CLASS TEST

Sl.: 03 SP_ME_FGHIS_220722

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STRENGTH OF MATERIALS

MECHANICAL ENGINEERING

Date of Test : 22/07/2022

ANSWER KEY ➤ Strength of Materials

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

DETAILED EXPLANATIONS

1. (c)

$$P_e = \frac{\pi^2 EI_{\min}}{l_e^2}$$

$$P_e \propto \frac{1}{l_e^2}$$

P_e = Buckling load

$I_{\min}$ = Moment of inertia about centroidal axis

l_e = Effective length (Least for fixed at both ends)

2. (b)

$$\text{Change in slope } (\Delta\theta) = \frac{\text{Area of bending moment diagram}}{EI}$$

$$\text{Change in deflection} (\Delta y) = \frac{\text{Moment of area of bending moment diagram}}{EI}$$

3. (a)

$$\text{Circumferential strain} = \frac{\delta d}{d} = \frac{Pd}{4tE}(2-\mu)$$

$$\because \quad \delta d = \frac{Pd^2}{4tE}(2-\mu)$$

4. (b)

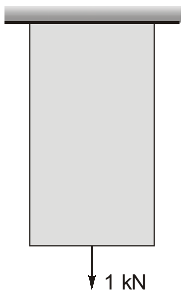
Due to tensile stress, longitudinal strain will be tensile but the lateral strain will be compressive

5. (b)

6. (a)

For the uniaxial tensile loading, minor principal stress will be zero.

7. (b)



Given:

$$A = 100 \text{ mm}^2$$

$$P = 1 \text{ kN}$$

$$L = 100 \text{ mm}$$

$$E = 1 \times 10^5 \text{ N/mm}^2$$

$$\because \quad \text{Strain energy, S.E.} = \frac{1}{2}\times\frac{P^2L}{AE} = \frac{1}{2}\times\frac{1\times10^3\times10^3\times100}{100\times10^5}$$

$$= 5 \text{ Nmm}$$

8. (c)

Deflection of a simply supported beam is proportional to,

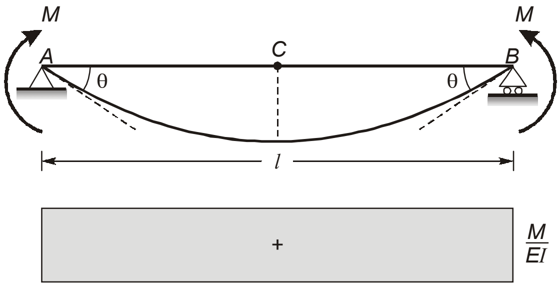
$$\delta \propto \frac{PL^3}{EI}$$

$\therefore$ Increasing I, decreasing L or P will reduce deflection.

9. **(c)**

A ductile material fails through a cup and cone type of failure.

10. **(a)**



$$\theta_C - \theta_A = \text{Area of } \frac{M}{EI} \text{ diagram}$$

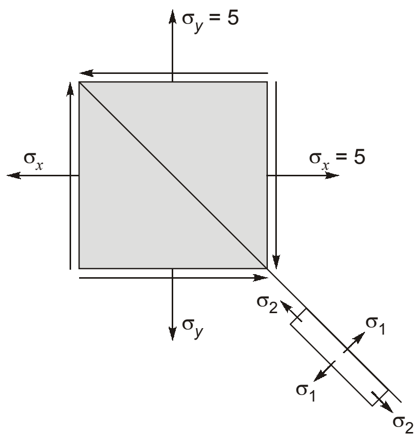
$$0 - \theta_A = +\frac{M}{EI}\times\frac{l}{2} = \frac{Ml}{2EI}$$

$$\theta_A = -\frac{Ml}{2EI}$$

$$\theta_A = \frac{Ml}{2EI} \text{ (Anticlockwise)}$$

$\because$ $$\frac{Ml}{EI} = 2\theta_A = 2\theta$$

11. **(b)**



$$\sigma_x + \sigma_y = \sigma_1 + \sigma_2$$

$$5 + 5 = 10 + \sigma_2$$

$$\sigma_2 = 0$$

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

$$\sigma_1 = \frac{5+5}{2} + \sqrt{\left(\frac{5-5}{2}\right)^2 + \tau_{xy}^2}$$

$$10 = 5 + \tau_{xy}$$

$$\tau_{xy} = \tau = 5.0 \text{ MPa}$$

12. (c)

Smallest normal stress:

$$\sigma_2 = \frac{E}{1-\mu^2}(\in_2 + \mu \in_1)$$

$$= \frac{3\times 10^5}{1-0.25^2}(-0.00014 + 0.25\times 0.0006)$$

$$= 3.2 \text{ MPa}$$

13. (a)

$$\frac{1}{2}\times P \times \delta l = 50 \qquad \in = \frac{\delta l}{l}$$

or $$\frac{1}{2} P \times \in \times l = 50$$

or $$\in l = \frac{100}{10} = 10 \text{ m}$$

14. (b)

$$M = 80 \cdot x - 64(x-1) \ \forall\ x \in (1, 4)$$

At centre $$x = 4 \text{ m}$$

$$M = (80 \times 4) - 64(3) = 128 \text{ kNm}$$

15. (a)

Given, $\sigma_1 = 100$ MPa, $\sigma_2 = 50$ MPa,
$\sigma_3 = 25$ MPa, $S_{yt} = 220$ MPa,

For maximum shear strain energy theory,

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \le 2\left(\frac{S_{yt}}{N}\right)^2$$ [Where, N = factor of safety]

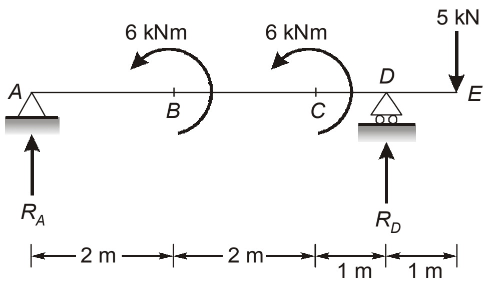
$$(100 - 50)^2 + (50 - 25)^2 + (25 - 100)^2 = 2\left(\frac{220}{N}\right)^2$$

After solving,

$\because$ Factor of safety, $N = 3.326 \sim$ **3.33**

16. (b)

Horizontal load at J produces a couple of 6 kNm (anticlockwise) and a thrust of 6 kN at A (→), load of 6 kN at H produces 6 kNm couple (anticlockwise) and a thrust of 6 kN at A (←). Therefore, net thrust at A becomes zero.



For support reactions, take moments about A,

$$\Sigma M_A = 0$$

$$\Rightarrow \quad 6 + 6 + 5R_D - 5 \times 6 = 0$$

$$\therefore \quad R_D = 3.6 \text{ kN}$$

$$\Rightarrow \quad R_A = 5 - 3.6 = 1.4 \text{ kN}$$

Bending moment diagram:

$$M_A = 0 \text{ kNm}$$

$$M_B = R_A \times 2 = 1.4 \times 2 = 2.8 \text{ kNm}$$

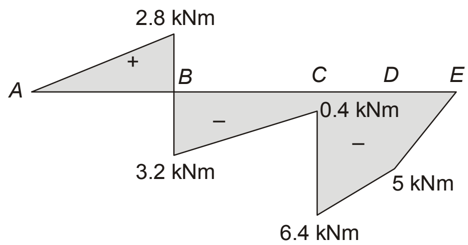
$$M'_B = 2.8 - 6 = -3.2 \text{ kNm}$$

$$M_C = 1.4 \times 4 - 6 = -0.4 \text{ kNm}$$

$$M'_C = -0.4 - 6 = -6.4 \text{ kNm}$$

$$M_D = 1.4 \times 5 - 6 - 6 = -5 \text{ kNm}$$

$$M_E = 0 \text{ kNm}$$



17. (c)

For avoiding tensile stress on the beam cross section.

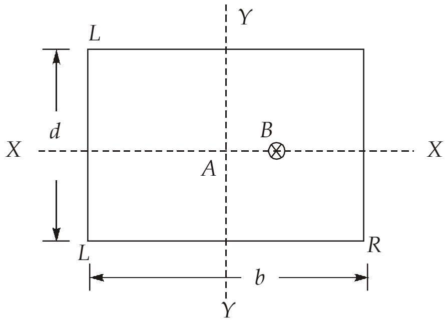
for taking section AB,

$$\sigma_{LS} \le 0$$

$$-\sigma_{axial} + [\sigma_{b,\,max}]_{y\text{-}y} \le 0$$

$$[(\sigma_b)_{max}]_{y\text{-}y} \le \sigma_a$$

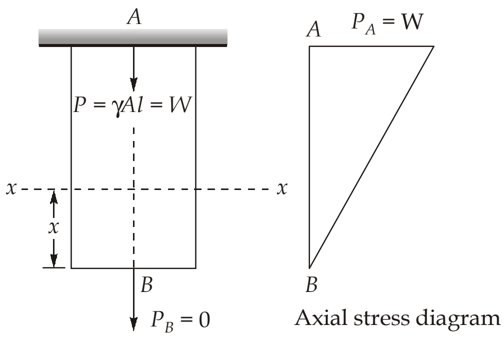
$$\frac{M_y}{Z_{y-y}} \le \frac{P}{A}$$



$$\frac{P\times e}{\frac{db^2}{6}} \le \frac{P}{bd}$$

$$e \le \frac{b}{6}$$

18. (c)



$$P_{x-x} = \gamma \times A \times x$$

where γ is load density

$$(\sigma_{\text{axial}})_{x-x} = \frac{P_{x-x}}{A_{x-x}}$$

$$(\sigma_{\text{axial}})_{x-x} = \gamma \times x$$

Axial stress diagram is triangle and independent of area.

19. (a)

$$K = \frac{E}{3(1-2\mu)} = \frac{100}{3(1-2\times 0.2)} = \frac{100}{3\times 0.6} = 55.555 \text{ GPa}$$

$$\sigma_x = \sigma_y = \sigma_z = \frac{P}{A} = \frac{250\times 10^3}{40\times 40\times 10^{-6}} = 156.25 \text{ MPa}$$

$$K = \frac{\sigma}{\in_v} = \frac{\sigma\times V}{(\Delta V)}$$

$$\Delta V = \frac{156.25\times (40)^3}{55.555\times 10^3} \text{ mm}^3$$

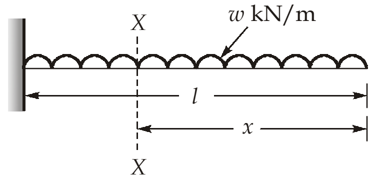
Change in volume, $\Delta V = 180 \text{ mm}^3$

20. **(b)**

Value of deflection is under uniformly distributed load for cantilever beam.

$$(\text{Bending moment})_{X\text{-}X'},\ M_b = -(w \times x)\left(\frac{x}{2}\right)$$

$$U = \int_0^L \frac{M^2 dx}{2EI} = \int_0^L \frac{w^2 x^4 dx}{8EI} = \frac{w^2}{8EI} \times \frac{L^5}{5} = \frac{W^2 L^3}{40EI}$$



21. **(a)**

$$\frac{\tau}{r} = \frac{G\theta}{l}$$

$$r = \frac{\tau \times l}{G\theta} = \frac{1200 \times 100}{10^6 \times \left(\frac{1.5\pi}{180}\right)}$$

$$r = \frac{1200 \times 100 \times 180}{10^6 \times 1.5\pi}$$

$$r = 4.5836 \text{ cm}$$

$$d = 9.1672 \text{ cm}$$

22. **(a)**

$$\sigma_h = \frac{pd}{2t \times \eta_{LJ}} = \frac{6 \times 150}{2 \times 12.5 \times 0.8} = 45 \text{ MPa}$$

$$\sigma_l = \frac{pd}{4t \times \eta_{CJ}} = \frac{6 \times 150}{4 \times 12.5 \times 0.9} = 20 \text{ MPa}$$

$$\frac{\delta d}{d} = \frac{1}{E}(\sigma_h - \mu\sigma_L) = \frac{1}{200 \times 10^3}(45 - 0.25 \times 20)$$

$$\frac{\delta d}{d} = 0.2 \times 10^{-3}$$

$$\delta d = 0.2 \times 150 \times 10^{-3} \text{ mm}$$

$$\delta d = 0.03 \text{ mm}$$

23. **(c)**

In case of composite bar,

$$(\delta_{th})_{Cu} - (\delta_{axial})_{Cu} = (\delta_{th})_{steel} + (\delta_{axial})_{steel}$$

$$(\delta_{axial})_{Cu} + (\delta_{axial})_{steel} = (\delta_{th})_{Cu} - (\delta_{th})_{steel}$$

$$\frac{\sigma_1 L}{E_1} + \frac{\sigma_2 L}{E_2} = \alpha_1 TL - \alpha_2 TL$$

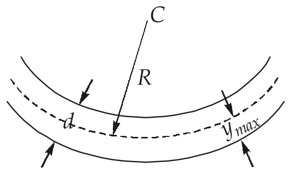
$$\left(\frac{\sigma_1}{E_1}+\frac{\sigma_2}{E_2}\right)L = (\alpha_1 - \alpha_2)TL$$

$$\frac{\sigma_1}{E_1}+\frac{\sigma_2}{E_2} = (\alpha_1 - \alpha_2)T$$

24. (c)

Diameter of wire, d = 20 mm

So, $$y_{\max} = \frac{d}{2}=\frac{20}{2} = 10 \text{ mm}$$



Radius of curvature, R = 10 m

Bending equation

$$\frac{\sigma_{\max}}{y_{\max}} = \frac{E}{R}$$

$$\Rightarrow \quad \frac{\sigma_{\max}}{10\times10^{-3}} = \frac{200\times10^{3}}{10}$$

$$\Rightarrow \quad \sigma_{\max} = 200 \text{ MPa}$$

25. (a)

$$\Delta L_s = \Delta L_A$$

$$\Rightarrow \quad \left(\frac{PL}{AE}\right)_S = \left(\frac{PL}{AE}\right)_A$$

$$\frac{P_s}{P_A} = \frac{A_S E_S/L_S}{A_A E_A/L_A}=\frac{0.5\times200/2}{2\times100/1}=0.25$$

26. (a)

Length of the rod, l = 6000 mm

Fall of temperature, T = 120 – 40 = 80°C

When the ends yield by 1.1 mm.

$$\text{Thermal strain} = \frac{\text{Contraction prevented}}{\text{Original length}} = \frac{\alpha Tl-\delta}{l} = \frac{12\times10^{-6}\times80\times6000-1.1}{6000}$$

$$= \frac{4.66}{6000} = 7.7667\times10^{-4}$$

Thermal stress = Thermal strain × Young's modulus

$$= \frac{4.66}{6000}\times210\times10^{3}\text{ N/mm}^2 = 163.1 \text{ N/mm}^2 = 163.1 \text{ MPa}$$

27. (b)

$\Sigma F_x = 0$,

$$\Rightarrow \quad H_A = P$$

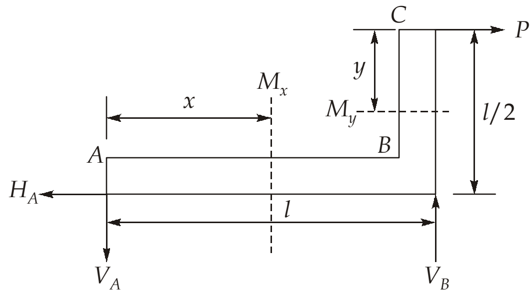
$\Sigma M_A = 0$

$$\Rightarrow \quad V_B \times l = P \times \frac{l}{2}$$

$$V_B = \frac{P}{2}$$

$\Sigma F_y = 0$

$$\Rightarrow \quad V_A = V_B = \frac{P}{2}$$



Strain energy stored by the bracket,

$$U = U_{AB} + U_{BC}$$

$$= \int_0^l \frac{M_x^2 dx}{2EI} + \int_0^{l/2} \frac{M_y^2 dy}{2EI} = \int_0^l \frac{\left(-\frac{Px}{2}\right)^2 dx}{2EI} + \int_0^{l/2} \frac{(Py)^2 dy}{2EI}$$

$$= \frac{P^2}{8EI}\left[\frac{x^3}{3}\right]_0^l + \frac{P^2}{2EI}\left[\frac{y^3}{3}\right]_0^{l/2}$$

$$= \frac{P^2}{8EI} \times \frac{l^3}{3} + \frac{P^2 (l/2)^3}{6EI} = \frac{P^2 l^3}{24EI} + \frac{P^2 l^3}{48EI}$$

$$U = \frac{P^2 l^3}{16EI}$$

Horizontal deflection at C,

$$\delta_C = \frac{\partial U}{\partial P} = \frac{\partial}{\partial P}\left(\frac{P^2 l^3}{16EI}\right)$$

$$\delta_C = \frac{2Pl^3}{16EI}$$

$$\delta_C = \frac{Pl^3}{8EI}$$

28. (a)

$$\frac{d^2 v}{dx^2} = \frac{M}{EI}$$

$$\frac{dM}{dx} = F$$

$$\frac{dF}{dx} = -q$$

From above three relations, we get

$$v'''' = -\frac{q(x)}{EI} \text{ or } \frac{d^4 v}{dx^2} = -\frac{q(x)}{EI}$$

29. (a)

Deflection of cantilever beam at free end.

1. Due to uniform loading, w

$$\Delta_1 = \frac{wL^4}{8EI}$$

2. Due to a point load, P

$$\Delta_2 = \frac{PL^3}{3EI}$$

Here P is the spring force (F_s)

Net deflection due to superposition, s is

$$s = \Delta_1 - \Delta_2$$

$$\frac{F_s}{k} = \frac{wL^4}{8EI} - \frac{F_s L^3}{3EI}$$

$$F_s = \frac{3kwL^4}{24EI + 8kL^3}$$

30. (d)

As given: $K = \frac{2}{3}E$

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

$\Rightarrow$ $E = 3 \times \frac{2}{3} E (1 - 2\mu)$

or $0.5 = 1 - 2\mu$

or $\mu = 0.25$

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