CLASS TEST

S.No. : 01JP_ME_110522

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MECHANICAL ENGINEERING

Strength of Materials

Duration : 1:00 hr. **Maximum Marks : 50**

Read the following instructions carefully

1. This question paper contains **30** objective questions. **Q.1-10** carry one mark each and **Q.11-30** carry two marks each.
2. Answer all the questions.
3. Questions must be answered on Objective Response Sheet (**ORS**) by darkening the appropriate bubble (marked **A**, **B**, **C**, **D**) using HB pencil against the question number. Each question has only one correct answer. In case you wish to change an answer, erase the old answer completely using a good soft eraser.
4. There will be **NEGATIVE** marking. For each wrong answer **1/3rd** of the full marks of the question will be deducted. More than one answer marked against a question will be deemed as an incorrect response and will be negatively marked.
5. Write your name & Roll No. at the specified locations on the right half of the **ORS**.
6. No charts or tables will be provided in the examination hall.
7. Choose the **Closest** numerical answer among the choices given.
8. If a candidate gives more than one answer, it will be treated as a **wrong answer** even if one of the given answers happens to be correct and there will be same penalty as above to that questions.
9. If a question is left blank, i.e., no answer is given by the candidate, there will be **no penalty** for that question.

DO NOT OPEN THIS TEST BOOKLET UNTIL YOU ARE ASKED TO DO SO

Q.No. 1 to Q.No. 10 carry 1 mark each

Q.1 For a simply supported beam of length 'l' subjected to downward load of uniform intensity w, match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

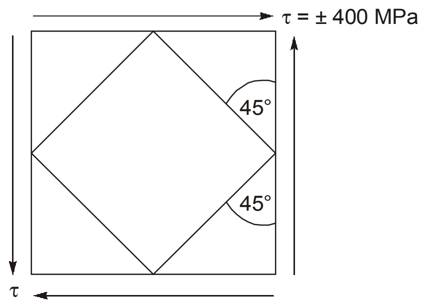
List-I
A. Slope of shear force diagram
B. Maximum shear force
C. Maximum deflection
D. Magnitude of maximum bending moment

List-II
1. $\dfrac{5wl^4}{384EI}$
2. w
3. $\dfrac{wl^2}{8}$
4. $\dfrac{wl}{2}$

Codes:

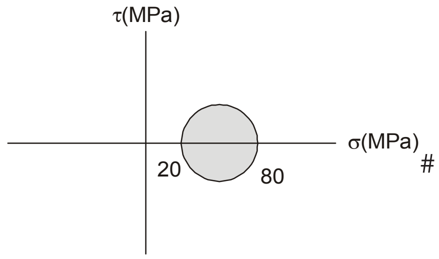
	A	B	C	D
(a)	1	2	3	4
(b)	3	1	2	4
(c)	2	3	1	4
(d)	2	4	1	3

Q.2 What are the normal and shear stresses on the 45° planes shown?



(a) $\sigma_1 = -\sigma_2 = 400$ MPa and $\tau = 0$
(b) $\sigma_1 = \sigma_2 = 400$ MPa and $\tau = 0$
(c) $\sigma_1 = \sigma_2 = -400$ MPa and $\tau = 0$
(d) $\sigma_1 = \sigma_2 = \tau = \pm 200$ MPa

Q.3 The Mohr's circle of plane stress for a point in a body is shown. The design is to be done on the basis of the maximum shear stress theory for yielding. Then, yielding will just begin if the designer chooses a ductile material whose yield strength is

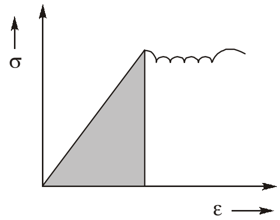


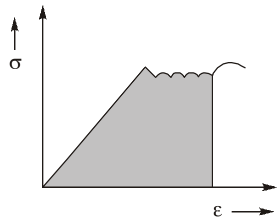
(a) 60 MPa (b) 40 MPa
(c) 80 MPa (d) 30 MPa

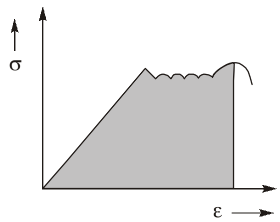
Q.4 If two shaft of the same length, one of which is hollow, transmit equal torque and have equal maximum stress, then they should have equal
(a) Polar moment of inertia
(b) Polar section modulus
(c) Angle of twist
(d) None of these

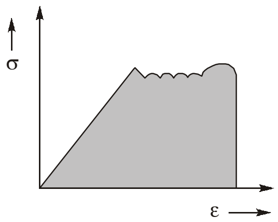
Q.5 A solid uniform metal bar of diameter D and length L is hanging vertically from its upper end. The elongation of the bar due to self weight is
(a) Proportional of L and inversely proportional to D^2
(b) Proportional to L^2 and inversely proportional to D^2
(c) Proportional to L but independent of D
(d) Proportional to L^2 but independent of D

Q.6 Toughness for mild steel under uniaxial tensile loading is given by the shaded portion of the stress strain diagram as shown in figure ?

(a)


(b)


(c)


(d) 

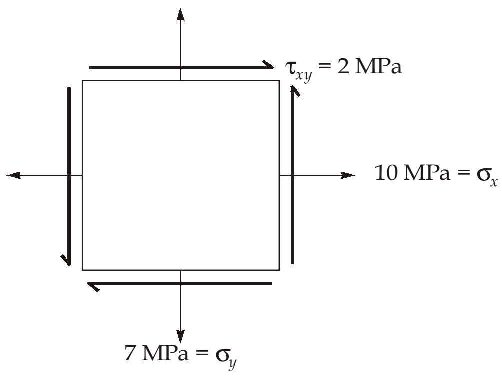
Q.7 A thin cylinder of inner radius 300 mm and thickness 10 mm subjected to an internal pressure of 6 MPa. The average circumferential stress in kPa is

(a) 18×10^4 (b) 9×10^4
(c) 45×10^3 (d) 18×10^3

Q.8 A shaft of diameter 8 cm is subjected to a bending moment of 3000 Nm and a twisting moment of 4000 Nm. The equivalent bending moment of shaft according to maximum principal stress theory is

(a) 8000 (b) 4000
(c) 2000 (d) 1000

Q.9 A structural member subjected to plane stress condition with stress shown below. Material yield strength is 18 MPa. What is the factor of safety for the design using Tresca's failure theory?



(a) 3.6 (b) 2.6
(c) 1.64 (d) 4.64

Q.10 A cylindrical vessel is made of steel with inside diameter 2 m. Thickness of wall is 40 mm and consider the pressure vessel as thin walled. The vessel is subjected to internal pressure of 3.5 kPa. Also an axial tensile load of 200 kN is applied on the vessel. What is the hoop strain at a point on the surface of cylindrical vessel?

E_{steel} = 200 GPa
G_{steel} = 80 GPa

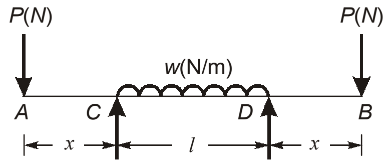
(a) 3.83×10^{-7} (b) 1.75×10^{-7}
(c) -6.12×10^{-7} (d) -3.83×10^{-7}

Q. No. 11 to Q. No. 30 carry 2 marks each

Q.11 U_1 and U_2 are the strain energies stored in a prismatic bar due to axial tensile forces P_1 and P_2, respectively. The strain energy U stored in the same bar due to combined action of P_1 and P_2 will be

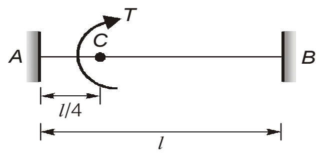
(a) $U = U_1 + U_2$ (b) $U = U_1 U_2$
(c) $U < U_1 + U_2$ (d) $U > U_1 + U_2$

Q.12 If the beam shown in the given figure is to have zero bending moment at its middle point, the overhang X should be:



(a) $\dfrac{wl^2}{4P}$ (b) $\dfrac{wl^2}{6P}$
(c) $\dfrac{wl^2}{8P}$ (d) $\dfrac{wl^2}{12P}$

Q.13 A round shaft of diameter 'd' and length 'l' fixed at both ends 'A' and 'B' is subjected to a twisting moment 'T' at 'C' at a distance of $l/4$ from 'A' (see figure). The torsional stresses in the parts AC and CB will be

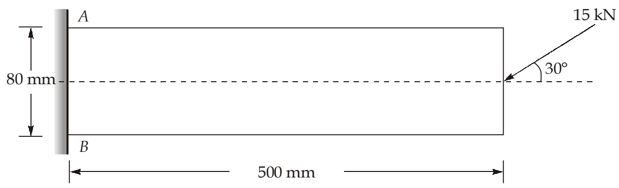


(a) equal (b) in the ratio 1 : 3
(c) in the ratio 3 : 1 (d) indeterminate

Q.14 A wooden tie is 50 mm wide, 110 mm deep and 1.5 meters long. It is subjected to an axial pull of 30 kN. The stretch of the member is found to be 0.625 mm. The Young's modulus for the tie material is

(a) 961.53 N/mm² (b) 13090.90 N/mm²
(c) 15000 N/mm² (d) 1800 N/mm²

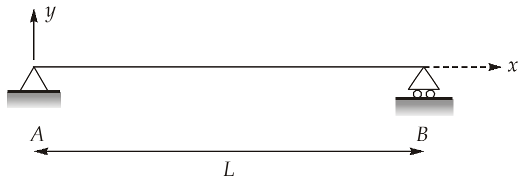
Q.15 A cantilever beam is loaded as shown in figure. What is the value of stress at point B? (E = 200 GPa) (Given beam is having circular cross-section)



(a) 74.6 MPa (comp.)
(b) 77.2 MPa (comp.)
(c) 72.0 MPa (tensile)
(d) 80.3 MPa (comp.)

Q.16 A beam is simply supported at its end A and B with roller support at 'B'. Deflection curve of the beam is $\Delta = \dfrac{-2W_0 L^4}{\pi^4 EI}\sin\left(\dfrac{\pi x}{L}\right)$.

What is the loading on the beam?



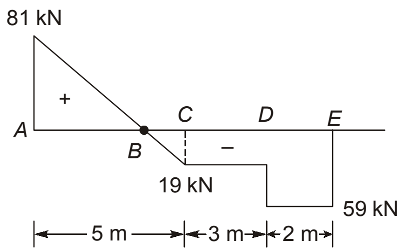
(a) $W_0 \cos\left(\dfrac{\pi x}{L}\right)$

(b) $2W_0 \cos\left(\dfrac{\pi x}{L}\right)$

(c) $W_0 \sin\left(\dfrac{\pi x}{L}\right)$

(d) $2W_0 \sin\left(\dfrac{\pi x}{L}\right)$

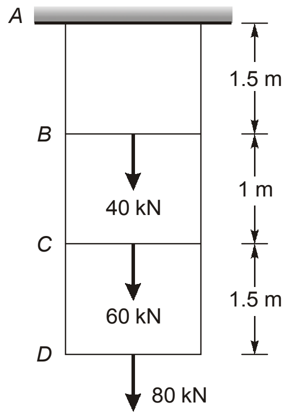
Q.17 The shear force diagram for a beam $ABCDE$, supported at A and one more points is shown in figure. The maximum bending moment is



(a) 164 kN-m (b) 185 kN-m
(c) 225 kN-m (d) 284 kN-m

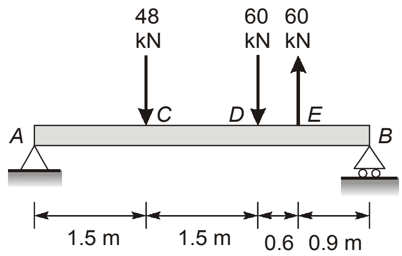
Q.18 A steel bar of 4 m length and uniform cross-sectional area of 1200 mm^2 is suspended vertically and loaded as shown in figure. The elongation of the bar will be

[Take, $E = 2.05 \times 10^5$ N/mm^2]



(a) 1.25 mm (b) 2.15 mm
(c) 3.15 mm (d) 4.25 mm

Q.19 Consider the following beam with loading as shown below

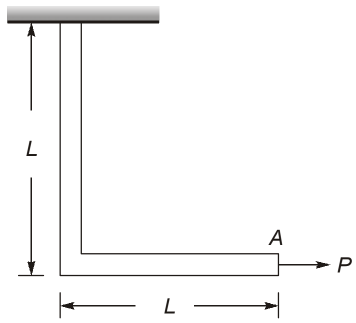


Maximum absolute value of shear force is
(a) 40 kN (b) 8 kN
(c) 68 kN (d) 28 kN

Q.20 A thin cast iron water main 10 m long, 0.5 m inside diameter and 25 mm wall thickness seems full of water and is simply supported at the ends. The maximum normal stress in the simply supported beam neglecting the weight of cast iron is
(a) 4.91 MPa (b) 6.91 MPa
(c) 7.91 MPa (d) 8.91 MPa

Q.21 A 200 × 100 × 50 mm steel block is subjected to a hydrostatic pressure of 15 MPa. The Young's modulus and Poisson's ratio of the material are 200 GPa and 0.3 respectively.
The change in the volume of the block in mm^3 is
(a) 85 (b) 90
(c) 100 (d) 100

Q.22 A frame is subjected to a load P as shown in the figure. The frame has a constant flexural rigidity EI. The effect of axial load is neglected. The vertical deflection at point A due to the applied load P is



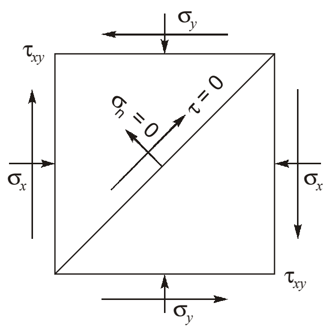
(a) $\dfrac{PL^3}{3EI}$ (b) $\dfrac{PL^3}{2EI}$

(c) $\dfrac{PL^3}{6EI}$ (d) $\dfrac{PL^3}{8EI}$

Q.23 A brass wire of diameter d = 1.6 mm and length 60 cm is tightly stretched between fixed points A and B at its ends so that it is under a tension of 150 N. If the temperature of the wire subsequently drops by 25°C, what is the maximum shear stress in the wire? The coefficient of thermal expansion for brass is $\alpha_b = 19 \times 10^{-6}/°C$ and modulus of elasticity (E_b) = 100 GPa.

(a) 61.05 MPa (b) 47.05 MPa
(c) 122.10 MPa (d) 74.60 MPa

Q.24 For the square element shown in figure, both the normal stress and the shear stress on the diagonal plane ab are zero. If $\sigma_x = \sigma_y = -35$ MPa. The major principal stress is



(a) 35 MPa (b) 70 MPa
(c) 100 MPa (d) 120 MPa

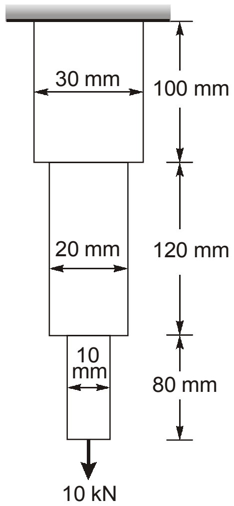
Q.25 A cantilever beam of 2 m length supports a triangularly distributed load over its entire length, the maximum of which is at the free end. The maximum shear force in the beam is 37.5 kN, what is the Bending moment at the fixed end?

(a) 50×10^6 N - mm
(b) 12.5×10^6 N - mm
(c) 100×10^6 N - mm
(d) 25×10^6 N - mm

Q.26 A solid steel shaft 50 mm in diameter is fixed rigidly and concentrically inside a bronze sleeve 75 mm external diameter. Modulus of rigidity of sleeve is 8×10^4 N/mm^2 and that of bronze is 4×10^4 N/mm^2. The angle of twist in a 1.50 metre length of the composite shaft under the action of a torque of 800 N-m is

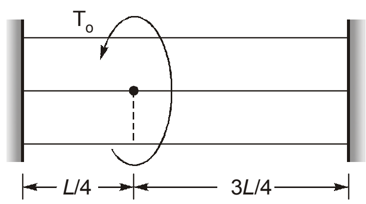
(a) 0.231° (b) 0.462°
(c) 0.572° (d) 0.672°

Q.27 What is the strain energy of the stepped bar as shown in the figure?
[Take E = 200 GPa]



(a) 0.38 N-m (b) 0.42 N-m
(c) 0.50 N-m (d) 0.56 N-m

Q.28 A solid shaft of diameter d and length L is fixed at both the ends. A torque, T_0 is applied at a distance, L/4 from the left end as shown in the figure given below.

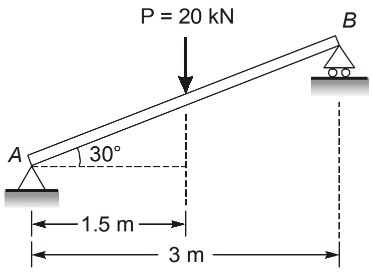


The difference of magnitude of maximum and minimum shear stress in the shaft is

(a) $\dfrac{16T_0}{\pi d^3}$ (b) $\dfrac{12T_0}{\pi d^3}$

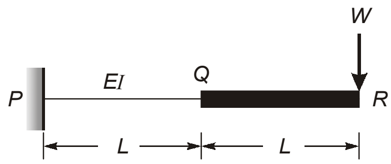
(c) $\dfrac{8T_0}{\pi d^3}$ (d) $\dfrac{4T_0}{\pi d^3}$

Q.29 An inclined beam shown in figure is loaded at the middle of its span by a force P = 25 kN. Section modulus and area of cross-section of the beam is 24×10^{-3} m^3 and 480 cm^2 respectively. What is the maximum compressive stress developed in the beam ?



(a) 0.21 MPa (b) 6.25 MPa
(c) 6.46 MPa (d) 10.83 MPa

Q.30 In the cantilever beam PQR shown in figure below, the segment PQ has flexural rigidity EI and the segment QR has infinite flexural rigidity



The deflection and slope of the beam at Q are respectively.

(a) $\dfrac{5WL^3}{6EI}$ and $\dfrac{3WL^2}{2EI}$

(b) $\dfrac{WL^3}{3EI}$ and $\dfrac{WL^2}{2EI}$

(c) $\dfrac{WL^3}{2EI}$ and $\dfrac{WL^2}{EI}$

(d) $\dfrac{WL^3}{3EI}$ and $\dfrac{3WL^2}{2EI}$

■■■■

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STRENGTH OF MATERIALS

MECHANICAL ENGINEERING

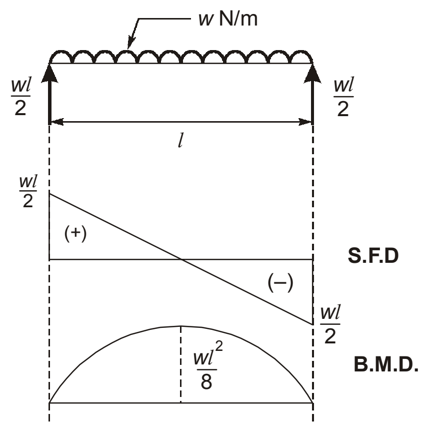
Date of Test : 11/05/2022

ANSWER KEY

1.	(d)	7.	(a)	13.	(c)	19.	(c)	25.	(a)
2.	(a)	8.	(b)	14.	(b)	20.	(a)	26.	(b)
3.	(c)	9.	(c)	15.	(b)	21.	(b)	27.	(a)
4.	(b)	10.	(c)	16.	(d)	22.	(b)	28.	(b)
5.	(d)	11.	(d)	17.	(a)	23.	(a)	29.	(c)
6.	(d)	12.	(c)	18.	(b)	24.	(b)	30.	(a)

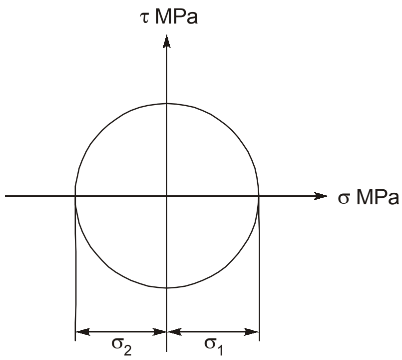
DETAILED EXPLANATIONS

1. (d)



2. (a)

It is a case of pure shear stress,



$$\sigma_1 = +400 \text{ MPa}$$
$$\sigma_2 = -400 \text{ MPa}$$
$$\tau = 0$$

3. (c)

As per maximum shear stress theory,

$$\text{Absolute } \tau_{max} = \text{Max of } \left[\frac{\sigma_1 - \sigma_2}{2}, \frac{\sigma_1}{2}, \frac{\sigma_2}{2}\right]$$
$$= \frac{\sigma_{yt}}{2} \left(\sigma_{yt} = \text{yield point stress}\right)$$
$$= \frac{80}{2} = \frac{\sigma_{yt}}{2}$$
$$\therefore \quad \sigma_{yt} = 80 \text{ MPa}$$

4. (b)

$\frac{T}{J} = \frac{\tau}{R}$, Here T and τ are same, so $\frac{J}{R}$ should be same i.e. polar section modulus will be same.

5. (d)

Elongation due to self weight $= \frac{\gamma L^2}{2E}$ γ-(specific weight).

6. (d)

Toughness is the ability of material to absorb the energy upto facture point i.e. toughness is the total area under stress-strain curve.

7. (a)

$$\text{Circumferential stress} = \frac{Pd_i}{2t}$$

$$P = 6 \text{ MPa}$$
$$d_i = 600 \text{ mm}$$
$$t = 10 \text{ mm}$$

$$\sigma_c = \frac{6 \times 600}{2 \times 10} = 180 \text{ MPa}$$
$$= 180 \times 1000 \text{ kPa}$$
$$= 18 \times 10^4 \text{ kPa}$$

8. (b)

$$M = 3000 \text{ Nm}$$
$$T = 4000 \text{ Nm}$$
$$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$
$$= \frac{1}{2}\left[3000 + \sqrt{(3000)^2 + (4000)^2}\right]$$
$$= 8000 \times \frac{1}{2} = 4000 \text{ Nm}$$

9. (c)

$$\sigma_x = 10 \text{ MPa}$$
$$\sigma_y = 7 \text{ MPa}$$
$$\tau_{xy} = 2 \text{ MPa}$$

$$\max\left(\frac{\sigma_1}{2}, \frac{\sigma_2}{2}, \frac{\sigma_1 - \sigma_2}{2}\right) = \frac{S_{yt}}{2N}$$

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \frac{17}{2} \pm \frac{\sqrt{3^2 + 4 \times 4}}{2} = \frac{17 \pm 5}{2}$$

$$\sigma_1 = 11 \text{ MPa} \qquad \sigma_2 = 6 \text{ MPa}$$

$$\Rightarrow \quad \frac{\sigma_1}{2} = \frac{S_{yt}}{2N}$$

$$\Rightarrow \quad \sigma_1 = \frac{S_{yt}}{N} = \frac{18}{N}$$

$$\Rightarrow \quad 11 = \frac{18}{N}$$

$$\Rightarrow \quad N = 1.636$$

10. (c)

Given data: d = 2 m , t = 40 mm, P = 3.5 kPa, F = 200 kN

$$E = 2G(1+\mu)$$

$$\frac{200}{2\times 80} = 1+\mu$$

$$\mu = 0.25$$

$$\sigma_h = \frac{Pd}{2t}$$

$$= \frac{3.5\times 2000}{2\times 40}\times 10^3 = 87.5 \text{ kPa}$$

$$\sigma_l' = \frac{Pd}{4t} = 0.04375 \text{ MPa} = 43.75 \text{ kPa}$$

$$\sigma_l'' = \frac{F}{\pi dt} = 795.77 \text{ KPa}$$

$$\Rightarrow \quad \varepsilon_h = \frac{1}{E}\left[\sigma_h - \mu(\sigma_l' + \sigma_l'')\right] = -6.12\times 10^{-7}$$

11. (d)

We know that strain energy,

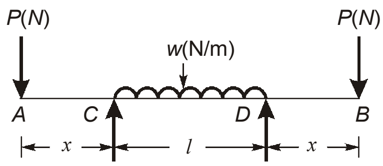
$$U = \frac{P^2L}{2AE}$$

It is obvious from the above equation that strain energy is proportional to the square of load applied. We know that sum of squares of two number is less than the square of their sum.

$[(P_1 + P_2)^2 > P_1^2 + P_2^2]$

Thus $\quad U > U_1 + U_2$

12. (c)



From the symmetry of the figure,

$$R_C = R_D = P + \frac{wl}{2}$$

Bending moment at mid point,

$$= -\frac{wl}{2}\times\frac{l}{4} + R_C\times\frac{l}{2} - P\left(x+\frac{l}{2}\right) = 0$$

gives $\quad x = \dfrac{wl^2}{8P}$

13. (c)

$$\frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{L} \text{ or } \tau = \frac{GR\theta}{L}$$

$$\tau \propto \frac{1}{L}$$

14. (b)

$$\text{Area} = 50 \times 110 = 5500 \text{ mm}^2$$
$$P = 30 \text{ kN} = 30 \times 10^3 \text{ N}$$
$$\text{Young's modulus} = \frac{\text{Longitudnal stress}}{\text{Longitudnal strain}}$$
$$\text{Stress} = \frac{F}{A} = \frac{30 \times 10^3}{5500} = 5.4545 \text{ N/mm}^2$$
$$\text{Strain} = \frac{\Delta L}{L} = \frac{0.625}{1500} = 4.16 \times 10^{-4}$$
$$E = \frac{5.4545}{4.16 \times 10^{-4}} = 13090.90 \text{ N/mm}^2$$

15. (b)

$$A = \frac{\pi}{4} \times 80^2 = 5026.55 \text{ mm}^2$$
$$I = \frac{\pi}{64} \times d^4 = \frac{\pi}{64} \times 80^4$$
$$I = 2010619.30 \text{ mm}^4$$

Direct compressive stress due to horizontal component,

$$\sigma_a = \frac{15 \cos 30° \times 10^3}{A} = \frac{15000 \times \cos 30°}{5026.55}$$
$$\sigma_a = 2.584 \text{ MPa (comp.)}$$

Bending stress at point B due to vertical component of loads,

$$\sigma_b = \frac{My}{I} \text{ (Comp. at point } B)$$
$$\sigma_b = \frac{(15 \times 10^3 \sin 30°) \times 0.5 \times 40 \times 10^{-3}}{2010619.30 \times 10^{-12}}$$

Bending stress at point B, $\sigma_b = 74.604$ MPa (Comp.)

Total stress at point B, $\sigma_{total} = \sigma_b + \sigma_a = 74.604 + 2.584$

$$\sigma_{\text{total}} = 77.188 \text{ MPa} \quad \text{(Comp.)}$$

16. (d)

$$M = EI \frac{d^2 y}{dx^2}$$
$$\Rightarrow \quad M = EI \frac{d^2}{dx^2}\left(\frac{-2W_0 L^4}{\pi^4 EI} \sin\left(\frac{\pi x}{L}\right)\right)$$
$$\Rightarrow \quad M = \frac{-2W_0 L^4}{\pi^4} \times \left[\frac{d^2}{dx^2}\left(\sin\left(\frac{\pi x}{L}\right)\right)\right]$$
$$\Rightarrow \quad M = \frac{2W_0 L^2}{\pi^2} \sin\left(\frac{\pi x}{L}\right)$$
$$\Rightarrow \quad \text{Shear force} = EI \frac{d^3 y}{dx^3} = \frac{2W_0 L}{\pi} \cos\left(\frac{\pi x}{L}\right)$$
$$\Rightarrow \quad \text{Load} = -EI \frac{d^4 x}{dx^4} = +2W_0 \sin\left(\frac{\pi x}{L}\right)$$

17. (a)

Shear force is varying linearly between *AC*, therefore, there is uniformly distributed load between *AC*.

$$R_A = 81 \text{ kN}$$

Uniformly distributed load between *A* and *C*

$$= \frac{81-(-19)}{5} = 20 \text{ kN/m}$$

$$\text{Vertical load at } D = 59 - 19 = 40 \text{ kN}$$

$$R_E = 59 \text{ kN}$$

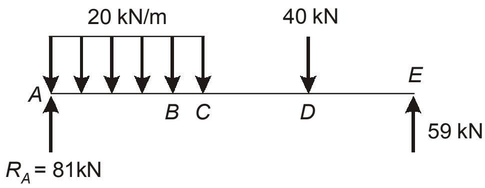
Now,
$$\frac{81}{a} = \frac{19}{5-a}$$

$$\Rightarrow \quad a = \frac{405}{100} = 4.05$$

Bending moment is maximum where shear force changes sign.

$$\text{Maximum Bending Moment} = \frac{1}{2} \times 81 \times 4.05 = 164.025 \text{ kN-m}$$

Alternate :



For maximum bending moment,

$$\text{S.F.} = 0$$

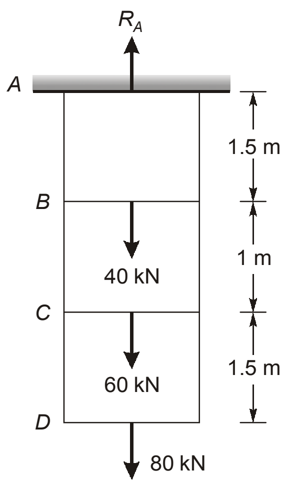
$$81 = 20x$$

$$x = 4.05$$

$$\text{Maximum Bending Moment} = 81 \times 4.05 - \frac{20 \times 4.05 \times 4.05}{2}$$

$$= 164.025 \text{ kN-m}$$

18. (b)



$$R_A = 40 + 60 + 80 = 180 \text{ kN}$$

Force P_1 on portion *AB* = 180 kN (tensile)

Force P_2 on portion *BC* = 180 – 40 = 140 kN (tensile)

Force P_3 on portion *CD* = 80 kN (tensile)

$$\Delta = \frac{1}{AE}(P_1L_1 + P_2L_2 + P_3L_3)$$

$$\Delta = \frac{1}{1200 \times 2.05 \times 10^5} \times [180 \times 1500 + 140 \times 1000 + 80 \times 1500] \times 10^3$$

$$= \frac{530000 \times 10^3}{1200 \times 2.05 \times 10^5} = 2.15\,\text{mm}$$

19. (c)

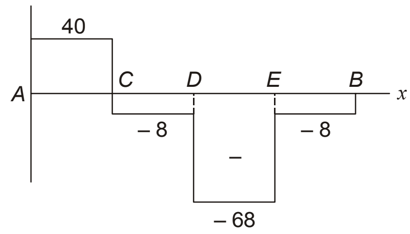
$$\Sigma M_B = 0$$

$$R_A \times 4.5 = 48 \times 3 + 60 \times 1.5 - 60 \times 0.9$$

$$R_A = 40\text{ kN (upward)}$$

$$R_B = 48 - 40 = 8\text{ kN (upward)}$$

Making shear force diagram



Shear force diagram

Maximum shear force = 68 kN

20. (a)

$$\text{Weight of water} = \rho V g = 1000 \times \frac{\pi}{4} \times d^2 \times l \times 9.81$$

$$= 1000 \times \frac{\pi}{4} \times (0.5)^2 \times 10 \times 9.81 = 19261.89\ N$$

And this is uniformly distributed,

$$\Rightarrow \quad M_{\text{maximum}} = \frac{wl^2}{8} = \frac{19261.89 \times 10 \times 1000}{8}\ \text{N-mm}$$

$$\sigma_{\text{maximum}} = \frac{M_{\max}}{Z} = \frac{19261.89 \times 10 \times 1000}{8 \times \pi \times d^2 \times t} \times 4$$

$$= \frac{19261.89 \times 10 \times 1000 \times 4}{8 \times \pi \times (500)^2 \times 25} = 4.91\text{ MPa}$$

21. (b)

We know that,

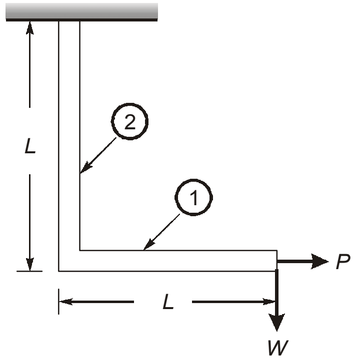
$$\frac{\Delta V}{V} = \frac{3\sigma}{E}[1 - 2\mu]$$

$$\therefore \quad \frac{\Delta V}{200 \times 100 \times 50} = \frac{3 \times 15}{200 \times 1000}[1 - (2 \times 0.3)]$$

$$\Delta V = 90\text{ mm}^3$$

22. (b)

For finding the vertical deflection assuming a dummy vertical load W.



$$(S.E)_1 = \int_0^L \frac{(Wx)^2 dx}{2EI} = \frac{W^2L^3}{6EI}$$

$$(S.E)_2 = \int_0^L \frac{(WL - Px)^2 dx}{2EI}$$

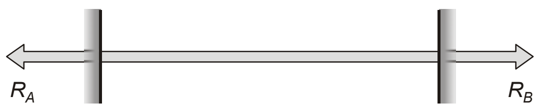
$$= \int_0^L \frac{(W^2L^2 + P^2x^2 - 2WLx)\,dx}{2EI} = \frac{W^2L^3}{2EI} + \frac{P^2L^3}{6EI} - \frac{2WPL^3}{4EI}$$

$$(S.E)_{\text{Total}} = \frac{W^2L^3}{6EI} + \frac{W^2L^3}{2EI} + \frac{P^2L^3}{6EI} - \frac{2WPL^3}{4EI}$$

$$\delta_A = \frac{(S.E)}{\partial W} = \frac{2WL^3}{6EI} + \frac{2WL^3}{2EI} + 0 - \frac{2PL^3}{4EI}$$

Putting $W = 0$, $$\delta_A = \left(\frac{PL^3}{2EI}\right) = \frac{PL^3}{2EI} \text{(downward)}$$

23. (a)



$R_A = R_B$ = Initial tension (P_1) + Tension produced due to thermal contraction (P_2)

$$\frac{P_2 l}{AE} = \alpha \Delta T l$$

$$\Rightarrow \quad P_2 = \alpha \Delta TAE$$

$$= 19 \times 10^{-6} \times 25 \times \frac{\pi}{4} \times (1.6)^2 \times 100 \times 10^3 = 95.504 \text{ N}$$

$$R_A = P_1 + P_2 = 245.504 \text{ N}$$

Normal stress $= \dfrac{R_A}{A} = \dfrac{245.504}{\frac{\pi}{4} \times (1.6)^2} = 122.104$ MPa

Maximum shear stress $= \dfrac{\sigma}{2} = 61.05$ MPa

24. (b)

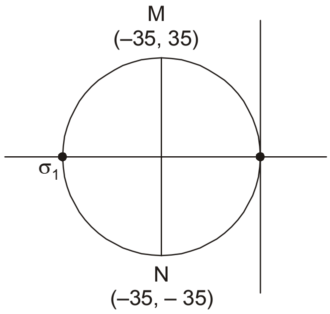
According to given conditions,

$$(\sigma_n)_{\text{at } \theta = 45°} = \frac{1}{2}(\sigma_x + \sigma_y) + \frac{1}{2}(\sigma_x - \sigma_y)\cos 2\theta + \tau_{xy} \sin 2\theta = 0$$

$$0 = -35 + \tau_{xy}$$

$$\Rightarrow \quad \tau_{xy} = 35 \text{ MPa}$$

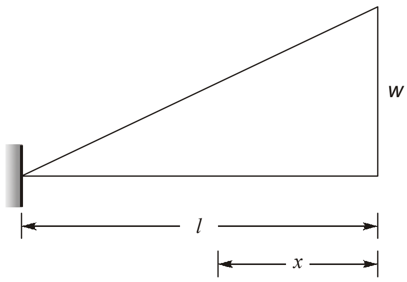
Using Mohr's circle,



Radious at Mohr's circle = 35 MPa

σ_1 = Major principal stress = $2R$ = 70 MPa (Compressive)

25. (a)



$$\text{Maximum shear force} = \frac{wl}{2} = 37.5 \text{ kN}$$

$$\Rightarrow \quad w = \frac{37.5 \times 2}{2} = 37.5 \text{kN/m}$$

$$\text{Bending moment at }, x = l$$

$$= \frac{wl}{2} \times \frac{2}{3} \times l = \frac{wl^2}{3}$$

$$= \frac{37.5 \times 10^3}{10^3} \times \frac{(2)^2 \times 10^6}{3} = 50 \times 10^6 \text{ N-mm}$$

26. (b)

$$J_s = \frac{\pi}{32} \times (50)^4 = 613592 \text{ mm}^4$$

$$J_b = \frac{\pi}{32} \times (75^4 - 50^4) = 2492719 \text{ mm}^4$$

$$T_s = \frac{G_s J_s \theta}{l} \quad \text{and} \quad T_b = \frac{G_b J_b \theta}{l}$$

$$\text{The total torque, } T = T_s + T_b = (G_s J_s + G_b J_b)\frac{\theta}{l}$$

$$\theta = \frac{Tl}{G_s J_s + G_b J_b} = \frac{(800 \times 10^3)(1.5 \times 10^3)}{(8 \times 10^4 \times 613592) + (4 \times 10^4 \times 2492719)}$$

$$= 0.008065 \text{ radian} = 0.462°$$

27. (a)

$$\text{Total strain energy} = \frac{1}{2}P_1\delta_1 + \frac{1}{2}P_2\delta_2 + \frac{1}{2}P_3\delta_3$$

$$= \frac{1}{2} \times P \times \frac{PL_1}{A_1 E} + \frac{1}{2}P \times \frac{PL_2}{A_2 E} + \frac{1}{2} \times P \times \frac{PL_3}{A_3 E}$$

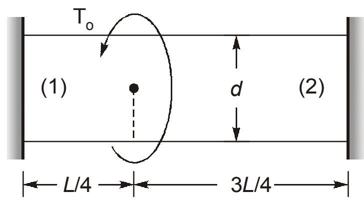
$$= \frac{P^2}{2E}\left[\frac{L_1}{A_1} + \frac{L_2}{A_2} + \frac{L_3}{A_3}\right]$$

$$= \frac{(10 \times 1000)^2}{2 \times 200 \times 10^9}\left[\frac{100 \times 4 \times 1000}{\pi \times (30)^2} + \frac{120 \times 4 \times 1000}{\pi \times (20)^2} + \frac{80 \times 4 \times 1000}{\pi \times (10)^2}\right]$$

$$= 0.3855 \text{ N-m}$$

28. (b)

$$T_1 = \frac{T_0 \times \frac{3L}{4}}{L} = \frac{3T_0}{4}$$



$$T_2 = \frac{T_0 \times \frac{L}{4}}{L} = \frac{T_0}{4}$$

$$\text{Maximum shear stress} = \frac{16 \times \frac{3T_0}{4}}{\pi d^3} = \frac{12T_0}{\pi d^3}$$

At, $r = 0$

Shear stress $= 0$

$$\text{Difference} = \frac{12T_0}{\pi d^3} - 0 = \frac{12T_0}{\pi d^3}$$

29. (c)

Force perpendicular to beam $= P\cos 30°$

Axial force in beam $= P\sin 30°$ (compressing)

$$\text{Direct stress, } \sigma_d = \frac{-P\sin 30°}{A} = \frac{20 \times 10^3 \times 0.5}{480 \times 10^{-4}} = 0.2083 \text{ MPa}$$

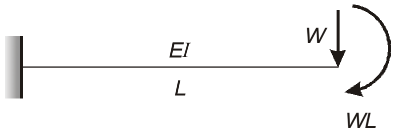
$$\text{Maximum bending stress} = \frac{WL}{4} / Z = \frac{\frac{P\cos 30°}{4} \times \frac{3}{\cos 30°}}{24 \times 10^{-4}} = 6.25 \text{ MPa}$$

Maximum compressive stress in the beam

$$= 0.2083 + 6.25 = 6.4583 \text{ MPa}$$

30. (a)

The given cantilever beam can be modified in to a beam as shown below



$$\text{Deflection at, } Q = \frac{WL^3}{3EI} + \frac{WL \times L^2}{2EI}$$

$$= \frac{2WL^3 + 3WL^3}{6EI} = \frac{5WL^3}{6EI}$$

$$\text{Slope at, } Q = \frac{WL^2}{2EI} + \frac{WL \times L}{EI}$$

$$= \frac{WL^2 + 2WL^2}{2EI} = \frac{3WL^2}{2EI}$$

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