STRENGTH OF MATERIALS TEST 4

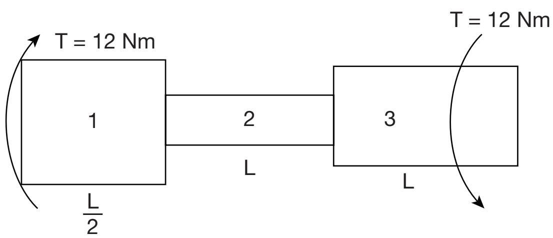
Number of Questions 25 **Time:60 min.**

Directions for questions 1 to 25: Select the correct alternative from the given choices.

1. A 100 mm diameter, 10 m long shaft is used to transmit power at 150 rpm. If angle of twist produced is 5° for a length of 10 m, maximum intensity of shear stress produced in MPa is
(Modulus of rigidity = 82 kN/mm^2)

(A) 25.27 (B) 28.76
(C) 32.64 (D) 35.78

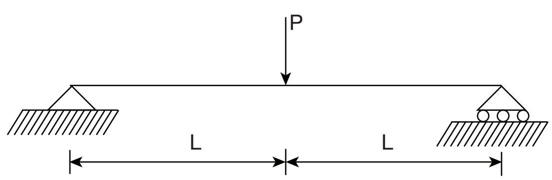
2.



A shaft as shown in figure is subjected to a torque 12 Nm at the ends. Torsional stiffness of the portions 1, 2 and 3 of the shaft are 40 Nm/rad, 20 Nm/rad and 30 Nm/rad respectively. Angular deflections between the ends is

(A) 0.7 rad (B) 0.9 rad
(C) 1.3 rad (D) 1.5 rad

3.



Strain energy stored in the beam with flexural rigidity *EI*, loaded as shown in the figure is

(A) $\dfrac{P^2L^2}{6EI}$ (B) $\dfrac{P^2L^2}{12EI}$

(C) $\dfrac{P^3L^2}{6EI}$ (D) $\dfrac{P^2L^2}{12EI}$

4. A cantilever beam of 5 m length is subjected to a moment of 15 kN-m at the free end. If flexural rigidity of the beam is 20,000 kNm^2, maximum deflection of the beam is

(A) 4.726 mm (B) 6.334 mm
(C) 8.132 mm (D) 9.375 mm

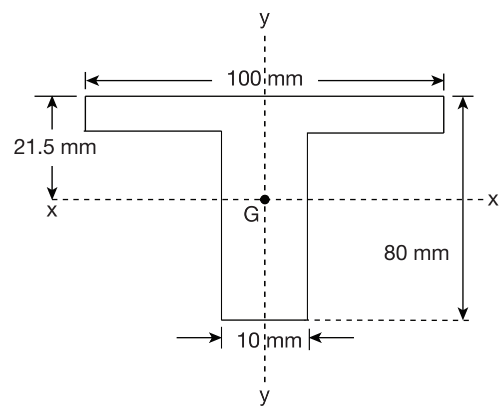
5. A simply supported beam of span 4 m loaded with a uniformly distributed load of 4 kN/m has a rectangular cross section 50 mm wide and 100 mm deep. If Young's modulus is 2 × 10^5 N/mm^2 maximum deflection of the beam is

(A) 16 mm (B) 12 mm
(C) 10 mm (D) 8 mm

6. A 600 mm diameter water pipe has to withstand a water head of 50 m. If permissible stress of pipe material is 20 N/mm^2 then thickness of pipe required is (specific weight of water = 9810 N/m^3)

(A) 7.36 mm (B) 8.48 mm
(C) 9.96 mm (D) 10.52 mm

7.



For a column of cross section as shown above and length 3 m has one end fixed and other end free. Values of Young's modulus and moments of intertia are as follows

E = 20 GN/m^2
I_x = 953000 mm^4
I_y = 839000 mm^4

The buckling load using Euler's equation is

(A) 30.647 kN (B) 38.441 kN
(C) 41.162 kN (D) 46.003 kN

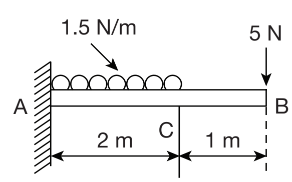
8. A tensile load of 60 kN is applied on a bar of cross–sectional area 360 mm^2. If the strain energy stored in the bar is 500 N-mm, what is the length of the bar? (E = 210 GPa)

(A) 21 mm (B) 10.5 mm
(C) 42 mm (D) 5.25 mm

9. The bending moment diagram of a beam carrying uniformly distributed load follows

(A) Linearity (B) Parabolic law
(C) Cubic law (D) Is constant

10. What is the maximum shear force due to the loading as given in a cantilever beam?



(A) 5 N (B) 6.5 N
(C) 7 N (D) 8 N

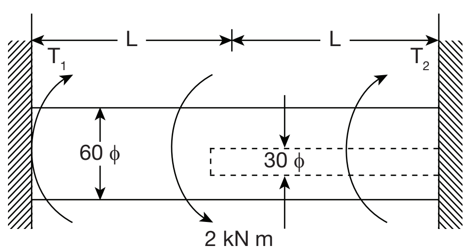
11. A cantilever of circular cross section of span 2 m carries a uniformly distributed load of 30 kN/m. If the maximum shear stress produced is to be limited to 2 N/mm^2 the required diameter of the beam at the fixed end is
(A) 196 mm (B) 226 mm
(C) 292 mm (D) 347 mm

12. A 10 m long 100 mm diameter shaft is transmitting 115 kW power at 150 rpm. If modulus of rigidity of the shaft is 82 kN/mm^2, maximum intensity of shear stress produced in the shaft in N/mm^2 is
(A) 31.774 (B) 37.286
(C) 39.342 (D) 42.864

13. A hollow circular shaft of 6 m length and inner and outer diameter of 80 mm and 100 mm is subjected to a torque of 8 kN-m. If modulus of rigidity is 80 GPa, angle of twist produced per metre length is
(A) 0.9885° (B) 1.2882°
(C) 2.966° (D) 5.93°

14. A torque of 24 kN-m is transmitted by a solid shaft with a maximum shear stress of 75 N/mm^2. If the shaft is to be replaced by a hollow shaft with same maximum shear stress whose internal diameter is 0.6 times the outer diameter, the percentage saving in weight is
(A) 26.2% (B) 29.8%
(C) 32.2% (D) 36.4%

15.

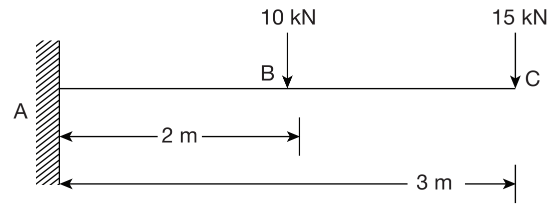


A shaft of length 2ℓ and outside diameter 60 mm fixed at both ends is subjected to a torque of 2 kN-m at the centre. Half of the shaft is hollow with inside diameter 30 mm. The ratio of reaction torques T_1 and T_2 at the ends is
(A) 1 (B) 1.067
(C) 0.5 (D) 1.667

16. A steel bar of 20 mm diameter and 1 m length is freely suspended from a roof. The bar is provided with a collar at the bottom end. If modulus of elasticity is 2×10^5 N/mm^2 and maximum permissible stress is 300 N/mm^2, maximum weight that can fall on the collar from a height of 60 mm is
(A) 1149.36 N (B) 1120.22 N
(C) 1080.42 N (D) 1060.32 N

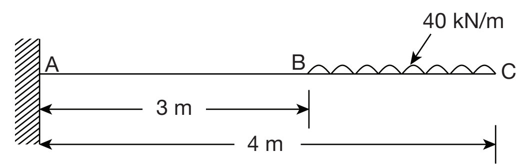
17. A hollow circular shaft of 150 mm outside diameter, 120 mm inner diameter and length 1 m is transmitting 1000 kW power at 350 rpm. Strain energy stored in the shaft is (Modulus of rigidity = 80 kN/mm^2)
(A) 158.57 J (B) 151.34 J
(C) 145.62 J (D) 138.74 J

18.



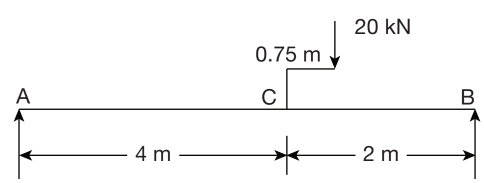
For the cantilever loaded as shown in figure, value of flexural rigidity is 4×10^4 kN-m^2. Deflection at the end C is
(A) 2.147 mm (B) 2.923 mm
(C) 3.624 mm (D) 4.542 mm

19.



A cantilever is loaded as shown in the figure. If flexural rigidity is 36×10^4 kN-m^2 deflection at point C is
(A) 2.62 mm (B) 2.14 mm
(C) 1.93 mm (D) 1.56 mm

20.



A simply supported beam AB is loaded at point C at a distance 4 m from A, as shown in figure. Flexural rigidity of the beam is 15,000 kN-m^2. Deflection at point C is
(A) 8.26 mm (B) 6.34 mm
(C) 5.15 mm (D) 3.85 mm

21. A thin cylindrical shell, 2 m long has 300 mm diameter and thickness of metal 10 mm. It is completely filled with water at atmospheric pressure. Values of Young's modulus and Poisons ratio for the shell material is 2×10^5 N/mm^2 and 0.3 respectively. If an additional 30,000 mm^3 of water is pumped in, pressure developed in the vessel is
(A) 1.489 N/mm^2 (B) 1.786 N/mm^2
(C) 2.525 N/mm^2 (D) 2.932 N/mm^2

22. A thin cylindrical shell of 200 mm diameter, 10 mm metal thickness and 2 m length is completely filled with a fluid at atmospheric pressure. Values of Young's modulus and Poisson's ratio are 2×10^5 MPa and 0.3 respectively. When an additional quantity of fluid is pumped in, volumetric strain produced is 3.98×10^{-4}. Change in length of the tank in mm is

(A) 0.06832 (B) 0.07785
(C) 0.08379 (D) 0.09264

23. A simply supported beam of span 6 m gave a maximum deflection of 12 mm when loaded at mid span with a concentrated load of 10 N. When it is used as a strut with pin joined ends the expected buckling load is

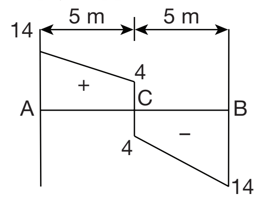
(A) 986.4 N (B) 1028.1 N
(C) 1136.2 N (D) 1268.3 N

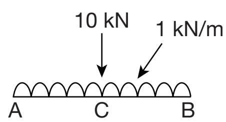
24. A hollow cast iron column of outside diameter 200 mm and inside diameter 160 mm is 4.5 m long and has one end fixed and other end hinged. If crushing strength is 550 N/mm^2, Rankine's critical load is

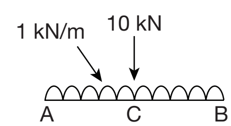
(Take Rankine's constant = $\frac{1}{1600}$ for both ends hinged)

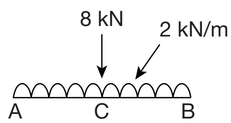
(A) 2445.63 kN (B) 2562.72 kN
(C) 2671.82 kN (D) 2772.34 kN

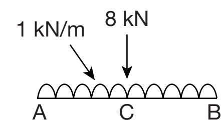
25. According to the given shear force diagram (kN) the loading on the simply supported beam would be



(A)


(B)


(C)


(D)


Answer Keys

1. D	**2.** C	**3.** D	**4.** D	**5.** A	**6.** A	**7.** D	**8.** A	**9.** B	**10.** D
11. B	**12.** B	**13.** A	**14.** B	**15.** B	**16.** A	**17.** A	**18.** D	**19.** C	**20.** D
21. A	**22.** C	**23.** B	**24.** A	**25.** C					

Hints and Explanations

1. $L = 10$ m $= 10{,}000$ mm

$d = 100$ mm, $R = 50$ mm

$N = 150$ rpm

$G = 82$ kN / mm^2

$$\theta = 5° = \frac{5 \times \pi}{180} \text{ radian}$$

$$\frac{G\theta}{L} = \frac{\tau_s}{R}$$

$$\frac{82 \times 10^3}{10{,}000} \times \left(5 \times \frac{\pi}{180}\right) = \frac{\tau_s}{50}$$

$\Rightarrow \quad \tau_s = 35.78$ N/mm^2 = 35.78 MPa. Choice (D)

2. Torsional stiffness $k_T = \frac{T}{\theta}$

$$\therefore \quad \theta = \frac{T}{k_T}$$

Angular deflection between ends = $\theta_1 + \theta_2 + \theta_3$

$$= T\left[\frac{1}{k_{T_1}} + \frac{1}{k_{T_2}} + \frac{1}{k_{T_3}}\right]$$

$$= 12\left[\frac{1}{40} + \frac{1}{20} + \frac{1}{30}\right] = 1.3 \text{ rad.}$$ Choice (C)

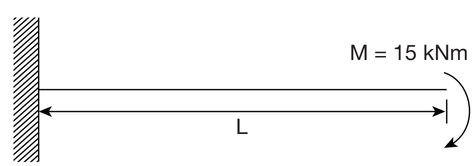
3. Strain energy stored $= 2\int_0^L \frac{(M_x)^2\,dx}{2EI}$

Where M_x = Bending moment at a distance x

$$= 2\int_0^L \frac{\left(\frac{Px}{2}\right)^2 dx}{2EI}$$

$$= \frac{P^2}{4EI}\left[\frac{x^3}{3}\right]_0^L = \frac{P^2L^3}{12EI}$$ Choice (D)

4.



$$y_{\max} = \frac{ML^2}{2EI}$$

Where EI = flexural rigidity

ie $y_{\max} = \frac{15 \times 5^2}{2 \times 20000} = 9.375 \times 10^{-3}$ m $= 9.375$ mm.

Choice (D)

5. Maximum deflection (at centre)

$$y_{\max} = \frac{5}{384}\frac{wL^4}{EI}$$

Given –
$w = 4$ kN/m
$L = 4$ m
$E = 2 \times 10^5$ N/mm^2 = 200 kN/mm^2 = 2×10^8 kN/m^2
$b = 50$ mm = 0.05 m
$d = 100$ mm = 0.1 m

$$I = \frac{bd^3}{12} = \frac{0.05\times(0.1)^3}{12} = 4.167 \times 10^{-6}\ \text{m}^4$$

$$\therefore\quad y_{\max} = \frac{5}{384}\times\frac{4\times 4^4}{2\times10^8\times4.167\times10^{-6}}$$

= 0.016 m = 16 mm. Choice (A)

6. $d = 600$ mm, $\sigma = 20$ N/mm^2
Pressure of water = $w\,h$
= 9810 × 50 N/m^2 = 0.4905 N/mm^2
Maximum stress = hoop stress

$$\sigma = \frac{pd}{2t} \quad t = \frac{pd}{2\sigma}$$

$$= \frac{0.4905\times600}{2\times20}$$

= 7.3575 mm or 7.36 mm. Choice (A)

7. Effective length for one end fixed and other end free column
$L = 2 \times$ Actual length
= 2 × 3000 = 6000 mm
$E = 200$ GN/m^2 = 2×10^5 N/mm^2
Euler's buckling load (crippling load)

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

$$= \frac{\pi^2 EI_y}{L^2} \quad [I_y \text{ being the smaller}]$$

$$= \frac{\pi^2\times2\times10^5\times839000}{(6000)^2} = 46{,}003\ \text{N} = 46.003\ \text{kN}.$$

Choice (D)

8. $U = 500$ N-mm, $A = 360$ mm^2,
$E = 210$ GPa = 210 kN/mm^2

Stress applied, $\sigma = \dfrac{60\times10^3}{360} = \dfrac{500}{3}$ N/mm^2

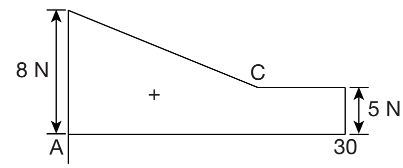
$\therefore$ Strain energy stored $U = \dfrac{\sigma^2}{2E}.V$

$$\therefore\quad 500 = \frac{\left(\frac{500}{3}\right)^2}{2\times210\times10^3}\times360\times L$$

$\therefore$ $L = 21$ mm Choice (A)

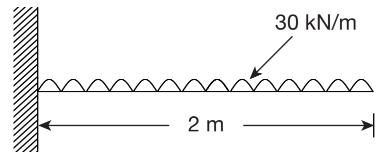
9. Choice (B)

10. The shear force diagram of the given beam will be



At point B the shear force is 5 N and is constant up to C and due to UDL the shear force increases linearly to 8 N at point A.
Maximum shear force = 8 N at point A Choice (D)

11.



Maximum shear force is at the fixed end and is
= 30 × 2 = 60 kN
Average shear stress at fixed end

$\tau_{av} = \dfrac{60}{A}$ kN/mm^2, where $A = \dfrac{\pi d^4}{4}$ mm^2

For circular sections maximum shear stress

$$\tau_{\max} = \tau_{av}\times\frac{4}{3}$$

i.e., $\tau_{\max} = \dfrac{60}{A}\times\dfrac{4}{3}$ kN/mm^2

But $\tau_{\max} = 2$ N/mm^2

$$\therefore\quad \frac{60}{A}\times\frac{4}{3}\times10^3 = 2$$

$\Rightarrow$ $A = 40000$ mm^2 = $\dfrac{\pi d^4}{4}$

$\Rightarrow$ $d = 225.67$ mm or 226 mm Choice (B)

12. $L = 10$ m = 10,000 mm
$d = 100$ mm; R = 50 mm
$N = 150$ rpm
$G = 82 \times 10^3$ N/mm^2

$$J = \frac{\pi d^4}{32} = \frac{\pi}{32}\times100^4$$

Power $P = 115\times10^3\,\text{W} = \dfrac{2\pi NT}{60}$

$$\Rightarrow \frac{2\pi\times150\times T}{60} = 115\times10^3$$

$\Rightarrow$ $T = 7321$ Nm

$$\frac{T}{J} = \frac{\tau}{R}$$

$$\frac{7321\times10^3}{\left(\frac{\pi}{32}\times100^4\right)} = \frac{\tau_{\max}}{50}$$

where τ_{max} = maximum shear stress

$\Rightarrow$ τ_{max} = 37.2855 N/mm² Choice (B)

13. $T = 8$ kN m = 8×10^6 N mm

$G = 80$ *Gpa* = 80×10^3 N/mm²

$L = 6$ m = 6×10^3 mm

$$J = \frac{\pi D^4}{32}(1-k^4) \text{ where } k = \frac{d}{D} = \frac{80}{100} = 0.8$$

$$\therefore \quad J = \pi \times \frac{100^4}{32} \times (1-0.8^4) = 5.796 \times 10^6$$

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

Angle of twist per metre length

$$\theta = \frac{TL}{GJ} \text{ where } L = 1 \text{ m} = 1000 \text{ mm}$$

$$= \frac{8 \times 10^6 \times 1000}{80 \times 10^3 \times 5.796 \times 10^6} = 0.01725 \text{ rad}$$

$= 0.9885°$. Choice (A)

14. $T = 24$ kN-m = 24×10^6 N/mm

$\tau = 75$ N/mm²

$$T = \tau \times z_p = \tau \frac{\pi d^3}{16}$$

$$24 \times 10^6 = \frac{75 \times \pi \times d^3}{16}$$

$\Rightarrow$ $d = 117.68$ mm

For hollow shaft

$$k = \frac{d}{D} = 0.6$$

$$T = \tau \frac{\pi D^3}{16}(1-k^4)$$

$$24 \times 10^6 = \frac{75 \times \pi D^3}{16}\left(1-0.6^4\right)$$

$\Rightarrow$ $D = 123.25$ mm

Area of cross section of solid shaft

$$= \frac{\pi \times (117.68)^2}{4}$$

Area of cross section of hollow shaft

$$= \frac{\pi}{4}\left(D^2 - d^2\right) = \frac{\pi}{4}D^2\left(1-k^2\right)$$

$$= \frac{\pi}{4} \times (123.25)^2\left(1-0.6^2\right)$$

For same length and specific weight,
weight is proportional to area of cross section
Percentage saving in weight

$$= 100\left[\frac{(117.68)^2 - (123.25)^2\left(1-0.6^2\right)}{(117.68)^2}\right]$$

$= (1 - 0.702)\ 100$

$= 0.298 \times 100 = 29.8\%$. Choice (B)

15. Angle of twist is same for both ends

i.e., $\theta_1 = \theta_2$

$$\theta_1 = \frac{T_1 L}{GJ_1} = \frac{T_1 L}{G\frac{\pi}{32}(60)^4}$$

$$\theta_2 = \frac{T_2 L}{GJ_2} = \frac{T_2 L}{\left(60^4 - 30^4\right) \times G \times \frac{\pi}{32}}$$

$$\therefore \quad \frac{T_1}{(60)^4} = \frac{T_2}{\left(60^4 - 30^4\right)}$$

$$\Rightarrow \quad \frac{T_1}{T_2} = 1.067.$$ Choice (B)

16. $A = \frac{\pi}{4} \times 20^2 = 100\,\pi$

$L = 1$ m = 1000 mm

$E = 2 \times 10^5$ N/mm²

Maximum stress $\sigma = 300$ N/mm²

Instantaneous extension permitted Δ

$$= \frac{\sigma}{E} \times L = \frac{300 \times 1000}{2 \times 10^5} = 1.5 \text{ mm}$$

Work done by load = $W(60 + 1.5)$

= 61.5 W Nm

$$\text{Strain energy} = \frac{\sigma^2}{2E} \times AL$$

$$= \frac{300^2 \times 100\pi \times 1000}{2 \times 2 \times 10^5} = 22500\,\pi$$

Equating work done with strain energy

61.5 W = 22500 π

$\Rightarrow$ $W = 1149.36$ N. Choice (A)

17. $P = 1000$ kW = 1000×10^6 N-mm/s

$N = 350$ rpm

$d_1 = 150$ mm, $d_2 = 120$ mm

$L = 1$ m = 1000 mm, $G = 80$ kN/mm²

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

$$\text{i.e., } 1000 \times 10^6 = \frac{2\pi \times 350 \times T}{60}$$

$\Rightarrow$ $T = 27.284 \times 10^6$ N-mm

$$J = \frac{\pi}{32}\left(d_1^4 - d_2^4\right) = \frac{\pi}{32}\left(150^4 - 120^4\right)$$

$= 29.343 \times 10^6$ mm⁴

$$\tau = \frac{T}{J} \times \frac{d_1}{2}$$

$$= \frac{27.284}{29.343} \times \frac{150}{2} = 69.74 \text{ N/mm}^2$$

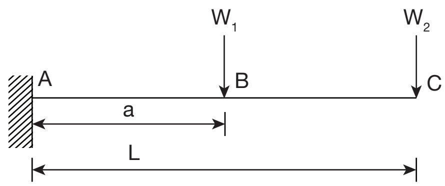
Strain energy stored

$$U = \frac{\tau_s^2}{4G} \times \left(\frac{d_1^2 + d_2^2}{d_1^2}\right) \times volume$$

$$= \frac{(69.74)^2}{4\times 80\times 10^3}\times\left(\frac{150^2+120^2}{150^2}\right)\times\frac{\pi}{4}\left(150^2-120^2\right)\times 1000$$

= 158574 N-mm = 158.57 J. Choice (A)

18.



For loading as shown above, deflection at C

$$y_c = \frac{W_1a^3}{3EI}+\frac{W_1a^2}{2EI}(L-a)+\frac{W_2L^3}{3EI}$$

$E\,I = 4\times 10^4$ kN-m^2

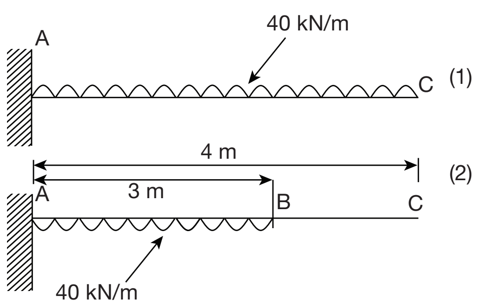
Substituting corresponding values,

$$y_c = \frac{1}{4\times 10^4}\left[\frac{10\times 2^3}{3}+\frac{(3-2)\times 10\times 2^2}{2}+\frac{15\times 3^3}{3}\right]$$

$= 45.42\times 10^{-4}$ m

= 4.542 mm. Choice (D)

19.



Loading of the beam can be split into as shown below

Total deflection at C

= downward deflection due to loading (1)

− upward deflection due to loading (2)

$$= \frac{wL^4}{8EI}-\left[\frac{wa^4}{8EI}+\frac{wa^3}{6EI}(L-a)\right]$$

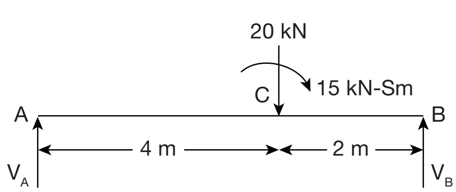
Where $a = 3$ m, $L = 4$ m

$$= \frac{w}{EI}\left\{\frac{L^4}{8}-\left[\frac{a^4}{8}+\frac{a^3}{6}(L-a)\right]\right\}$$

$$= \frac{40}{36\times 10^4}\left[\frac{4^4}{8}-\left(\frac{3^4}{8}+\frac{3^3}{6}\times 1\right)\right]$$

$= 19.3\times 10^{-4}$ m = 1.93 mm. Choice (C)

20.



Equivalent loading of the given loading is as shown above.

Taking moment about B

$V_A\times 6 = 20\times 2 - 15$

$$V_A = \frac{20\times 2-15}{6} = 4.167 \text{ kN}$$

$Mx = 4.167\,x - 20(x-4) + 15(x-4)^0$

$$= EI\,\frac{d^2y}{dx^2}$$

$$EI\frac{dy}{dx} = C_1 + 4.167\frac{x^2}{2} - 20\frac{(x-4)^2}{2} + 15(x-4)$$

$$EI\,y = C_2 + C_1x + 4.167\times\frac{x^3}{6} - 10\frac{(x-4)^3}{3} + 15\frac{(x-4)^2}{2}$$

At $x = 0$, $y = 0$

$\therefore\quad 0 = C_2 + 0 + 0$

$C_2 = 0$

At $x = 6$, $y = 0$

$$\therefore\quad 0 = 0 + 6\,C_1 + 4.167\times\frac{6^3}{6} - 10\times\frac{2^3}{3} + \frac{15}{2}\times 2^2$$

$= 6C_1 + 150 - 26.67 + 30$

$\Rightarrow\quad C_1 = -25.555$

Deflection at point C

ie at $x = 4$,

$$EI\,y_c = -25.555\times 4 + 4.167\times\frac{4^3}{6} = -57.772$$

$$y_c = \frac{-57.772}{15000}$$

$= -3.85\times 10^{-3}$ m $= -3.85$ mm

= 3.85 mm down ward Choice (D)

21. $L = 2000$ mm; $d = 300$ mm

$t = 10$ mm; $E = 2\times 10^5$ N/mm^2

$\mu = 0.3$

$\delta\,V = 30{,}000$ mm^3

$$V = \frac{\pi d^2}{4}L = \frac{\pi}{4}\times(300)^2\times 2000$$

Volumetric strain

$$= \frac{\delta V}{V} = \frac{30000\times 4}{\pi\times(300)^2\times 2000} = 2.122\times 10^{-4}$$

$$\text{Volumetric strain} = \frac{pd}{4tE}(5-4\mu)$$

$$\therefore\quad 2.122\times 10^{-4} = \frac{p\times 300}{4\times 10\times 2\times 10^5}(5-4\times 0.3)$$

$\Rightarrow\quad p = 1.489$ N/mm^2.

Choice (A)

22. $L = 2000$ mm, $d = 200$ mm, $t = 10$ mm

$$\frac{\delta v}{v} = 3.98\times 10^{-4}$$

$E = 2 \times 10^5$ N/mm^2, $\mu = 0.3$

$$\frac{\delta v}{v} = \frac{pd}{4tE}(5-4\mu)$$

$$\therefore \quad 3.98 \times 10^{-4} = \frac{p \times 200}{4 \times 10 \times 2 \times 10^5}(5 - 4 \times 0.3)$$

$\Rightarrow \quad p = 4.1895$ N/mm^2

Longitudinal strain

$$\frac{\delta L}{L} = \frac{pd}{4tE}(1-2\mu)$$

$$= \frac{4.1895 \times 200}{4 \times 10 \times 2 \times 10^5}(1 - 2 \times 0.3)$$

$= 4.1895 \times 10^{-5}$

Change in length $= 4.1895 \times 10^{-5} \times 2000$

$= 0.08379$ mm Choice (C)

23. Deflection of simply supported beam with concentrated load at centre

$$\delta = \frac{WL^3}{48EI}$$

$$\text{i.e, } 12 = \frac{10 \times (6000)^3}{48EI}$$

$\Rightarrow \quad EI = 3.75 \times 10^9$

$$\text{Euler's crippling load} = \frac{\pi^2 EI}{L^2}$$

$$= \frac{\pi^2 \times 3.75 \times 10^9}{(6000)^2} = 1028.1 \text{ N.}$$ Choice (B)

24. External diameter = 200 mm

Internal diameter = 160 mm

$$\text{Effecting length} = \frac{\text{Actual length}}{\sqrt{2}}$$

$$= \frac{4.5 \times 10^3}{\sqrt{2}} = 3181.98 \text{ mm}$$

$f_c = 550$ N/mm^2

$$a = \frac{1}{1600}$$

$$k^2 = \frac{I}{A} = \frac{\frac{\pi}{64}(200^4 - 160^4)}{\frac{\pi}{4}(200^2 - 160^2)}$$

$$= \frac{1}{16}(200^2 + 160^2) = 4100$$

$k = 64.031$ mm

Rankine's critical load

$$P_{cr} = \frac{f_c A}{1 + a\left(\ell/k\right)^2}$$

$$= \frac{550 \times \frac{\pi}{4}(200^2 - 160^2)}{1 + \frac{1}{1600}\left(\frac{3181.98}{64.031}\right)^2}$$

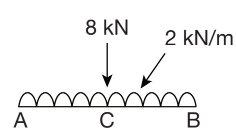
$$= \frac{6220353.454}{2.543456} = 2445{,}630 \text{ N}$$

$= 2445.63$ kN. Choice (A)

25. At point A the shear force is increasing suddenly, therefore the reaction at $A = 14$ kN,

- From A to C the intensity is decreasing linearly from 14 kN to 4 kN, therefore there is a uniformly distributed load of $\left(\frac{14-4}{5}\right) = \frac{10}{5} = 2$ kN/m
- At point C, the shear force decreases suddenly, therefore a point load of $4 - (-4) = 8$ kN is acting at C
- From C to B the shear force is increasing linearly from -4 kN to -14 kN, therefore a UDL of $\left(\frac{-4-(-14)}{5}\right) = \frac{10}{5} = 2$ kN/m is acting in between

C to B



Choice (C)