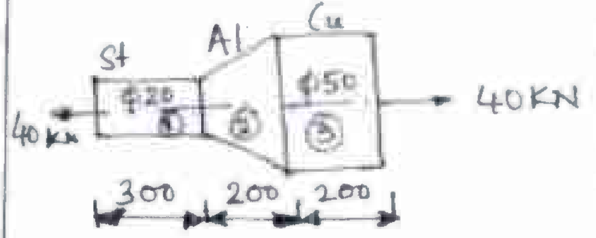
Signature of Scrutinizer

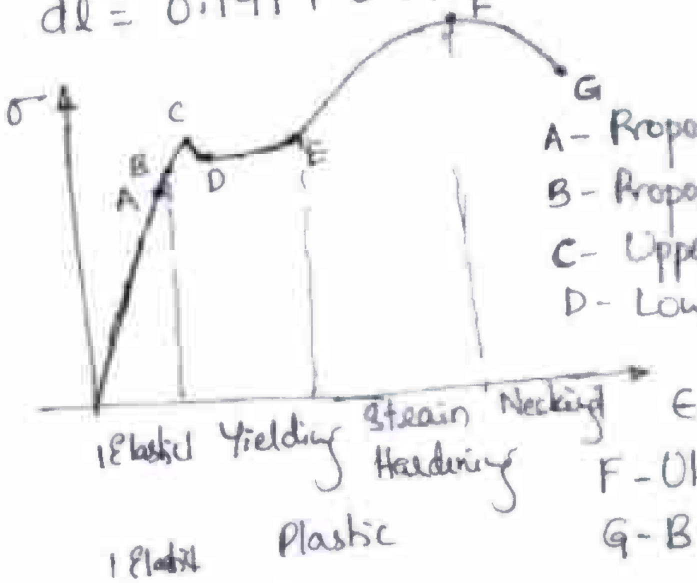
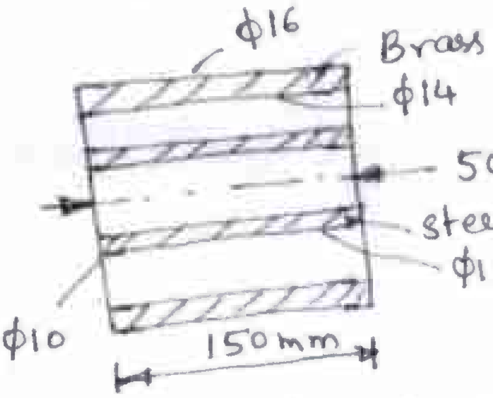
Subject Title : Mechanics of Materials **Subject Code :** 18ME32

Question Number	Solution	Marks Allocated
	Module-1	
Q.1(a)	(i) Poisson's ratio = $\dfrac{\text{lateral strain}}{\text{longitudinal strain}}$ within elastic limit	01 } 01 each
	(ii) Stress — 01 (iii) % Reduction in area = $\dfrac{A_i - A_f}{A_i} \times 100$	01, 01
	(iv) Toughness	01
(b)	(see figure below)	Fig — 01
	$\epsilon_{AC} = \dfrac{PC'}{AC} = \dfrac{CC'}{\sqrt{2}} \dfrac{1}{\sqrt{2}\,CD} = \dfrac{CC'}{2CD} = \dfrac{\gamma}{2}$ $\because \gamma = \dfrac{CC'}{CD}$	02
	$\epsilon_{AC} = \dfrac{\tau}{2G}$ —(1) $\because \gamma = \dfrac{\tau}{G}$	
	$\epsilon_{AC} = \dfrac{\sigma_1}{E} - \mu \dfrac{\sigma_2}{E} = \dfrac{\tau}{E}(1+\mu)$ —(2)	02
	From ① & ② $\epsilon_{AC} = \dfrac{\tau}{2G} = \dfrac{\tau}{E}(1+\mu) \Rightarrow \boxed{E = 2G(1+\mu)}$	01
(c)	$dl_1 = \dfrac{Pl_1}{A_1E_1} = \dfrac{40\times10^3 \times 300}{\left(\frac{\pi}{4}\times 20^2\right) 200\times10^3} = 0.191\ \text{mm}$	03







Question Number	Solution	Marks Allocated
Q.1 (c)	$dl_2 = \frac{4Pl_2}{\pi d_1 d_2 E} = \frac{4\times40\times200}{\pi\times20\times50\times70} = 0.146\ mm$	03
	$dl_3 = \frac{Pl_3}{A_3E_3} = \frac{40\times200}{(\frac{\pi}{4}\times50^2)\times100} = 0.041\ mm$	03
	Total elongation $dl = dl_1 + dl_2 + dl_3$ $dl = 0.191 + 0.146 + 0.041 = \boxed{0.378\ mm}$	01
Q2 (a)	 A - Proportional limit B - Proportional limit C - Upper yield point D - Lower yield pt F - Ultimate stress G - Breaking stress	06
(b)	 $A_s = \frac{\pi}{4}(d_o^2 - d_i^2)$ $= \frac{\pi}{4}(12^2 - 10^2)$ $= 34.55\ mm^2$	[illegible]
	$A_B = \frac{\pi}{4}(16^2 - 14^2) = 47.12\ mm^2$	01
	$P_S + P_B = P_{Total} = 500\ kN$	01
	$dl_s = dl_b = \frac{P_S l}{A_S E_S} = \frac{P_B l}{A_B E_B} \Rightarrow \frac{P_S}{34.55\times200} = \frac{P_B}{47.12\times100}$	

Subject Title : Mechanics of Materials — Subject Code : 18ME32

Question Number	Solution	Marks Allocated

$P_S = \frac{P}{B} = 1.466\,P_B$ — 03

$1.466\,P_B + P_B = 500\,kN$

$P_B = \underline{202.72}\,kN \quad P_S = \underline{297.28}\,kN$ — 01

$dl = \frac{297.28 \times 150}{34.55 \times 200} = \frac{202.72 \times 150}{47.12 \times 100} = 6.45\,mm$ — 02

Q2(c)

$T_1 = -20^\circ C \quad T_2 = 60^\circ C$

$E = 80 \times 10^3\,N/mm^2$

$\Delta = 2.5\,mm \quad \alpha_B = 18 \times 10^{-6}/^\circ C$

Free expansion $= \alpha l \Delta T$

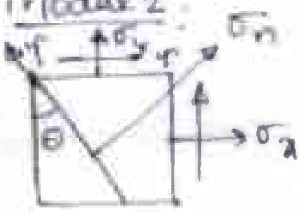
~~Stress induced~~ $= 18 \times 10^{-6} \times 3 \times 10^3 \times 80 = 4.32\,mm$ — 02

Stress induced $\frac{\sigma l}{E} = \alpha l \Delta T - 2.5 = 4.32 - 2.5 = 1.82\,mm$ — 01

$\sigma = \frac{E \times 1.82}{l} = \frac{80 \times 10^3 \times 1.82}{3 \times 10^3} = 48.53\,N/mm^2$ — 03

Module 2

Q3(a)

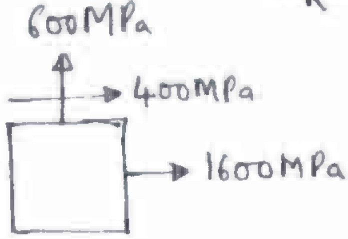


$\sigma_n = \left(\frac{\sigma_x + \sigma_y}{2}\right) + \left(\frac{\sigma_x - \sigma_y}{2}\right)\cos 2\theta + \tau \sin 2\theta$ — 04

$\tau = -\left(\frac{\sigma_x - \sigma_y}{2}\right)\sin 2\theta + \tau \cos 2\theta$ — 04

$\sigma_R = \sqrt{\sigma_n^2 + \tau^2}, \quad \phi = \tan^{-1}\left(\frac{\tau}{\sigma_n}\right)$ — 02

3(b)

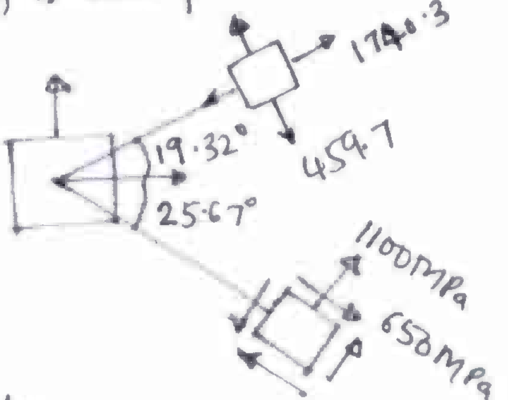


$\sigma_x = 1600\,MPa$

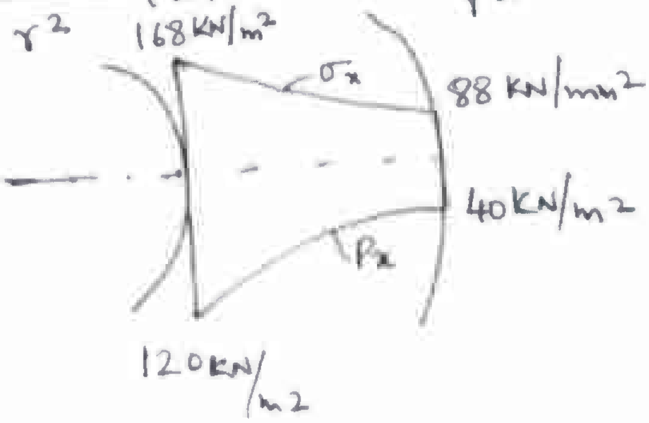
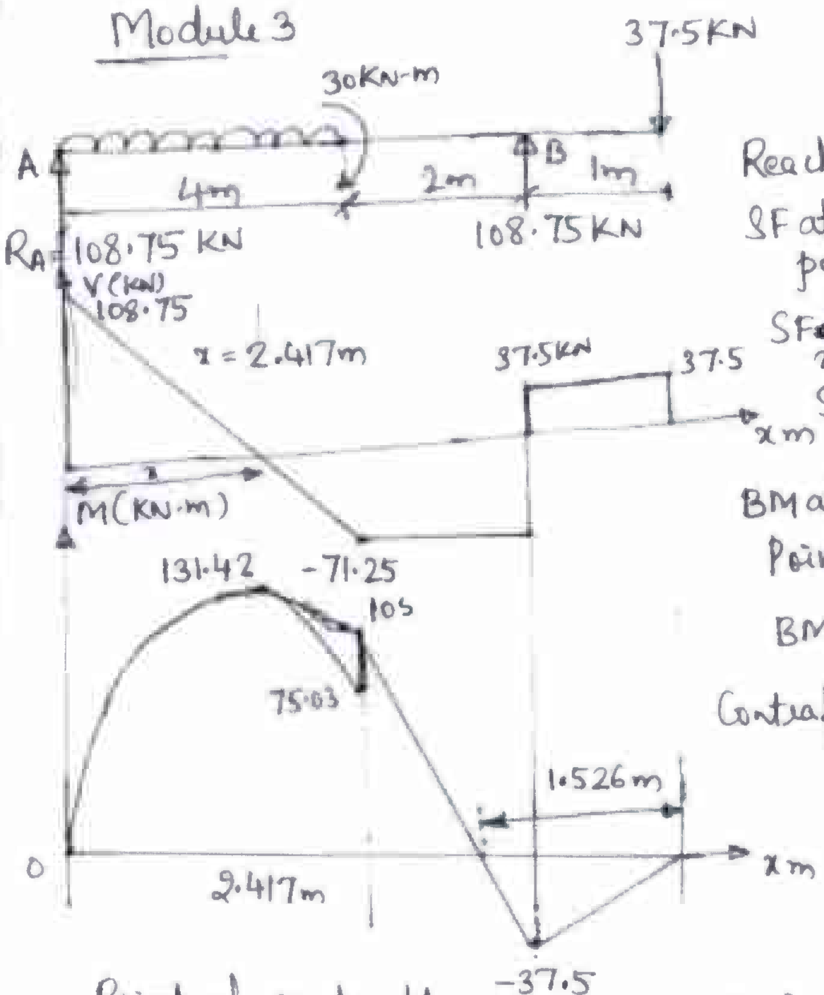
$\sigma_y = 600\,MPa$

$\tau = 400\,MPa$

Subject Title : Mechanics of Materials   Subject Code : 18ME32

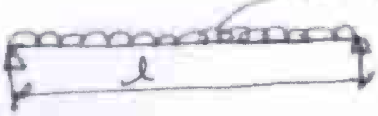
Question Number	Solution	Marks Allocated
3(b)	(i) $\sigma_{n_{max}} = 1740.3\ MPa\ (T)$ $\sigma_{min} = 459.7\ MPa\ (T)$	
	$\theta_{np_1} = 19.32^\circ$ $\theta_{np_2} = 90 + 19.32 = 109.32^\circ$	04
	(ii) $\tau_{max} = 640.3\ MPa$	
	$\theta_{s_1} = -25.67^\circ$ $\theta_{s_2} = 64.32^\circ$	03
	σ_n on shear plane $= 1100\ MPa$	
		03
	~~Module~~	
Q4(a)	$\sigma_h = \frac{7 \times 75}{2 \times 2.5} = 105\ \frac{N}{mm^2}$ $\sigma_l = 52.5\ N/mm^2$	02
	Max shear stress $= 26.25\ N/mm^2$	
	$\epsilon_d = \frac{7 \times 75}{2 \times 2.5 \times 2 \times 10^5}\left(1 - \frac{0.3}{2}\right) = 4.4625 \times 10^{-4}$	03
	$\delta d = 0.033\ mm$	
	$\epsilon_l = \frac{7 \times 75}{4 \times 2.5 \times 2 \times 10^5}(1 - 2 \times 0.3) = 1.05 \times 10^{-4}$	03
	$dl = 0.02625\ mm$	
	$\epsilon_v = 9.975 \times 10^{-4}$, $dv = 4406.82\ mm^2$	02

Subject Title: Mechanics of Materials **Subject Code:** 18ME32

Question Number	Solution	Marks Allocated
Q4(b)	$P_x = \frac{B}{r^2} - A$, $120 = \frac{B}{0.04^2} - A$, $40 = \frac{B}{0.06^2} - A$	
	$A = 24$ $B = 0.2304$	04
	$\sigma_x = \frac{0.2304}{r^2} + 24$ $P_x = \frac{0.2304}{r^2} - 24$	02
		04
	Module 3	
Q5		Reactions — 02 SF at Salient points — 05 SF at $x = 2.417$ m — 01 SFD — 02 BM at Salient Points — 06 BMD — 02 Contraflexure pt — 02
	Point of contraflexure $x = 1.526$ m	

Q. No	Solution	Marks

Q6(a)



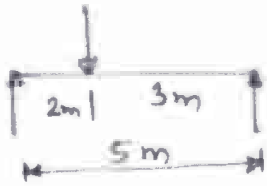
$I = \frac{bd^3}{12}$ $y_{max} = \frac{d}{2}$.

$Z = \frac{bd^2}{6} = \frac{150 \times 250^2}{6} = 1562500\ mm^3$

$M = \sigma_{per} Z = 20 \times 1562500 = 31250000$ N-mm

(i) Max B Moment $= \frac{wl^2}{8} = 31250000 \Rightarrow w = 10000$ N/m $= 10$ kN/m — 05

(ii)



$\left(\frac{P \times 2 \times 3}{5}\right) \times 1000 = 31250000$ — 05

$P = 26.04$ kN

(b)

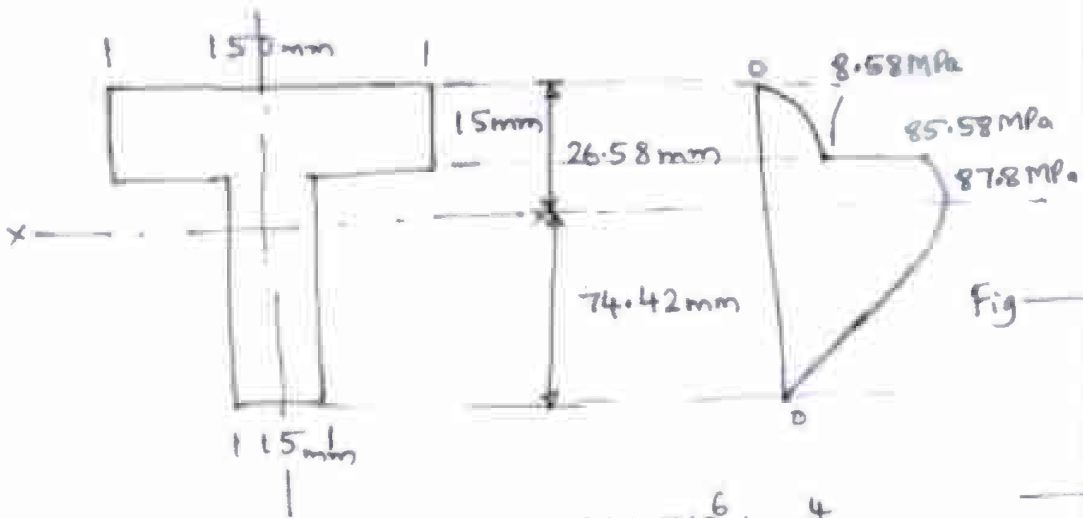


Fig — 02

— 03

$\bar{y} = 26.58$ mm $I_{xx} = 2.844 \times 10^6\ mm^4$ — 05

Shear stress at ~~each~~ salient points

Module 4

Q7 (a) Derivation — 08 Assumptions — 02

$\frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{L}$ Derivation — 08

Assumptions — 02

(b) $M = 10$ kN-m, $T = 15$ kN-m $\sigma_{yt} = 250$ N/mm², $E = 200$ GPa, FOS = 3

$\sigma_1 = \frac{32M}{\pi d^3} = \frac{32 \times 10 \times 10^6}{\pi d^3} = \frac{101.86 \times 10^6}{d^3}$ N/mm² — 02

$\tau = \frac{16T}{\pi d^3} = \frac{16 \times 15 \times 10^6}{\pi d^3} = \frac{76.39 \times 10^6}{d^3}$ N/mm² — 02

Max principal stress $\frac{1}{2}\left(\sigma_1 + \sqrt{\sigma_1^2 + 4\tau^2}\right) = \frac{\sigma_{yt}}{FOS} \Rightarrow d = 119.65$ mm — 03

Max shear stress $\sqrt{\sigma_1^2 + 4\tau^2} = \frac{\sigma_{yt}}{FOS} \Rightarrow d = 103.28$ mm — 03

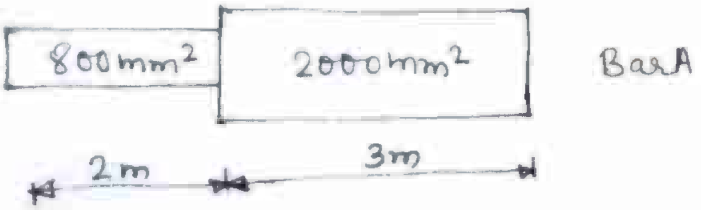
Q8 (a) Max principal stress theory — 04

Max shear stress theory — 04

Subject Title: Mechanics of Materials Subject Code: 18ME32

Q.No	Solution	Marks
8(b)	$P = 300\,kW = 300\times10^3\,W$, $N = 120\,rpm$, $\tau = 80\,N/mm^2$	
	$d_i = 0.6\,d_o$	
	$T = \dfrac{60\times(300\times10^3)}{2\pi(120)} = 23.87\times10^6\ N\,mm$	02
	Solid shaft	
	$\dfrac{T}{J} = \dfrac{\tau}{R} \Rightarrow \dfrac{23.87\times10^6}{(\frac{\pi}{32}d^4)} = \dfrac{80}{0.5d} \Rightarrow d = 115\,mm$	04
	Hollow shaft	
	$J = \dfrac{\pi}{32}(d_o^4 - 0.6\,d_o^4) = 0.0855\,d_o^4$	
	$\dfrac{23.87\times10^6}{0.0855\,d_o^4} = \dfrac{80}{0.5\,d_o} \Rightarrow d_o = 120.41\,mm$, $d_i = 72.25\,mm$	04
	% Saving in Wt $= \dfrac{W_S - W_H}{W_S}\times100 = 29.86\%$	02
	Module 5	
9(a)	Castigliano's theorem I with applications	05
	Castiglianos theorem II	03
(b)	$I = \dfrac{\pi\times200^4}{64} - \dfrac{\pi\times160^4}{64} = 46369908\ mm^4$	02
	$L_e = \dfrac{4.5}{2} = 2.25\,m = 2250\,mm$	01
	$P_E = \dfrac{\pi^2 EI}{L_e^2} = \dfrac{\pi^2\times1\times10^5\times46369908}{(2250)^2} = 9040052.3\,N$	03
	$A = \dfrac{\pi}{4}(200^2 - 160^2) = 11309.73\ mm^2$ $K = 64.031\,mm$	01
	$P_R = \dfrac{\sigma_c A}{1 + a(L_e/K)^2} = \dfrac{550\times11309.73}{1 + \frac{1}{1600}\times\left(\frac{2250}{64.031}\right)^2} = 3510907.3\,N$	03
	$P_E/P_R = \dfrac{9040052.3}{3510907.3} = 2.575$	01
	Safe load by Rankine's formula $= 1404.36\,kN$	01
	OR	
10(a)	 Derivation of $P_E = \dfrac{\pi^2 EI}{(2l)^2}$	10

Q.No	Solution	Marks allotted
Q10(b)		



$$U_A = \frac{100^2}{2(2\times10^5)}(800\times2000) + \frac{40^2}{2(2\times10^5)}(2000\times3000) = 64 \text{ N-m}$$ — (05)

$$U_B = \frac{52.63^2}{2(2\times10^5)}(1520\times5000) = 52.63 \text{ Nm}$$ — (04)

$$\frac{U_A}{U_B} = \frac{64}{52.63} = 1.216$$ — 01

—— o —— END ——

Approved by

Dr. M.S. Govinde Gowda
Chairman,
BOE, Mechanical Board, VTU.

" APPROVED "
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