CLASS TEST

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STRUCTURAL ANALYSIS

CIVIL ENGINEERING

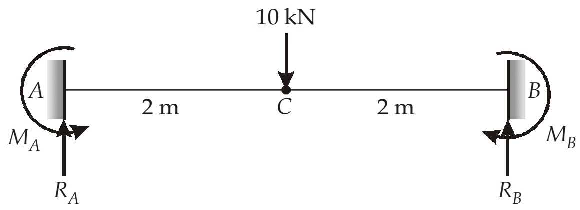
Date of Test : 22/07/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (b)



$$M_A = M_B = M \text{ (say)} \qquad [\because \text{ Due to symmetry}]$$

Taking moment about C (from left)

$$R_A \times 2 - M = 0$$

$\Rightarrow$ $$M = 2R_A$$

Also; $$R_A = R_B = 5 \text{ kN} \qquad \text{(due to symmetry)}$$

$$M = 2 \times 5 = 10 \text{ kNm}$$

2. (c)

Taking moments about crown i.e. C (from left),

$$H_A \times 2R = V_A \times 2R$$

$\Rightarrow$ $$H_A = V_A$$

Similarly, for BC, $$H_B = V_B$$

Now, as $$H_A = H_B \text{ and thus,}$$

$\therefore$ $$V_A = V_B = \frac{W}{2}$$

3. (a)

Let the force in each wire be S.

$\therefore$ $$(2 \sin 45°) \times S = P$$

$$S = \frac{P}{\sqrt{2}}$$

So strain energy stared in wire AO

$$= \left(\frac{P}{\sqrt{2}}\right)^2 \times \frac{l}{2AE} = \frac{P^2 l}{4AE} = \frac{P^2 l}{kAE} \qquad \therefore k = 4$$

4. (c)

5. (c)

If concentrated load 'W' acts at any point which makes angle α with the horizontal on a semi-circular two hinged arch, the horizontal thrust is given by,

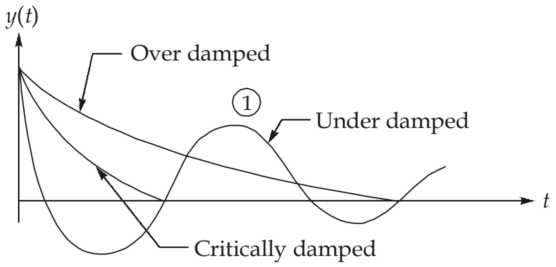
$$H = \frac{W}{\pi}\sin^2\alpha$$

$$= \frac{10}{\pi} \times \sin^2 60 = \frac{7.5}{\pi} \text{ kN}$$

6. (c)

Horizontal force remains constant while tension along length changes.

7. (b)



8. (c)

9. (a)

Using Maxwell-Betti's theorem,

$$300 \times \Delta_A = 100 \times \Delta_B + 200 \times \Delta_C$$

$$\Delta_A = \frac{100 \times 10}{300} + \frac{200 \times 15}{300} = \frac{10}{3} + 10 = \frac{40}{3} \text{ mm}$$

10. (b)

Internal static indeterminacy = 0

External static indeterminacy = 9 – 3 = 6

$$\therefore \quad D_s = D_{se} + D_{si} = 6 + 0 = 6$$

11. (d)

$$\text{Each vertical reaction} = V = \frac{wl}{2}$$

$$\text{Horizontal reaction} = H = \frac{wl^2}{8h}$$

$$T_{max} = \sqrt{V^2 + H^2} = \sqrt{\left(\frac{wl}{2}\right)^2 + \left(\frac{wl^2}{8h}\right)^2}$$

$$\simeq \frac{wl^2}{8h}\left[1 + \frac{1}{2} \times \frac{16h^2}{l^2}\right] \qquad (\because l \gg h)$$

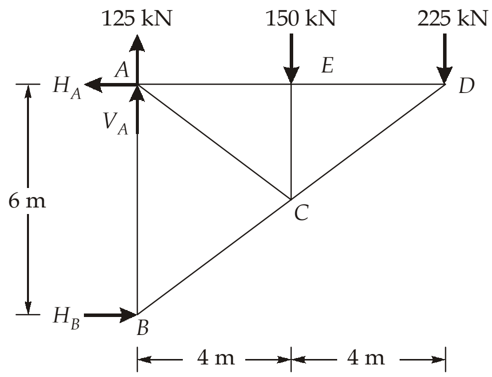
$$= \left(\frac{wl^2}{8h} + wh\right)$$

$$T_{\min} = H = \frac{wl^2}{8h}$$

$$\therefore \quad T_{\max} - T_{\min} = \left(\frac{wl^2}{8h} + wh\right) - \left(\frac{wl^2}{8h}\right)$$

$$= wh$$

12. (d)



$\Sigma M_B = 0;\quad H_A \times 6 = 150 \times 4 + 225 \times 8$

$\Rightarrow\quad H_A = 400$ kN $(\leftarrow)$

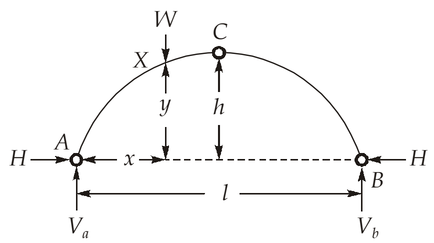
$\Sigma F_x = 0;$ So, $H_B = 400$ kN $(\rightarrow)$

$\Sigma F_y = 0;\quad V_A + 125 = 150 + 225$

$\Rightarrow\quad V_A = 250$ kN

$$\therefore \quad \text{Reaction at } A = \sqrt{V_A^2 + H_A^2} = \sqrt{250^2 + 400^2} = 471.7 \text{ kN}$$

13. (c)



$$V_a = \frac{W(l-x)}{l}, \quad V_b = \frac{Wx}{l}$$

$$\Sigma M_C = 0 \quad \text{(From right end)} \Rightarrow H \times h = \frac{Wx}{l} \times \frac{l}{2}$$

$$\Rightarrow \quad H = \frac{Wx}{2h}$$

The maximum B.M. occurs under the load.

$$\therefore \quad BM_x = \frac{W(l-x)}{l} \times x - \frac{Wx}{2h} \times \frac{4h}{l^2} x(l-x)$$

$$\Rightarrow \quad BM_x = \frac{Wx(l-x)}{l} - \frac{2W}{l^2} x^2 (l-x)$$

For absolute maximum B.M.,

$$\frac{d(BM_x)}{dx} = 0;$$

$$\Rightarrow \quad \frac{W}{l}(l-2x) = \frac{2W}{l^2}(2lx - 3x^2)$$

$$\Rightarrow \quad 6x^2 - 6lx + l^2 = 0$$

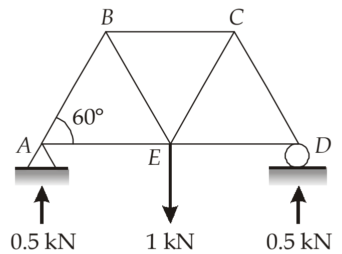
$$\Rightarrow \quad x = \frac{6-2\sqrt{3}}{12}l \qquad \left(\text{since } x < \frac{l}{2}\right)$$

$$\Rightarrow \quad x = \frac{l}{2} - \frac{l}{2\sqrt{3}} \text{ from } A$$

$\therefore$ From crown, distance of maximum B.M. on either side = $\frac{l}{2} - x = \frac{l}{2\sqrt{3}}$

14. (d)

Apply a unit load at joint E

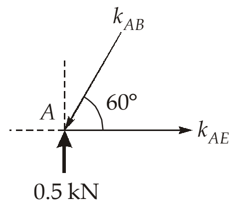


$$\delta_E = \Sigma K(L\alpha\Delta T) \qquad \ldots(1)$$

At joint A; $\Sigma F_y = 0$

$$\Rightarrow \quad 0.5 - K_{AB}\sin 60° = 0$$

$$\therefore \quad K_{AB} = \frac{1}{\sqrt{3}} \quad \text{(compressive)}$$



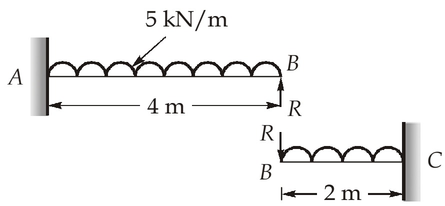
Also; $K_{AB} = K_{CD}$ (Due to symmetry)

From (1)

$$\therefore \quad \delta_E = \left(\frac{1}{\sqrt{3}} \times 2 \times 12 \times 10^{-6} \times 20\right) \times 2 \text{ m} = 0.55 \text{ mm}$$

15. (b)

Let the reaction at the roller (R) be redundant



$$\therefore \quad (\Delta_B)_{AB} = (\Delta_B)_{BC}$$

$$\Rightarrow \quad \frac{5\times(4)^4}{8EI} - \frac{R(4)^3}{3EI} = \frac{5(2)^4}{8EI} + \frac{R(2)^3}{3EI}$$

$$\Rightarrow \quad \frac{160}{EI} - \frac{64R}{3EI} = \frac{10}{EI} + \frac{8R}{3EI} \quad \Rightarrow \quad R = 6.25 \text{ kN}$$

$\therefore$ Moment at A, M_A = $R \times 4 - 5 \times 4 \times 2 = 6.25 \times 4 - 5 \times 4 \times 2$

= 25 – 40

= –15 kN-m

Therefore, the magnitude of moment at A = 15 kN-m.

16. (b)

Since stiffness matrix is inverse of flexibility matrix.

$$\therefore \text{ If} \quad [A] = k\begin{bmatrix} a & b \\ c & d \end{bmatrix}$$

then $$[A]^{-1} = \frac{1}{k|A|}\begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

$\therefore$ Stiffness matrix, $$[k] = \frac{6EI}{7L^3}\begin{bmatrix} 16 & -5 \\ -5 & 2 \end{bmatrix}$$

17. **(b)**

$\therefore$ k_{12} = Force developed at (1) due to unit displacement at (2) while restraining other displacements

$$k_{12} = \frac{2EI}{4} = \frac{EI}{2}$$

18. **(d)**

Stiffness of member OA $= \frac{3EI}{L}$

Stiffness of member OB $= \frac{4EI}{L}$

Stiffness of member OC $= \frac{4EI}{L}$

$$\therefore \quad \Sigma k = \frac{4EI}{L} + \frac{3EI}{L} + \frac{4EI}{L}$$

$$= \frac{11EI}{L}$$

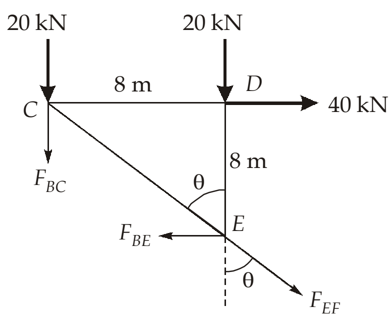
$$\therefore \quad \frac{M}{\theta} = \frac{11EI}{L}$$

$$\Rightarrow \quad M = \frac{11EI}{L}\theta$$

$\therefore$ For $\theta = 1$ unit

$$M = \frac{11EI}{L}$$

19. **(d)**



Cut a section through BC, BE and EF and considering its right portion

$$\Sigma F_y = 0; \Rightarrow \quad 20 + 20 + F_{EF}\cos\theta + F_{BC} = 0 \qquad \text{...(1)}$$

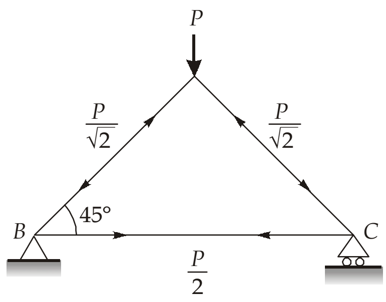
$$\Sigma M_E = 0; \Rightarrow \quad F_{BC} \times 8 + 20 \times 8 = 40 \times 8$$

$$\Rightarrow \quad F_{BC} = 20 \text{ kN}; \ (\sin\theta = \cos\theta = \frac{1}{\sqrt{2}}) \qquad (\because \theta = 45°)$$

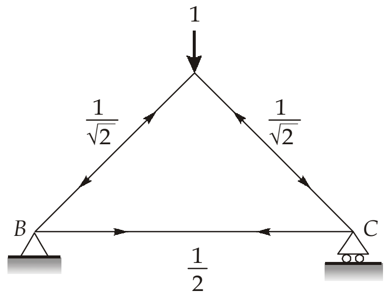
From (1); $F_{EF} = -60\sqrt{2}$ kN (–ve i.e. compression)

$\therefore$ Magnitude of $F_{EF} = 60\sqrt{2}$ kN

20. (b)



P-forces



K-system of forces

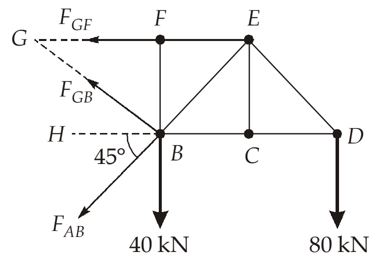
(All other remaining members will have zero force)

Deflection at *A*,
$$\Delta_A = \Sigma \frac{PKL}{AE} = \frac{\frac{P}{\sqrt{2}} \times \frac{1}{\sqrt{2}} \times \frac{L}{\sqrt{2}}}{AE} \times 2 + \frac{\frac{P}{2} \times \frac{1}{2} \times L}{AE}$$
$$= \frac{PL}{AE}\left(\frac{1}{2\sqrt{2}} \times 2 + \frac{1}{4}\right) = 0.957\frac{PL}{AE} = k\frac{PL}{AE}$$

$\therefore$ $k = 0.957 \simeq 0.96$

21. (d)

By method of sections,



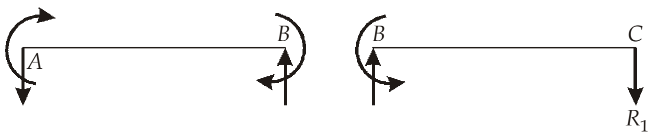
$$\Sigma M_G = 0; \Rightarrow F_{AB} \cos 45° \times 2 + F_{AB} \sin 45° \times 2 + 40 \times 2 + 80 \times 6 = 0$$

$\Rightarrow$ $\sqrt{2}\,F_{AB} + F_{AB}\sqrt{2} + 80 + 480 = 0$

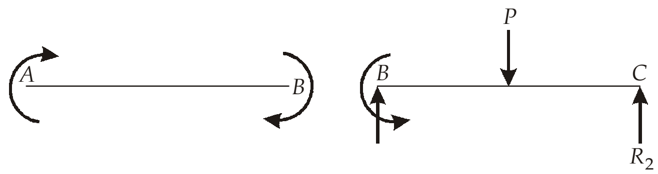
$\Rightarrow$ $F_{AB} = -197.989 \text{ kN} \simeq 197.99 \text{ kN} \simeq 198 \text{ kN (compressive)}$

22. (b)

Due to sinking of support *A*,



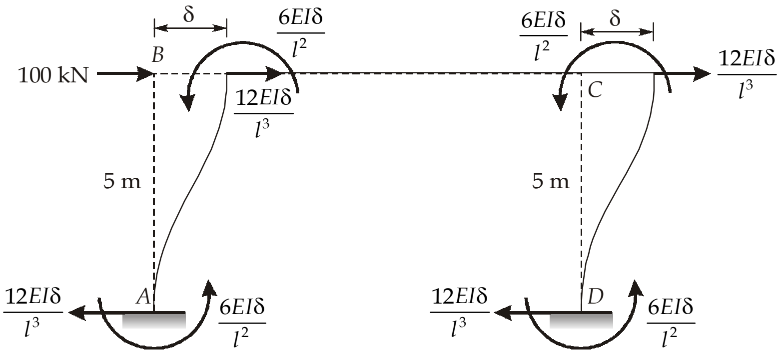
Due to load *P*



$\therefore$ $$R_C = R_1(\downarrow) + R_2(\uparrow) = R_2 - R_1 < R_2$$

Hence, reaction at C decreases.

23. (b)



$$\frac{12EI\delta}{l^3} + \frac{12EI\delta}{l^3} = 100$$

$$\Rightarrow \quad \frac{24EI\delta}{l^3} = 100$$

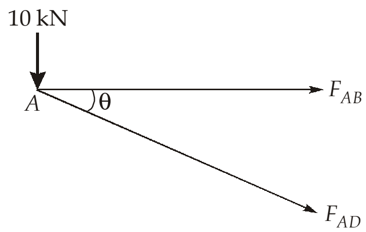
$$\Rightarrow \quad M_A = \frac{6EI\delta}{l^2}$$

$$= \frac{100 \times l}{4} = \frac{100 \times 5}{4} = 125 \text{ kNm}$$

24. (c)

Applying the method of joints

Consider joint A,



$$\Sigma F_y = 0$$

$$\Rightarrow \quad F_{AD} \sin\theta = -10$$

$$\Rightarrow \quad F_{AD} = \frac{-10}{\sin\theta}$$

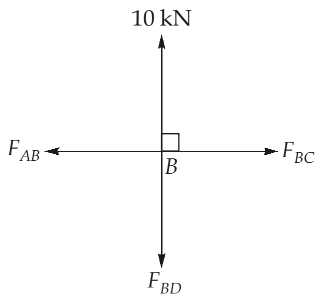
$$\Rightarrow \quad F_{AD} = -\frac{50}{3} \text{kN} = \frac{50}{3} \text{kN (C)}$$

$$\Sigma F_x = 0$$

$$\Rightarrow \quad F_{AD}\cos\theta = F_{AB}$$

$$\Rightarrow \quad F_{AB} = \frac{50}{3}\times\frac{4}{5} = \frac{40}{3}(T)$$

$\therefore$ Now consider joint B



$\therefore$ Take $\Sigma F_x = 0$

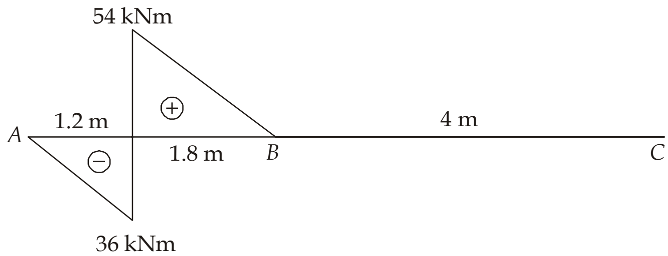
$$\Rightarrow \quad F_{AB} = F_{BC}$$

$$\Rightarrow \quad F_{BC} = \frac{40}{3}\text{ kN (T)}$$

So, correct option is (c).

25. (b)

Free bending moment diagram for the beam is shown below.



Free BM diagram

$$M_A = 0$$

$$a_1\bar{x}_1 = -\frac{1}{2}\times1.2\times36\times\frac{2}{3}(1.2)+\frac{1}{2}\times1.8\times54\left(1.2+\frac{1.8}{3}\right)$$

$$= 70.20 \text{ units}$$

Applying the theorem of three moments for span AB and BC,

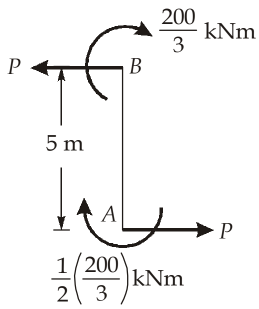
$$0\times3+2\,M_B\,(3+4)+M_c\times4 = \frac{6}{3}(70.20)$$

$$\Rightarrow \quad 7\,M_B + 2\,M_C = 70.20$$

26. (d)

Joint	Member	k	Σk	D.F.
B	BA	$\frac{8EI}{5}$	$\frac{12EI}{5}$	$\frac{2}{3}$
	BC	$\frac{4EI}{5}$		$\frac{1}{3}$

$$\therefore \quad M_{BA} = \frac{2}{3}\times 100 = \frac{200}{3} \text{ kNm}$$

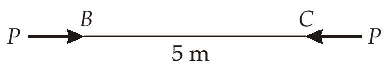


$$P \times 5 = \frac{200}{3} + \frac{100}{3}$$

$$\Rightarrow \quad 5 \times P = \frac{300}{3}$$

$$\Rightarrow \quad P = 20 \text{ kN}$$

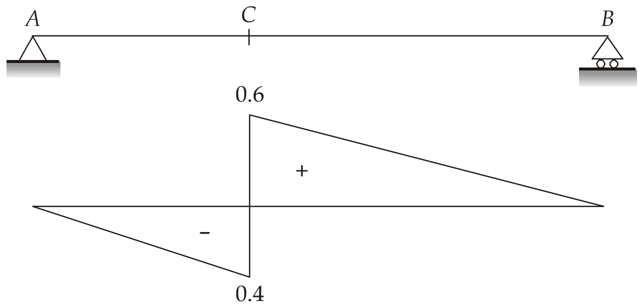
FBD of member BC is as shown below.



Hence force in member BC = 20 kN

27. (a)

ILD for SF at C is shown below



ILD for S.F. at C

For maximum positive shear force at C, BC should be covered with UDL

$$\therefore \quad \text{Maximum S.F.} = \frac{1}{2}\times 0.6\times 6\times 15$$

$$= 27 \text{ kN}$$

28. **(b)**

Applying Betti's theorem

$$25\times 0.002+15\times\frac{9}{1000} = 15\times\theta_A+22\times 0.004$$

$$\Rightarrow \qquad \theta_A = 0.00647 \text{ radian}$$

29. **(d)**

Elements in flexibility matrix can be positive or negative but the elements of leading diagonal must be positive since the displacement at any co-ordinate due to a unit force at that co-ordinate is always in the direction of unit force.

30. **(d)**

Selected joint can have more than two members but it should not have more than two unknown member forces.

■■■■