CLASS TEST

S.No.: 04DLSK_CE_OMNPQ_141025


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# STRENGTH OF MATERIALS

## CIVIL ENGINEERING

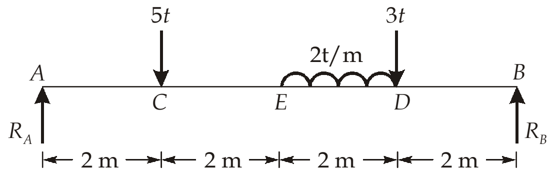
Date of Test : 14/10/2025

## ANSWER KEY

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

## DETAILED EXPLANATIONS

**1. (a)**




Taking moments about $B$,

$$R_A = \left(\frac{6}{8}\right)\times 5+\frac{3}{8}\times 4+3\times\frac{2}{8}$$

$$= 3.75 + 1.5 + 0.75 = 6t$$

Taking moment about $A$,

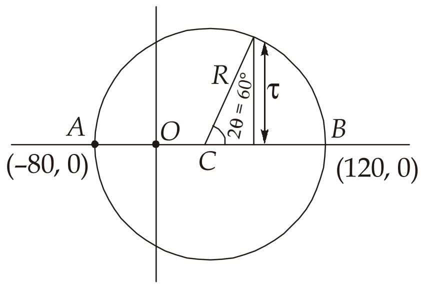
$$R_B = (5+3+2\times 2)-R_A$$

$$= 12t - 6t = 6t$$

$$\therefore \quad \frac{R_A}{R_B} = \frac{6t}{6t}=1$$

**2. (c)**

Radius, $$R = \frac{120-(-80)}{2}=100$$




Tangential stress, $$\tau = R\sin 2\theta$$

$$= 100 \sin 60°$$

$$= 100\times\frac{\sqrt{3}}{2}$$

$$= 50\sqrt{3}$$

**3. (a)**

The value of shear stress at the top edge and bottom edge of any section will always be zero.

**4. (b)**

In flitched beam has a composite section made of two or more materials joined together in such a manner that they behave as a unit piece end each material bends to the same radius of curvature. The total moment of resistance of a flitched beam is equal to the sum of the moments of resistance of individual sections.

**5. (c)**

The stress induced in metal-1 due to restriction = $E_1\alpha_1\Delta T$

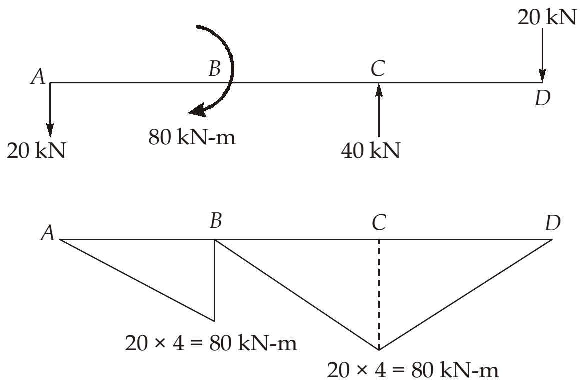
So, force required in metal-1 = $E_1\alpha_1\Delta T \times A_1$

Similarly for metal-2, force required = $E_2\alpha_2\Delta T \times A_2$

So, Total force required $= E_1\alpha_1\Delta T A_1 + E_2\alpha_2\Delta T A_2$

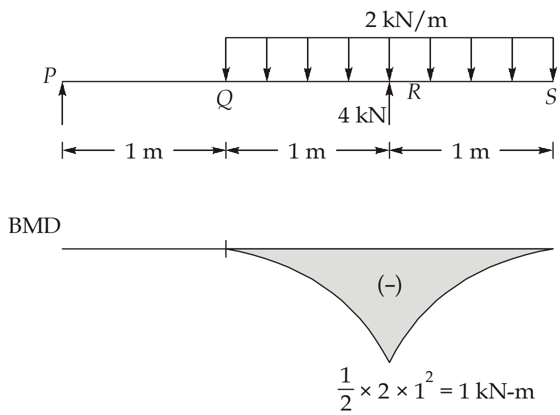
$= (E_1\alpha_1 A_1 + E_2\alpha_2 A_2)\,\Delta T$

**6. (d)**




**BMD**

**7. (b)**




**8. (d)**

As we know, $\dfrac{dV}{dx} = w$

$\Rightarrow \quad w = \dfrac{d}{dx}\left(5x^2\right) = 10x$

For midspan, $x = 1$ m

So, load intensity, $w = 10$ N/m

**9. (c)**

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

Since gap is only 3 mm.

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

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

$$\Rightarrow \quad R = 11.083 \text{ kN} \simeq 11.08 \text{ kN}$$

**10. (a)**

$$V = \frac{\pi}{4} D^2 l = \frac{\pi}{4}(120)^2 \left(1.5 \times 10^3\right) = 16.96 \times 10^6 \text{ mm}^3$$

So strain energy stored in shaft

$$U = \frac{\tau^2}{4G} \text{ Volume}$$

$$= \frac{50^2}{4 \times 80 \times 10^3} \times 16.96 \times 10^6$$

$$= 132.5 \times 10^3 \text{ N-mm}$$

$$= 132.5 \text{ N-m}$$

**11. (c)**

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

As both ends are hinged

So $\quad l_e = l = 2.3$ m

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

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

**12. (b)**

Since section is symmetric about $x$-$x$ and $y$-$y$, therefore centre of section will lie on the geometrical centroid of section.

The semi-circular grooves may be assumed together and consider one circle of diameter 60 mm.

$$\text{So,} \quad I_{xx} = \frac{80 \times (100)^3}{12} - \frac{\pi}{64}(60)^4$$

$$= 6.03 \times 10^6 \text{ mm}^4$$

Now for shear stress at neutral axis, consider the area above the neutral axis,

$$A\bar{y} = [80\times50\times25]-\frac{\pi}{2}(30)^2\times\frac{4\times30}{3\pi}$$

$$= 100000 - 18000 = 82000 \text{ mm}^3$$

$$b = 20 \text{ mm}$$

So,
$$\tau = \frac{VA\bar{y}}{Ib} = \frac{20\times10^3\times82000}{6.03\times10^6\times20}$$

$$= 13.60 \text{ MPa}$$

**13. (c)**

Area of tube,
$$A = \frac{\pi}{4}\left[40^2-25^2\right] = 765.8 \text{ mm}^2$$

$$I = \frac{\pi}{64}\left[D^4-d^4\right] = \frac{\pi}{64}\left[40^4-25^4\right] = 106488.9 \text{ mm}^4$$

We also know strain in alloy tube is,

$$\varepsilon = \frac{\delta l}{l} = \frac{4.8}{4\times10^3} = 0.0012$$

Modulus of elasticity for the alloy

$$E = \frac{\text{Load}}{\text{Area}\times\text{Strain}} = \frac{60\times10^3}{765.8\times0.0012}$$

$$= 65291.2 \text{ N/mm}^2$$

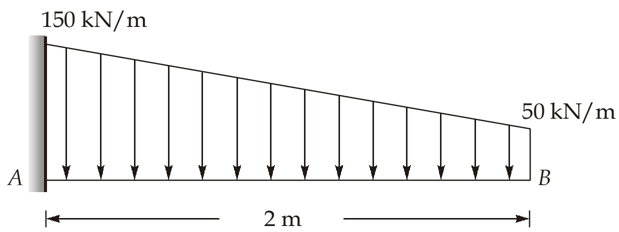
Since, column is pinned at its both ends, therefore equivalent length of the column

$$L_e = l = 4\times10^3 \text{ mm}$$

Euler's buckling load,
$$P_E = \frac{\pi^2EI}{l_e^2} = \frac{\pi^2\times65291.2\times106488.9}{(4\times10^3)^2}\text{N}$$

$$= 4.29 \text{ kN}$$

**14. (c)**




$$I = \frac{bd^3}{12} = \frac{150\times(200)^3}{12} = 10^8 \text{ mm}^4$$

We will split this load distribution i.e. trapezoidal load into a uniformly distributed load ($w_1$) of 50 kN/m and a triangular load ($w_2$) of 100 kN/m at A to zero at B.

So, deflection at free end

$$y_B = \frac{w_1l^4}{8EI}+\frac{w_2l^4}{30EI}$$

$$= \frac{50\times(2\times10^3)^4}{8\times(100\times10^3)\times10^8}+\frac{100\times(2\times10^3)^4}{30\times(100\times10^3)\times10^8}$$

$$= 10 + 5.3 = 15.3 \text{ mm}$$

**15. (b)**

$$\text{Total load} = 2\left[\frac{1}{2}\left(\frac{L}{2}\right)\times w_0\right]=\frac{w_0L}{2}$$

By symmetry, $R_1 = R_2 = \frac{1}{2}\times\text{Total load}$

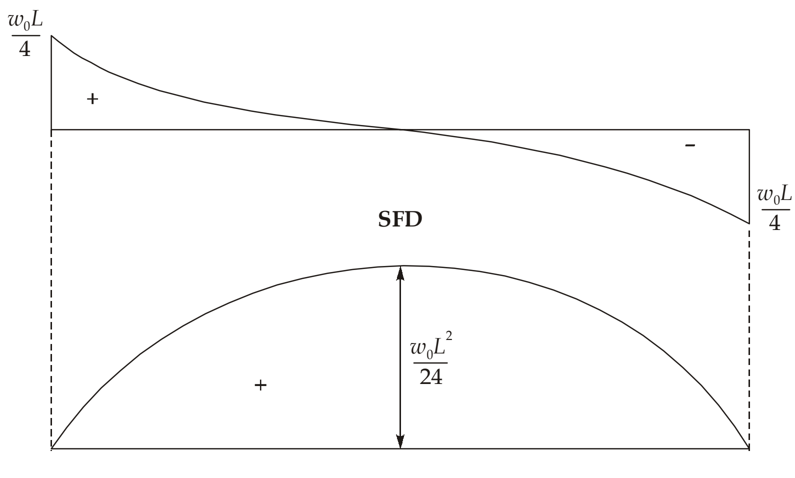
$\Rightarrow$ $R_1 = R_2 = \frac{w_0L}{4}$

Bending moment at $B$,

$$(M_B) = R_1\times\frac{L}{2}-\frac{1}{2}w_0\times\frac{L}{2}\times\frac{2}{3}\left(\frac{L}{2}\right)$$

$$= \frac{w_0L}{4}\times\frac{L}{2}-\frac{w_0}{2}\times\frac{L}{2}\times\frac{2}{3}\left(\frac{L}{2}\right)$$

$$= \frac{w_0L^2}{8}-\frac{w_0L^2}{12}=\frac{w_0L^2}{24}$$




**BMD**

**16. (a)**

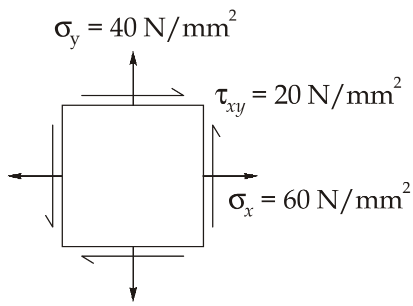
$$\sigma_{1/2} = \frac{P_1+P_2}{2}\pm\sqrt{\left(\frac{P_1-P_2}{2}\right)^2+q^2}$$

$$= \frac{60+40}{2}\pm\sqrt{\left(\frac{60-40}{2}\right)^2+20^2}$$

$$= 50 \pm 22.36$$

$\therefore$ $\sigma_1 = 72.36 \text{ N/mm}^2$ (T)

and $\sigma_2 = 27.64 \text{ N/mm}^2$ (T)




$$\tan 2\theta_p = \frac{2q}{P_1-P_2}=\frac{2\times20}{60-40}=2$$

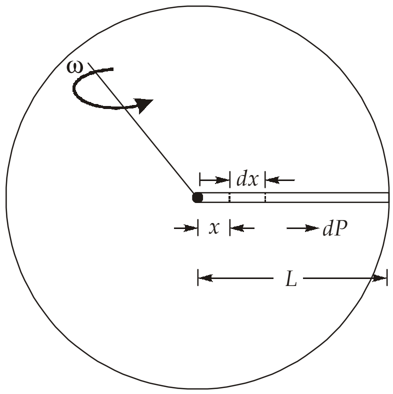
$$\therefore \quad 2\theta_p = 63.43° = 63°26'$$

$$\therefore \quad \theta_{P_1} = 31°43' \text{ and } \theta_{P_2} = 121°43'$$

$$\therefore \quad \tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{72.36 - 27.64}{2} = 22.36 \text{ N/mm}^2$$

$$\theta_{S_1} = 45° + \theta_{P_1} = 45° + 31° 43' = 76°43'$$

**17. (b)**




$$\delta = \frac{PL}{AE}$$

From the figure,

$$d\delta = \frac{dPx}{AE}$$

Centrifugal force on differential mass $dM$,

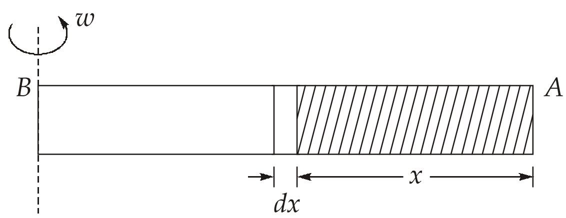
$$dP = dM \cdot \omega^2 x = (\rho A dx)\omega^2 x$$

$$\therefore \quad d\delta = \frac{(\rho A \omega^2 x dx)x}{AE}$$

$$\therefore \quad \delta = \frac{\rho\omega^2}{E}\int_0^L x^2 . dx = \frac{\rho\omega^2}{E}\left[\frac{x^3}{3}\right]_0^L$$

$$\Rightarrow \quad \delta = \frac{\rho\omega^2}{3E}\left[L^3 - 0^3\right] = \frac{\rho\omega^2 L^3}{3E}$$

**Alternate Solution:**




$$m_x = \rho A x$$

Distance between the C.G. of mass to the centre of rotation,

$$r = L - \frac{x}{2}$$

Centrifugal force, $F = m_x w^2 r = \rho A x\left(w^2\right)\left(L-\frac{x}{2}\right)$

Element elongation, $d\delta = \frac{Fdx}{AE} = \frac{Ax\rho\left(L-\frac{x}{2}\right)w^2dx}{AE}$

$$d\delta = \frac{\rho w^2\left(L-\frac{x}{2}\right)}{E}x.dx$$

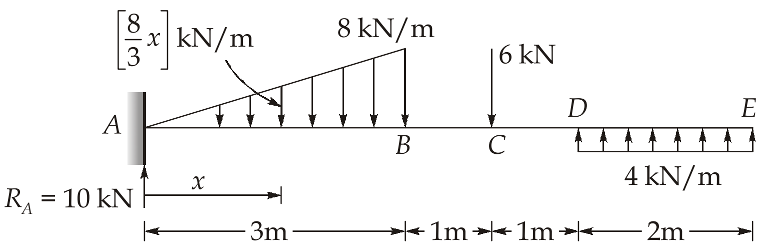
Total elongation, $\delta = \int_0^L \frac{\rho w^2}{E}\left(L-\frac{x}{2}\right)xdx$

$$= \frac{\rho w^2}{E}\left[L\left(\frac{L^2}{2}\right)-\left(\frac{x^3}{6}\right)_0^L\right]$$

$$= \frac{\rho w^2}{E}\left[\frac{L^2}{2}-\frac{L^3}{6}\right]$$

$$\delta = \frac{\rho w^2 L^2}{3E}$$

**18. (b)**




Let at a distance '$x$' from $A$, shear force is zero

$\therefore$ $SF_x = R_A - \frac{1}{2}(x)\frac{8}{3}x = 0$

$\Rightarrow$ $10 = \frac{4x^2}{3}$

$\Rightarrow$ $x = 2.7386$ m

$\therefore$ Beam at distance '$x$' ($BM_x$)

$$= 10x - \frac{1}{2}x\left(\frac{8}{3}x\right)\frac{x}{3}$$

$$= 10(2.7386) - \frac{4}{9}(2.7386)^3$$

$$= 18.26 \text{ kNm}$$

**19.** **(d)**

Change in temperature (fall) = 400 – 300 = 100°C

Area of cross-section of rod = $\frac{\pi}{4}(20)^2 = 314.16 \text{ mm}^2$

$\because$ Wall yield by 5 mm

$$\therefore \quad \frac{p_t L}{E} = \Delta = (L\alpha t - a), \quad \text{where } a = 5 \text{ mm}$$

$$\Rightarrow \quad p_t = \frac{E}{L}(L\alpha t - 5) = E\alpha t - \frac{5E}{L}$$

$$= \left(2\times10^5 \times 12\times10^{-6}\times100\right) - \frac{5\times2\times10^5}{8000}$$

$$= 240 - 125 = 115 \text{ N/mm}^2$$

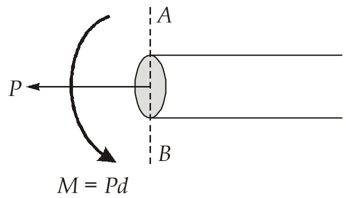
$\therefore$ Pull, $\quad P = p\,A = 115 \times 314.16 = 36128 \text{ N} = 36.128 \text{ kN}$

**20.** **(a)**

**Case 1:**

Maximum stress, $\quad \sigma_1 = \frac{P}{A} = \frac{4P}{\pi d^2}$

**Case 2:**




Maximum stress, $\quad \sigma_2 = \frac{P}{A} + \frac{My}{I}$

$$\Rightarrow \quad \sigma_2 = \frac{4P}{\pi d^2} + \frac{(Pd)\times(d/2)}{\frac{\pi}{64}d^4} = \frac{4P}{\pi d^2} + \frac{32P}{\pi d^2} = \frac{36P}{\pi d^2}$$

$$= 9\left(\frac{4P}{\pi d^2}\right) = 9\sigma_1 = n\sigma_1$$

$$\therefore \quad n = 9$$

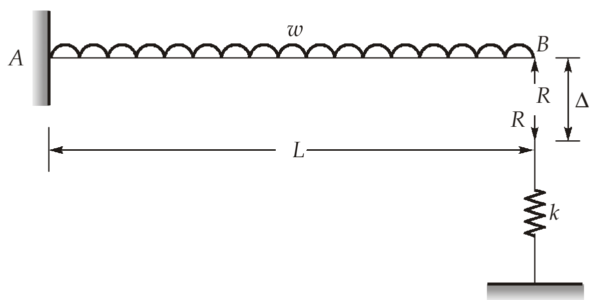
**21.** **(a)**

$$\Delta_B = \frac{R}{k} = \frac{wl^4}{8EI} - \frac{Rl^3}{3EI}$$

Since, $\quad k = \frac{EI}{l^3}$

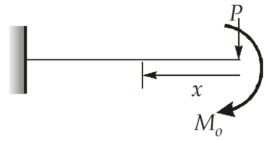
$$\therefore \quad \frac{Rl^3}{EI} + \frac{Rl^3}{3EI} = \frac{wl^4}{8EI}$$

$$\Rightarrow \quad R = \frac{3wL}{32}$$



**22. (c)**

Strain energy due to bending = $\int \frac{M_x^2 dx}{2EI}$




Since it varies with square, we can't apply principle of superposition.

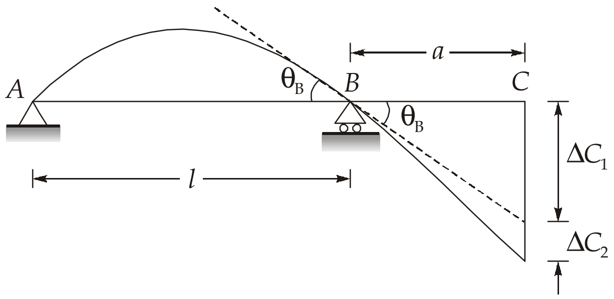
$$\int_o^L \frac{(-Px - M_o)^2 dx}{2EI} = \int_o^L \frac{P^2x^2 + M_o^2 + 2PxM_o}{2EI} dx$$

$$= \frac{1}{2EI}\left[\frac{P^2x^3}{3} + M_o^2 x + PM_o x^2\right]_o^L$$

$$= \frac{P^2L^3}{6EI} + \frac{M_o^2 L}{2EI} + \frac{PM_o L^2}{2EI}$$

**23. (d)**

The deformation of the beam will be as shown below.



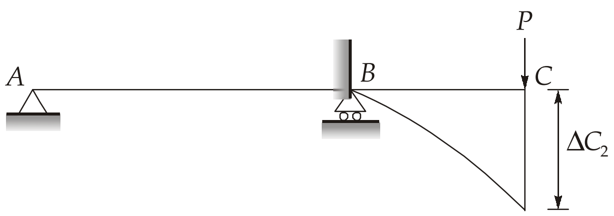

Now $\Delta C_1$ is produced due to deflection of $C$ as caused due to deformation of $AB$,

$$\Delta C_1 = \theta_B (BC) = \theta_B a$$

$$\theta_B = \frac{M_{BA} l}{3EI} = \frac{Pal}{3EI}$$

$$\therefore \quad \Delta C_1 = \frac{Pala}{3EI} = \frac{Pa^2 l}{3EI}$$

$\Delta C_2$ is produced due to deformation of $BC$

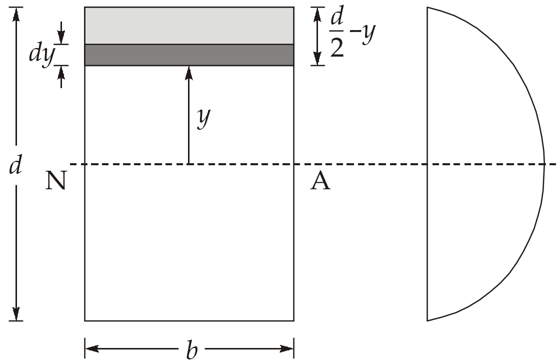



$$\Delta C_2 = \frac{Pa^3}{3EI}$$

So total deflection at $C, \Delta C = \Delta C_1 + \Delta C_2$

$$= \frac{Pa^2 l}{3EI} + \frac{Pa^3}{3EI}$$

**24. (b)**




Shear stress at '$y$' distance from neutral axis.

$$\tau = \frac{VQ}{It}$$

Where
$$Q = A\bar{y} = \left(\frac{d}{2} - y\right) b \times \left(y + \frac{\frac{d}{2} - y}{2}\right)$$

$\Rightarrow$
$$Q = \left(\frac{d}{2} - y\right) b \left(\frac{\frac{d}{2} + y}{2}\right)$$

$\Rightarrow$
$$Q = \left(\frac{d^2}{4} - y^2\right)\frac{b}{2}$$

$$I = \frac{bd^3}{12}$$

So,
$$\tau = \frac{V\left(\frac{d^2}{4} - y^2\right)\frac{b}{2}}{\frac{bd^3}{12} \times b} = \frac{6V}{d^3 b}\left(\frac{d^2}{4} - y^2\right)$$

Now shear force carried by elementary portion

$$dF = \tau dA$$
$$= \tau b dy$$

$$dF = \frac{6V}{d^3}\left(\frac{d^2}{4} - y^2\right) dy$$

So, shear force carried by upper 1/3$^{\text{rd}}$ portion:

$$F = \int_{d/6}^{d/2} \frac{6V}{d^3}\left(\frac{d^2}{4} - y^2\right) dy = \frac{6V}{d^3}\left[\frac{d^2}{4} y - \frac{y^3}{3}\right]_{d/6}^{d/2}$$

$$= \frac{6V}{d^3}\left[\frac{d^2}{4}\frac{d}{2} - \frac{d^3}{24} - \frac{d^2}{4}\frac{d}{6} + \frac{d^3}{216 \times 3}\right] = \frac{6V}{d^3} \times \frac{7d^3}{162}$$

$\therefore$
$$F = \frac{7V}{27}$$

**25. (a)**

Let $D$ = Diameter of shaft (in mm)

We know that power transmitted by shaft ($P$)

$$= \frac{2\pi NT}{60}$$

$$\Rightarrow \quad 100 = \frac{2\pi NT}{60} = \frac{2\pi \times 160 \times T}{60}$$

$$\Rightarrow \quad T = 5.968 \text{ kNm}$$

$\therefore$ Maximum torque, $T_{max} = 1.2\ T$

$$= 1.2 \times 5.968$$

$$= 7.162 \text{ kNm}$$

$$T_{max} = f_{\max} \frac{\pi}{16} D^3$$

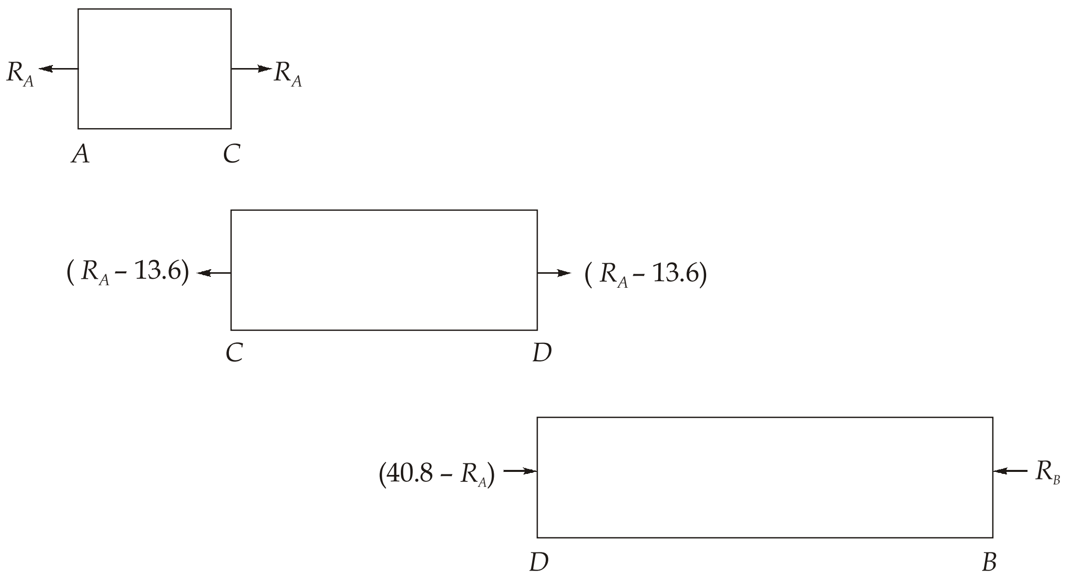
$$\Rightarrow \quad 7.162 \times 10^6 = \frac{\pi}{16} \times \tau \times D^3 = \frac{\pi}{16} \times 70 \times D^3$$

$$\Rightarrow \quad D^3 = \frac{7.162 \times 10^6 \times 16}{\pi \times 70}$$

$$\Rightarrow \quad D = (521082.378)^{1/3} = 80.57 \text{ mm}$$

**26. (a)**

Free body diagram is shown below,




$$R_A + R_B = 40.8 \qquad \text{...(i)}$$

Total change in length = 0

So, $\delta_{AC} + \delta_{CD} + \delta_{DB} = 0$

$$\frac{R_A \times 100}{AE} + \frac{(R_A - 13.6) \times 200}{AE} - \frac{(-R_A + 40.8) \times 300}{AE} = 0$$

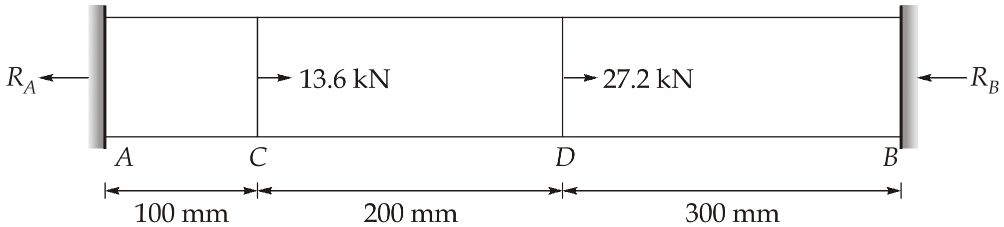
$$\Rightarrow \quad R_A + 2R_A - 27.2 + 3R_A - 122..4 = 0$$

$$\Rightarrow \quad R_A = 24.93 \text{ kN}$$

$$R_B = (40.8 - R_A) = -15.87 \text{ kN}$$

So ratio of magnitude of reactions i.e., $\dfrac{R_A}{R_B} = \dfrac{24.93}{15.87} = 1.57$

**Alternatively:**




$$R_A = \frac{13.6 \times 500}{600} + \frac{27.2 \times 300}{600} = 24.93\text{kN}$$

$$R_B = \frac{27.2 \times 300}{600} + \frac{13.6 \times 100}{600} = 15.87\text{kN}$$

$$\therefore \quad \text{Ratio of } \left(\frac{R_A}{R_B}\right) = \frac{24.93}{15.87} = 1.57$$

**27.** **(b)**

Let the forces induced in aluminium and steel rods be $P_a$ and $P_s$ respectively.

Now, $\quad P_a + P_s = W$

Balancing moment about the point where aluminum rod is hinged we have,

$$W \times 1 = P_s \times 3$$

$$\Rightarrow \quad P_s = \frac{W}{3}$$

But $\quad P_a + P_s = W$

$$\Rightarrow \quad P_a = W - \frac{W}{3} = \frac{2W}{3}$$

For the beam to remain horizontal, elongation in both the rods must be equal in the vertical direction.

$$\frac{P_a l_a}{A_a E_a} = \frac{P_s l_s}{A_s E_s}$$

$$\Rightarrow \quad \frac{A_a}{A_s} = \frac{P_a l_a E_s}{P_s l_s E_a}$$

$$\Rightarrow \quad \frac{A_a}{A_s} = \frac{\left(\frac{2W}{3}\right)}{(W/3)} \times \frac{2000}{3000} \times \frac{200}{70}$$

$$\Rightarrow \quad \frac{A_a}{A_s} = 3.8095 \simeq 3.8$$

**28. (d)**

Strongest beam is the one for which section modulus $Z$ is maximum.
Let rectangular section is of width $b$ and depth $d$,
Diameter of cylindrical log, $D$ = 300 mm

$$\therefore \quad b^2 + d^2 = D^2$$

$$\therefore \quad Z = \frac{bd^2}{6} = \frac{b(D^2 - b^2)}{6} = \frac{bD^2 - b^3}{6}$$

For maximum $Z$,

$$\frac{\partial Z}{\partial b} = 0$$

$$\Rightarrow \quad \frac{D^2 - 3b^2}{6} = 0$$

$$\Rightarrow \quad b = \frac{D}{\sqrt{3}}$$

$$\Rightarrow \quad b = \frac{300}{\sqrt{3}} = 173.2 \text{ mm}$$

**29. (c)**

$$\text{Maximum principle stress} \leq \frac{f_y}{\text{FOS}}$$

$$\text{Equivalent BM,} \quad M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$

$$= \frac{1}{2}\left[20 + \sqrt{20^2 + 40^2}\right]$$

$$= 32.36 \text{ kNm}$$

$$\text{Maximum principle stress} = \frac{32 M_e}{\pi D^3} \leq \frac{250}{2}$$

$$\Rightarrow \quad \frac{32 \times 32.36 \times 10^6}{\pi D^3} \leq 125$$

$$\Rightarrow \quad D \geq 138.15 \text{ mm}$$

**30. (b)**

Let, $P_s$ = Load shared by steel rod
$P_c$ = Load shared by copper rod

Taking moments about $A$,

$$P_s \times 1 + P_c \times 3 = 20 \times 4$$

$$\Rightarrow \quad P_s + 3P_c = 80 \quad \text{...(i)}$$

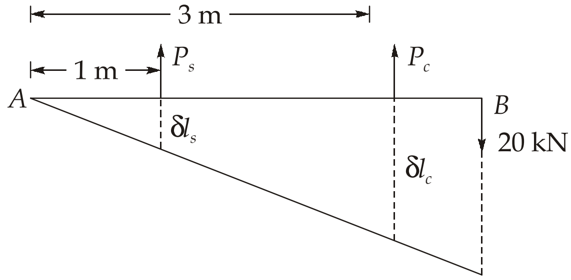
Now deformation of steel road due to load $P_s$ is,

$$\delta l_s = \frac{P_s\, l_S}{A_s\, E_s} = \frac{P_s \times 1 \times 10^3}{200 \times 200 \times 10^3} = 0.025 \times 10^{-3} P_s$$

And deformation of copper rod due to load $P_c$ is,

$$\delta l_c = \frac{P_c\, l_c}{A_c\, E_c} = \frac{P_c \times 2 \times 10^3}{400 \times 100 \times 10^3} = 0.05 \times 10^{-3} P_c$$

From the geometry of elongation of the steel rod and copper rod,




$$\frac{\delta l_c}{3} = \delta l_s$$

$$\Rightarrow \quad \delta l_c = 3\delta l_s$$

$$\Rightarrow \quad 0.05 \times 10^{-3}\, P_c = 3 \times 0.025 \times 10^{-3}\, P_s$$

$$\Rightarrow \quad P_c = 1.5\, P_s$$

Substituting this in eq. (i)

$$P_s + 3\,(1.5\, P_s) = 80$$

$$\Rightarrow \quad P_s = 14.5 \times 10^3 \text{ N}$$

So, stress in steel rod, $\sigma_s = \dfrac{P_s}{A_s} = \dfrac{14.5 \times 10^3}{200} = 72.5 \text{ N/mm}^2$

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