CLASS TEST

S.No. : 01IGCE-B+D-16082013

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STRENGTH OF MATERIALS

CIVIL ENGINEERING

Date of Test : 16/08/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (b)

	Material	**Modulus of elasticity (in GPa)**
1.	Steel	200 - 220
2.	Cast iron	100 - 160
3.	Brass	80 - 90
4.	Aluminum	60 - 80

2. (a)

Elongation due to self weight, $$\Delta = \frac{\gamma L^2}{2E}$$

$$= \frac{(89.2\times10^{-6})\times(15\times10^3)^2}{2\times(90\times10^3)} = 0.11 \text{ mm}$$

3. (c)

$$\text{Poisson's ratio, } \mu = \frac{3K-2G}{6K+2G}$$

$$= \frac{3\times6.93\times10^4 - 2\times2.65\times10^4}{6\times6.93\times10^4 + 2\times2.65\times10^4} = 0.33$$

4. (c)

$$\text{Strain energy, } U = \frac{1}{2}\times P\times\Delta$$

$$= \frac{1}{2}\times P\times\frac{PL^3}{48EI}$$

$$\therefore \quad U = \frac{P^2L^3}{96EI}$$

For $P = 1$; $U = \dfrac{L^3}{96EI}$

5. (b)

If a force acts on a body, then resistance to the deformation is known as stress.

6. (a)

The length of column is very large as compared to its cross-sectional dimensions.

7. (a)

Internal hinge in given beam becomes internal roller in conjugate beam.

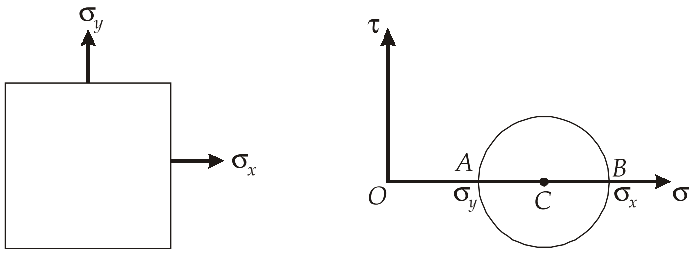
8. (a)

$$\text{Maximum shear stress,} \tau_{max} = \frac{16}{\pi D^3}\sqrt{M^2+T^2}$$

$$= \left[\frac{16}{\pi(100)^3}\sqrt{(8)^2+(6)^2}\right]\times10^6 = \frac{16}{\pi}\times\frac{10\times10^6}{10^6} = 50.93 \text{ MPa}$$

9. (a)

Assuming ($\sigma_x > \sigma_y$)



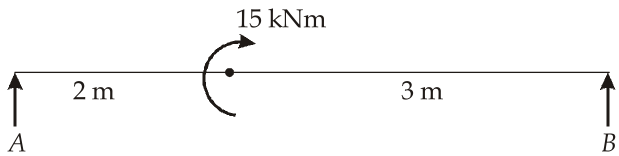
$$AB = \sigma_x - \sigma_y$$

$$AC = \frac{AB}{2} = \frac{\sigma_x - \sigma_y}{2}$$

$\therefore$ $$OC = OA + AC = \sigma_y + \frac{\sigma_x - \sigma_y}{2}$$

$$= \frac{\sigma_x + \sigma_y}{2}$$

10. (c)



$\Sigma F_y = 0$

$$R_A + R_B = 0$$

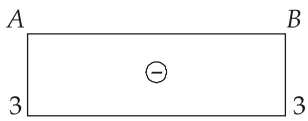
Also, $$\Sigma M_A = 0$$

$\Rightarrow$ $$R_B \times 5 = 15$$

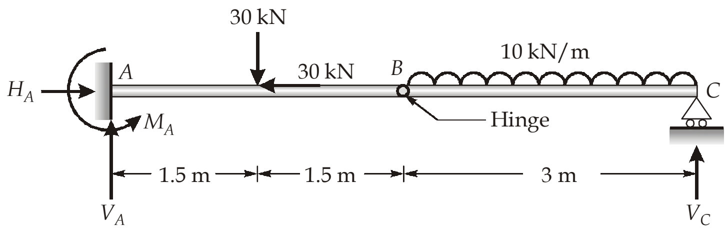
$\Rightarrow$ $$R_B = 3 \text{ kN}$$

So, $$R_A = -3 \text{ kN}$$

Now, the SFD for the beam will be as shown below:



11. (c)



$$V_A + V_C = 30 + 30 = 60 \text{ kN} \qquad (\Sigma F_y = 0) \qquad \text{...(i)}$$

$$H_A = 30 \text{ kN} \qquad (\Sigma F_x = 0) \qquad \text{...(ii)}$$

$$M_A + 30 \times 1.5 = 3V_A \qquad (\Sigma M_B = 0, \text{ Left} \rightarrow \text{Right}) \qquad ...(iii)$$

$$3V_C = 10 \times 3 \times 1.5 \qquad (\Sigma M_B = 0, \text{ Right} \rightarrow \text{Left}) \qquad ...(iv)$$

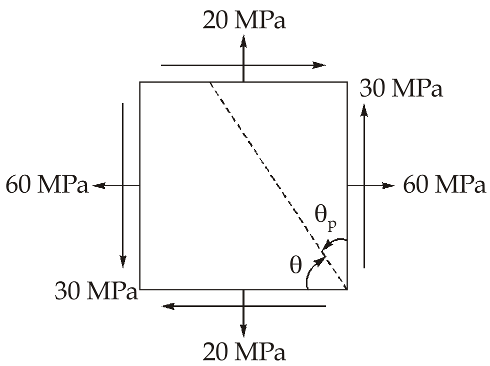
Solving equations (i), (ii), (iii) and (iv)

$$V_C = 15 \text{ kN}, V_A = 45 \text{ kN}, H_A = 30 \text{ kN}$$

$$\therefore \qquad \frac{\text{Reaction at A}}{\text{Reaction at C}} = \frac{\sqrt{45^2 + 30^2}}{15} = 3.6$$

12. (c)

Plane having zero shear stress is called principal planes.



$$\tan 2\theta_p = \frac{2\tau_{xy}}{\sigma_x - \sigma_y}$$

$$\tan 2\theta_p = \frac{2 \times 30}{60 - 20}$$

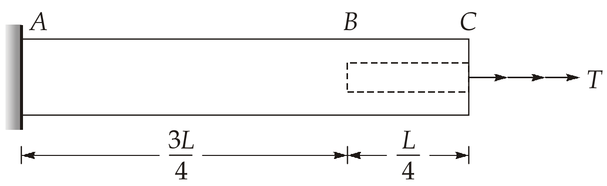
$$\tan 2\theta_p = 1.5$$

$$2\theta_p = \tan^{-1}(1.5)$$

$$\theta_p = 28.15°$$

Required angle from plane B, $\theta = 90° - 28.15° = 61.85°$ (Clockwise)

13. (a)



$$\theta_{AC} = \theta_{AB} + \theta_{BC}$$

$$\theta_C = \frac{T_{AB} \times L_{AB}}{GJ_{AB}} + \frac{T_{BC} \times L_{BC}}{GJ_{BC}} \quad (\because \theta_A = 0)$$

$$J_{BC} = \frac{\pi}{32}\left[D^4 - \left(\frac{D}{2}\right)^4\right]$$

$$J_{BC} = \frac{\pi}{32} D^4 \left[1 - \frac{1}{16}\right]$$

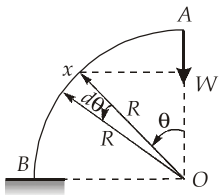
$$J_{BC} = \frac{15}{16} J_{AB} = \frac{15}{16} J$$

$$\therefore \qquad \theta_C = \frac{T \times \frac{3L}{4}}{GJ} + \frac{T \times \frac{L}{4}}{G \times \frac{15}{16} J}$$

$$= \frac{3}{4}\frac{TL}{GJ} + \frac{4}{15}\frac{TL}{GJ}$$

$$= \frac{45TL + 16TL}{60GJ} = \frac{61}{60}\frac{TL}{GJ}$$

14. (b)



$$U = \int \frac{M^2 ds}{2EI} = \int_0^{\pi/2} \frac{(WR \sin\theta)^2 (Rd\theta)}{2EI}$$

$$= \frac{W^2 R^3}{2EI} \int_0^{\frac{\pi}{2}} \sin^2 \theta d\theta = \frac{\pi}{8} \frac{W^2 R^3}{EI}$$

15. (a)

Given, M = 54.0 kNm and T_z = 72.0 kNm

Consider external and internal diameter as D and d (= 0.5 D) respectively,

Now, section modulus, $$Z = \frac{\pi D^3}{32}\left(1 - \frac{d^4}{D^4}\right) = \frac{\pi D^3}{32}\left(1 - \left(\frac{1}{2}\right)^4\right) = \frac{15\pi D^3}{512}$$

Polar section modulus,

$$Z_p = \frac{\pi D^3}{16}\left(1 - \frac{d^4}{D^4}\right) = \frac{15\pi D^3}{256}$$

Maximum shear stress is given by,

$$\tau_{max} = \frac{T}{Z_p} = \left(\frac{256}{15\pi D^3}\right) \times T_e$$

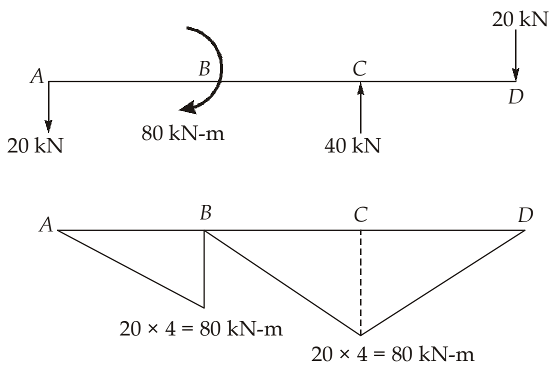
$$T_e = \sqrt{M^2 + T^2} = \sqrt{54^2 + 72^2} = 90 \text{ kNm}$$

Now, $$96 = \left(\frac{256}{15\pi D^3}\right)\times 90\times 10^6 \qquad (\because\ \tau_{permissible} = 96\text{ MPa})$$

$$D^3 = \frac{256}{15\pi}\times\frac{90\times 10^6}{96} = 5092958$$

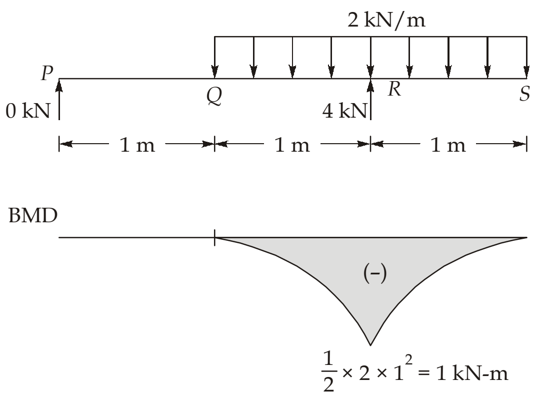
$$D = 172.05\text{ mm}$$

16. (d)

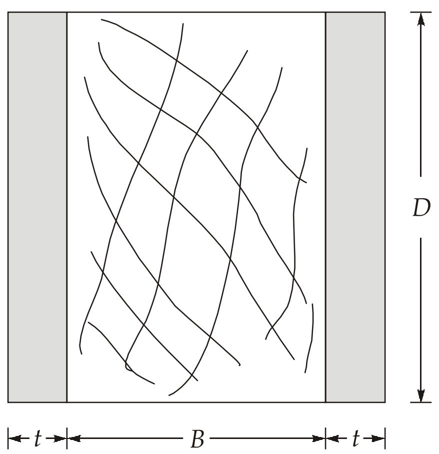


BMD

17. (b)



18. (b)

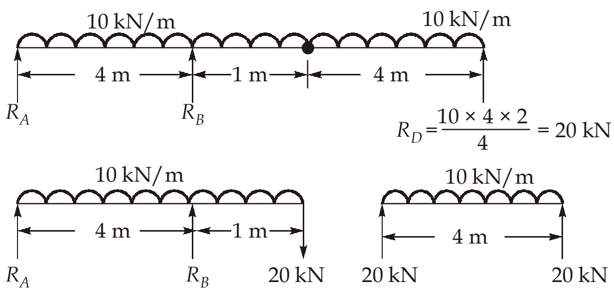


$$\text{MOR} = M_w + M_s$$

$$M = \sigma_w \times \frac{BD^2}{6} + m\sigma_w \times \frac{2tD^2}{6} \quad \left(\because \frac{\sigma_s}{\sigma_w} = \frac{E_s}{E_w} = m\right)$$

$$M = \frac{\sigma D^2}{6}[B + 2mt]$$

19. (c)



Now, $\quad M_B = -20 \times 1 - 10 \times \frac{1^2}{2} = -25\ \text{kN-m}$

$= 25$ kN-m (Hogging)

20. (a)

Principal strains, $\quad \varepsilon_{1/2} = \frac{\varepsilon_x + \varepsilon_y}{2} \pm \sqrt{\left(\frac{\varepsilon_x - \varepsilon_y}{2}\right)^2 + \left(\frac{\phi_{xy}}{2}\right)^2}$

$$= \left[\frac{800 + 200}{2} \pm \sqrt{\left(\frac{800 - 200}{2}\right)^2 + \left(\frac{-600}{2}\right)^2}\right] \times 10^{-6}$$

$\varepsilon_1 = 924.264 \times 10^{-6}$

$\varepsilon_2 = 75.74 \times 10^{-6}$

Thus major principal stress is,

$$\sigma_1 = \frac{E}{1 - \mu^2}(\varepsilon_1 + \mu\varepsilon_2) = \frac{200 \times 10^3}{1 - 0.3^2}(924.264 + 0.3 \times 75.74) \times 10^{-6}$$

$= 208.13$ MPa

21. (c)

Deflection at B due to load $= \frac{wl^4}{8EI} = \frac{10 \times (3000)^4}{8 \times 5 \times 10^{11}} = 202.5$ mm

Since gap is 3 mm.

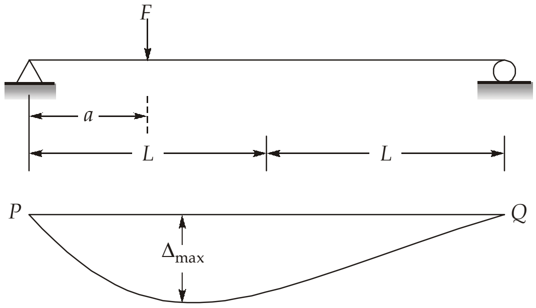
$\therefore \quad 202.5 - 3 = \frac{Rl^3}{3EI}$

$\Rightarrow \quad \frac{(202.5 - 3) \times 3 \times 5 \times 10^{11}}{(3000)^3} = R$

$\Rightarrow \quad R = 11.083 \times 10^3$ N $\simeq 11.08$ kN

22. (c)

The tentative deflection for the loading is shown.



So, option (c) is possible.

23. (d)

In pure bending case,

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

So, $$R = \frac{EI}{M}$$

When same M is applied,

$$\frac{R_1}{R_2} = \frac{(EI)_1}{(EI)_2}$$

$\Rightarrow$ $$\frac{2}{R_2} = \frac{70 \times \frac{\pi}{4} \times 2.5^4}{120 \times \frac{\pi}{4} \times 2^4}$$

$\Rightarrow$ $$R_2 = 1.404 \text{ m}$$

24. (b)

When both ends are clamped, $$(l_{\text{eff}})_1 = \frac{l}{2}$$

When one end is free, $$(l_{\text{eff}})_2 = 2l$$

Buckling load, $$P_{cr} = \frac{\pi^2 EI}{l_{eff}^2}$$

So, $$(P_{cr})_1 = \frac{4\pi^2 EI}{l^2}$$

Similarly, $$(P_{cr})_2 = \frac{\pi^2 EI}{4l^2}$$

So, $$\% \text{ change} = \frac{\frac{4\pi^2 EI}{l^2} - \frac{\pi^2 EI}{4l^2}}{\frac{4\pi^2 EI}{l^2}} \times 100 = \frac{4-(1/4)}{4} \times 100$$

$$= \left(1 - \frac{1}{16}\right) \times 100 = 93.75\%$$

25. (a)

We know that for a circular section,

Maximum shear stress, $\tau_{max} = \frac{4}{3}\tau_{av}$

where, $\tau_{av} = \frac{V}{A} = \frac{6675}{\frac{\pi}{4}\times 50^2} = 3.4\text{ N/mm}^2$

So, $\tau_{max} = \frac{4}{3}\times 3.4 = 4.53\text{ N/mm}^2$

26. (a)

As it is given that, $\varepsilon = \frac{\sigma}{E} = \frac{y}{R} = 3.0\times 10^{-5}$

So, $\frac{1}{R} = \frac{3.0\times 10^{-5}}{30}\text{ mm}^{-1} = 10^{-6}\text{ mm}^{-1}$

Also, in pure bending, $\frac{\sigma}{y} = \frac{M}{I} = \frac{E}{R} = \text{constant}$

For σ_{max}, y_{max} has to be used

So, $\sigma_{max} = \frac{E}{R}y_{max} = \frac{200\times 10^3}{R}\times y_{max}$

$\Rightarrow$ $\sigma_{max} = 200 \times 10^3 \times 10^{-6} \times 50\text{ MPa}$

$\Rightarrow$ $\sigma_{max} = 10\text{ MPa}$

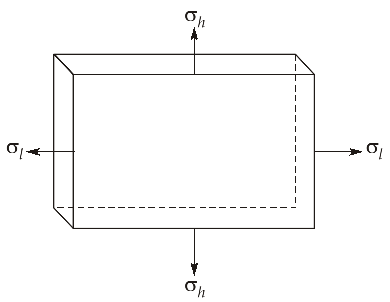
27. (c)

For a closed cylinder (thin), the two stress components induced due to internal pressure are,

$\sigma_h = \frac{pd}{2t}$ (Hoop stress)

$\sigma_l = \frac{pd}{4t}$ (Longitudinal stress)

If we neglect the pressure in radial direction, this becomes a plane stress condition.



For this condition, $\tau_{max} = \max.\left\{\frac{\sigma_h}{2}, \frac{\sigma_l}{2}, \frac{\sigma_h - \sigma_l}{2}\right\} = \frac{pd}{4t}$

For safety, $\tau_{max} \le \frac{(f_y/2)}{\text{FOS}}$

$\Rightarrow \quad \frac{p \times 2 \times 100}{4 \times 5} = \frac{100/2}{2}$

$\Rightarrow \quad p = 2.5 \text{ MPa}$

28. (c)

At y-y, slope of BMD is +ve and constant and hence shear force is +ve and constant

$$SF_{yy} = \frac{400 - 200}{4} = 50 \text{ kN}$$

29. (d)

$$\text{Rankine's crippling load} = \frac{\sigma_{cs} A}{1 + \alpha\left(\frac{l_e}{k}\right)^2}$$

As both ends are hinged

So $\quad l_e = l = 2.3 \text{ m}$

$$\therefore \quad P_R = \frac{335 \times 88.75\pi}{1 + \frac{1}{7500}\left[\frac{2.3 \times 10^3}{12.6}\right]^2}$$

$$= 17161.04 \text{ N} = 17.16 \text{ kN}$$

30. (a)

$$\sigma_{P_1/P_2} = \frac{P_1 + P_2}{2} \pm \frac{1}{2}\sqrt{(P_1 - P_2)^2 + (2q)^2}$$

Given $\sigma_{P2} = 0$

$\Rightarrow \quad (P_1 + P_2)^2 = (P_1 - P_2)^2 + 4q^2$

$\Rightarrow \quad 2P_1P_2 = 4q^2 - 2P_1P_2$

$\Rightarrow \quad P_1P_2 = q^2$

$\Rightarrow \quad q = \sqrt{P_1P_2}$

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