CLASS TEST

Sl.: 02 SP_ME_D+E_220622 [G]

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STRENGTH OF MATERIALS

MECHANICAL ENGINEERING

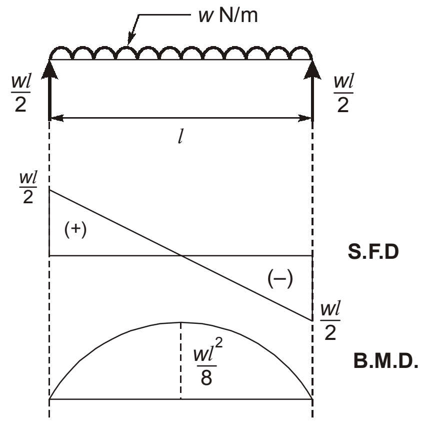
Date of Test : 22/06/2022

ANSWER KEY ➤ Strength of Materials

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

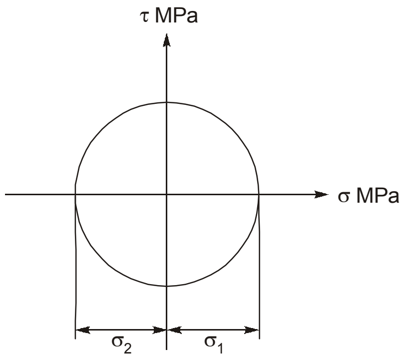
DETAILED EXPLANATIONS

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,

$$\text{Absolute } \tau_{max} = \text{Max of } \left[\frac{\sigma_1 - \sigma_2}{2}, \frac{\sigma_1}{2}, \frac{\sigma_2}{2}\right]$$

$$= \frac{\sigma_{yt}}{2}\left(\sigma_{yt} = \text{yield point stress}\right) = \frac{80}{2} = \frac{\sigma_{yt}}{2}$$

$\therefore$ $$\sigma_{yt} = 80 \text{ MPa}$$

4. (a)

$$\frac{T}{J} = \frac{G\theta}{L} \text{ or } \theta \propto \frac{1}{J} \text{ or } \theta \propto \frac{1}{d^4} \qquad \left(\because\ J = \frac{\pi d^4}{32}\right)$$

Here, $$\frac{\theta_{CB}}{\theta_{BA}} = \frac{\theta}{0.1} = \frac{d^4}{(d/2)^4}$$

$\Rightarrow$ $$\theta = 1.6 \text{ radian}$$

5. (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.

6. (a)

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

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

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

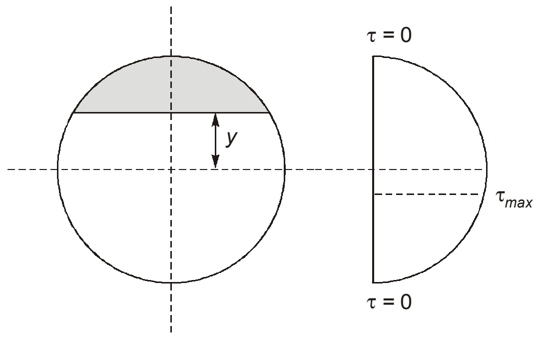
7. (c)

$$E = 1.25 \times 10^5 \text{ N/mm}^2$$
$$\mu = 0.25$$
$$E = 2G(1 + \mu)$$
$$1.25 \times 10^5 = 2G(1 + 0.25)$$
$$G = \frac{1.25 \times 10^5}{2 \times 1.25} = 0.5 \times 10^5 \text{ N/mm}^2$$

8. (d)
Since fluid element will be subjected to hydrostatic loading therefore Mohr's circle will reduce into a point on σ-axis.

$\therefore$ Radius of Mohr circle = 0 unit

9. (b)
Shear stress in circular cross-section



$$\tau = \frac{F}{3I}\left(r^2 - y^2\right)$$

We observe
1. Variation of τ versus y is a parabolic curve.
2. τ increases as y decreases.
3. $\tau = 0 \quad (y = r)$
4. at $y = 0$, τ is maximum

$$\tau = \frac{F}{3I}\left(r^2 - y^2\right)$$

$$\tau_{y=0} = \tau_{max} = \frac{F \times (d/2)^2}{3 \times \frac{\pi}{64} d^4} = \frac{F}{3\left(\frac{\pi}{16} d^2\right)}$$

$$\Rightarrow \quad \tau_{max} = \frac{4}{3}\frac{F}{A} = \frac{4}{3}\tau_{avg.}$$

$$\Rightarrow \quad \frac{\tau_{max}}{\tau_{avg}} = \frac{4}{3} = 1.33$$

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. (b)

$$\sigma_s A_s = \sigma_{cu} A_{cu}$$

$$\sigma_s \times \frac{\pi}{4}(50^2 - 44^2) = \sigma_{cu} \times \frac{\pi}{4}(35)^2$$

$$\Rightarrow \quad \sigma_s = 2.172\,\sigma_{cu}$$

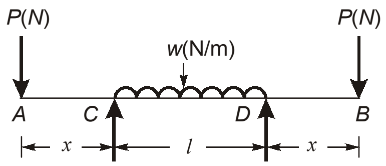
$$(l\alpha\Delta T)_s + \frac{\sigma_s \cdot l_s}{E_s} = (l\alpha\Delta T)_{cu} - \frac{\sigma_{cu} \cdot l_{cu}}{E_{cu}}$$

$$1.08 \times 10^{-5} \times 150 + \frac{\sigma_s}{2 \times 10^5} = 1.7 \times 10^{-5} \times 150 - \frac{\sigma_s}{2.172 \times 2 \times 10^5}$$

$$\Rightarrow \quad \frac{\sigma_s}{10^5}\left(\frac{2.172 + 1}{2 \times 2.172}\right) = 0.62 \times 10^{-5} \times 150$$

$$\Rightarrow \quad \sigma_s = 127.39 \text{ MPa}$$

13. (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 $\quad x = \dfrac{wl^2}{8P}$

14. (a)

$$\varepsilon_1 = 0.0013$$

$$\varepsilon_2 = -0.0013$$

$$E = 2 \times 10^5;\ \mu = 0.3$$

$$\sigma_1 = \frac{E}{(1 - \mu^2)}(\varepsilon_1 + \mu\varepsilon_2)$$

$$= \frac{2\times10^5}{1-0.09}[0.0013 - 0.3\times0.0013]$$

$$\sigma_1 = 200 \text{ MPa}$$

$$\sigma_2 = -200 \text{ MPa}$$

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = 200\text{MPa}$$

15. (d)

We know that deflection at *B* consists of deflection of wire *AB* due to self weight plus deflection due to weight of the wire *BC*.

We also know that deflection of wire at *B* due to self weight of wire *AB*.

$$\delta l_1 = \frac{(W/2)\times l/2}{2AE} = \frac{20\times(8\times10^3)}{2\times8\times(200\times10^3)} = 0.05\text{mm}$$

and deflection of the wire at *B* due to weight of the wire *BC*.

$$\delta l_2 = \frac{(W/2)\times l/2}{AE} = \frac{20\times(8\times10^3)}{8\times(200\times10^3)} = 0.1\text{ mm}$$

∴ Total deflection of wire at *B*.

$$\delta l_B = \delta l_1 + \delta l_2$$

$$= 0.05 + 0.1 = 0.15 \text{ mm}$$

16. (b)

We know that

$$\frac{G\theta}{L} = \frac{T}{J}$$

$$\therefore \quad \theta = \frac{TL}{GJ} = \frac{100\times5}{50000} = 0.01 \text{ rad}$$

Also, torsional strain energy = $\frac{1}{2}$

$$T\theta = \frac{1}{2} \times 100 \times 0.01$$

$$= 0.5 \text{ kN-m}$$

17. (a)

External diameter (D) = 38 mm;

Thickness = 2.5 mm

and length of column = 2.3 m = 2.3×10^3 mm

We know that area of the column section,

$$A = \frac{\pi}{4}[D^2 - d^2] = \frac{\pi}{4}\times[38^2 - 33^2]$$

$$= 278.8 \text{ mm}^2$$

and moment of inertia of column section,

$$I = \frac{\pi}{64}\left[D^4 - d^4\right] = \frac{\pi}{64}\left[38^4 - 33^4\right]$$

$$= 44.14 \times 10^3 \text{ mm}^4$$

$\therefore$ Least radius of gyration,

$$k = \sqrt{\frac{I}{A}} = \sqrt{\left(\frac{44.14 \times 10^3}{278.8}\right)} = 12.6 \text{ mm}$$

Since, the column is fixed at both ends, therefore effective length of column,

$$L_e = \frac{l}{2} = \frac{2.3 \times 10^3}{2} \text{mm}$$

$$\text{and slenderness ratio} = \frac{L_e}{k} = \frac{2.3 \times 10^3}{2 \times 12.6} = 91.26$$

18. (c)

$$\text{Shear stress } (\tau_{xy}) = \frac{2T}{\pi d^2 t} = \frac{2 \times 60000}{\pi \times (60)^2 \times 2}$$

$$= 5.305 \text{ N/mm}^2$$

$$\text{Hoop stress } (\sigma_y) = \frac{pd}{2t} = \frac{1.25 \times 60}{2 \times 2} = 18.75 \text{ N/mm}^2$$

$$\text{Longitudinal stress } (\sigma_x) = \frac{pd}{4t} = \frac{1.25 \times 60}{4 \times 2} = 9.375 \text{ N/mm}^2$$

$$\text{Principal stresses } (\sigma_1, \sigma_2) = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2}$$

$$= \frac{18.75 + 9.375}{2} \pm \sqrt{\left(\frac{9.375 - 18.75}{2}\right)^2 + (5.305)^2}$$

$$= 14.0625 \pm 7.07924$$

$$\text{Minor principal stress } (\sigma_2) = 6.98326 \text{ MPa.}$$

19. (a)

$$(\sigma_{max})_{per.} = 100 \text{ MPa} ; \quad b = \frac{d}{2}$$

$$(\sigma_b)_{max} = \frac{6M_{max}}{bd^2}$$

$$M_{max} = PL$$

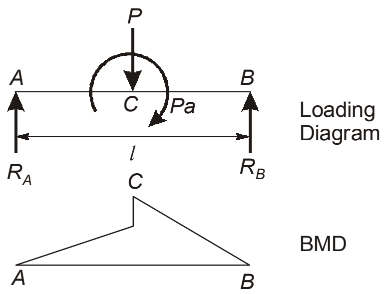
$$= 12 \times 10^3 \times 1.2 \times 10^3 \text{ N-mm}$$

$$100 = \frac{6 \times 12 \times 10^6 \times 1.2 \times 2}{d \times d^2}$$

$$d^3 = 12 \times 12 \times 12 \times 10^3$$

$$d = 120 \text{ mm}$$

20. (c)



Taking moment about R_a

$$-P \times \frac{l}{2} - Pa + R_b \times l = 0$$

$$R_b = \frac{P}{2} + \frac{Pa}{l} \text{ and } R_a = \frac{P}{2} - \frac{Pa}{l}$$

Maximum bending moment will be at centre 'c'

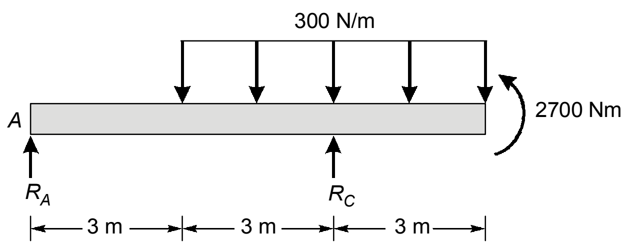
$$\therefore \quad M_c = R_a \times \frac{l}{2} + Pa$$

$$= \left(\frac{P}{2} - \frac{Pa}{l}\right) \times \frac{l}{2} + Pa$$

$$= \frac{Pl}{4} - \frac{Pa}{2} + Pa$$

$$\frac{Pl}{4} + \frac{Pa}{2} = \frac{10 \times 3}{4} + \frac{10 \times 0.4}{2} = 7.5 + 2 = 9.5 \text{ N-m}$$

21. (c)



$$\sum M_A = 0$$

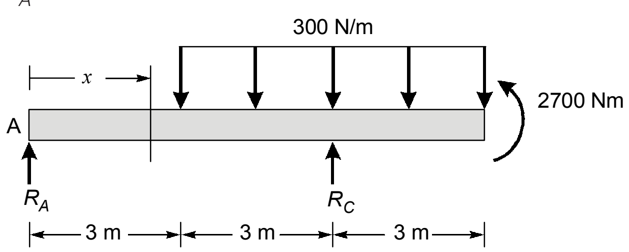
$$\Rightarrow \quad 300\,(6)\,(3 + 3) - R_C\,(6) - 2700 = 0$$

$$\Rightarrow \quad R_C = 1350 \text{ N}$$

$$\sum F_y = 0$$

$$\Rightarrow \quad R_A + R_C = 300\,(6)$$

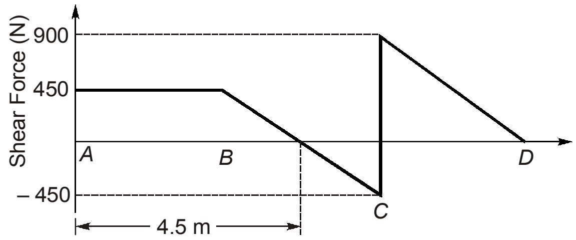
$$\Rightarrow \quad R_A = 450 \text{ N}$$



$V = 450$ N $\qquad 0 \le x < 3$m .....(iii)

$V = [450 - 300\,(x - 3)]$ N $\qquad 3 \text{ m} \le x < 6 \text{ m}$ .....(iv)

$$V = [450 - 300\,(x - 3) + 1350]\ \text{N} \qquad 6\ \text{m} \le x < 9\ \text{m} \qquad \text{.....(v)}$$



22. (c)

$$E = 3K\,(1 - 2\mu)$$

$$K = \frac{E}{3(1-2\mu)} = \frac{2.1\times10^5}{3\times(1-2\times0.25)} = 1.4\times10^5\ \text{N/mm}^2$$

$$\text{Pressure intensity} = Wh$$

$$= \frac{10008\times5000}{10^6}\text{N/mm}^2 = 50.04\ \text{N/mm}^2$$

$$k = \frac{\text{Volumetric stress}}{\text{Volumetric strain}}$$

$$\frac{\Delta V}{V} = e_V = \frac{50.04}{1.4\times10^5} = \frac{50.04}{1.4\times10^5}\times250^3$$

$$\Delta V = 5584.82\ \text{mm}^3$$

23. (c)

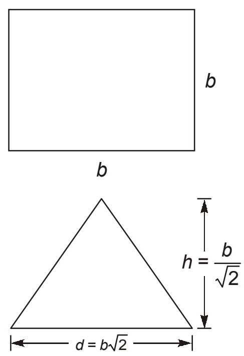
$$I_1 = \frac{bh^3}{12} = \frac{b^4}{12}$$

$$I_2 = 2^b\times\frac{dh^3}{12}$$

$$Z_1 = \frac{b^3}{6}$$

$$Z_2 = \frac{b^4}{12}\times\frac{2}{\sqrt{2}\,b} = \frac{b^3}{6\sqrt{2}}$$

$$\frac{Z_1}{Z_2} = \sqrt{2}$$

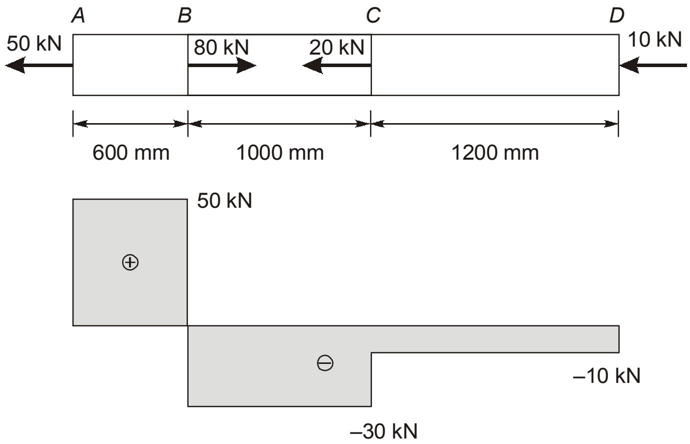


24. (b)

Deflection can be found by using super imposition method. Deflection due to point load (cantilever) $\delta_1 = \frac{Pl^3}{3EI}$ Deflection due to moment at end in cantilever $\delta_2 = \frac{Ml^2}{2EI}$. Summation of δ_1 and δ_2 will give the total deflection of the cantilever.

$$\therefore \qquad \delta_{\text{total}} = \left(\frac{PL^3}{3EI} + \frac{ML^2}{2EI}\right)$$

25. (a)



Axial loading diagram

Part AB: The section of the bar in this part is subjected to a tension of 50 kN.

$$\text{Extension of } AB = \frac{P_1 l_1}{AE} = \frac{50 \times 1000 \times 600}{1000 \times 1.05 \times 10^5} \text{mm}$$

$$= 0.2857 \text{ mm (extension)}$$

Part BC: The section of the bar in this part is subjected to a compression of 80 – 50 = 30 kN.

$$\text{Contraction of BC} = \frac{P_2 l_2}{AE} = \frac{30 \times 1000 \times 1000}{1000 \times 1.05 \times 10^5} \text{mm}$$

$$= 0.2857 \text{ mm (contraction)}$$

Part CD: The section of the bar in this part is subjected to a compression of 10 kN.

$$\text{Contraction of BC} = \frac{P_3 l_3}{AE} = \frac{10 \times 1000 \times 1200}{1000 \times 1.05 \times 10^5} \text{mm} = 0.1143 \text{ mm (contraction)}$$

∴ Change in length of the bar

$$= 0.2857 - 0.2857 - 0.1143 = -0.1143$$

i.e., decrease in length of the bar is 0.1143 mm.

26. (c)

Poisson's ratio is the ratio of lateral strain to longitudinal strain.

$$\mu = -\left(\frac{\text{lateral strain}}{\text{Longitudinal strain}}\right)$$

$$\varepsilon_v = \frac{1-2\mu}{E}(\sigma_x + \sigma_y + \sigma_z)$$

$$0 = \frac{1-2\mu}{E}(\sigma_x + \sigma_y + \sigma_z)$$

$$1 - 2\mu = 0$$

$$\mu = \frac{1}{2} = 0.5$$

27. (b)

$$D = 60\text{ mm}$$
$$P = 180\text{ kW}$$
$$f = 25\text{ Hertz}$$
$$\text{thickness (t)} = \frac{D-d}{2}$$
$$D \rightarrow \text{outer diameter}$$
$$d \rightarrow \text{Inner diameter}$$
$$P = \frac{2\pi NT}{60} \text{ or } \frac{2\pi fT}{1000}$$
$$T = \frac{180\times 1000}{2\times\pi\times 25}$$
$$T = 1145.92\text{ Nm}$$
$$\text{By torsional rigidity} = \frac{\tau}{R} = \frac{T}{J} = \frac{G\theta}{L}$$
$$\frac{J}{R} = \frac{T}{\tau}$$
$$\therefore \quad \frac{J}{R} = \text{Polar section modulus}$$
$$Z_P = \frac{1145.92\times 10^3}{60} = 19098.67\text{ mm}^3$$
$$Z_P = \frac{\pi}{16D}(D^4 - d^4)$$
$$d = 51.66\text{ mm}$$
$$\text{thickness} = \frac{D-d}{2} = \frac{60-51.66}{2} = 4.17\text{ mm}$$

28. (a)

Equivalent length,

$$L_e = 0.5\,L = 0.5\times 4 = 2\text{ m} = 2000\text{ mm}$$
$$I = Ak^2$$
$$\Rightarrow \quad \frac{b^4}{12} = b^2\times k^2$$
$$\Rightarrow \quad k^2 = \frac{b^2}{12}$$
$$\text{or,} \quad k = \frac{b}{\sqrt{12}} = \frac{40}{\sqrt{12}} = 11.547\text{ mm}$$
$$\text{Slenderness ratio} = \frac{L_e}{k} = \frac{2000}{11.547} = 173.2$$

Alternate:

For both ends fixed

$$L_e = \frac{L}{2}$$
$$K = \sqrt{\frac{I_{\min}}{A}} = \sqrt{\frac{b^4}{12\times b^2}} = \sqrt{\frac{b^2}{12}} = \frac{b}{\sqrt{12}}$$

Slenderness ratio

$$S = \frac{Le}{K} = \frac{L}{2K} = \frac{L\times\sqrt{12}}{2\times b} = \frac{4\times\sqrt{12}}{2\times 0.04} = 173.2$$

29. (d)

$$\text{Area of the bar} = A = \frac{\pi}{4}\times 15^2 = 176.7145 \text{ mm}^2$$

$$\text{Stress in the bar} = \sigma = \frac{10\times10^3}{176.7145} = 56.59 \text{ N/mm}^2$$

Strain energy stored per unit volume

$$= \frac{\sigma^2}{2E} = \frac{56.59^2}{2\times2\times10^5} = 8.006 \times 10^{-3} \text{ N/mm}^2$$

30. (d)

$$L = 1.25 \text{ m} = 1250 \text{ mm}$$

$$\varepsilon = 0.0015$$

$$y = 90 \text{ mm}$$

$$\frac{\sigma}{y} = \frac{E}{R} = \frac{M}{I}$$

$$R = \frac{Ey}{\sigma} = \frac{y}{(\sigma/E)} = \frac{y}{\varepsilon} = \frac{90}{0.0015} = 60000 \text{ mm} = 60 \text{ m}$$

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