Strength of Materials Test 1

Number of Questions 35 **Time:60 min.**

Directions for questions 1 to 35: Select the correct alternative from the given choices.

1. The maximum value of completely reversed stress that a material can withstand for an infinite number of cycle without any fatigue failure is known as
   (A) tensile limit (B) ultimate limit
   (C) endurance limit (D) yield limit

2. The radius of a sphere changes from 15 cm to 10 cm. The value of volumetric strain is
   (A) 1.5 (B) 1
   (C) 2 (D) 0.5

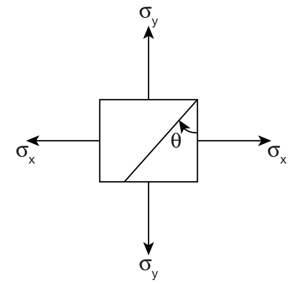
3. A rod of diameter '*d*' is subjected to twisting moment '*T*'. If 'τ' is shear stress applied and '*G*' is modulus of rigidity then proof resilience is
   (A) $\frac{\tau^2}{2G} \times$ Volume of rod
   (B) $\frac{\tau^2}{G} \times$ Volume of rod
   (C) $\frac{\tau}{2G} \times$ Volume of rod
   (D) $\frac{\tau}{G} \times$ Volume of rod

4. Three bars with different diameter and different length is attached in series from the fixed end. An axial load '*P*' is applied at free end. What is the magnitude of load carried by each bar individually?
   (A) 3*P* (B) $\frac{P}{3}$
   (C) *P* (D) Insufficient data

5. A steel rod 20 m long is at a temperature of 20°C. If temperature is raised by 60°C, then the free expansion of length in mm will be
   (Assume thermal stress coefficient, $\alpha = 12 \times 10^{-6}$°C)
   (A) 9.6 (B) 9.6×10^{-3}
   (C) 14.4 (D) 14.4×10^{-3}

6. Which one of the following assumption made in bending equation is NOT correct
   (A) Member is assumed to be prismatic.
   (B) Member is subjected to bending about one of its centroidal axis.
   (C) Bending moment = constant and Shear force = zero.
   (D) Cross–section plane is not plane after bending.

7. State of stress in 2-*D* is shown in the figure. Shear stress on a plane at an angle 'θ' from vertical principal plane is 'τ'. What will be the shear stress on a plane situated at an angle '90 + θ'?



   (A) –τ (B) +τ
   (C) 2τ (D) Zero

8. With one fixed end and other free end, a column of length '*L*' buckles at load P_1. Another column of same length and same cross–section hinged at both ends buckles at load P_2. The ratio of P_2/P_1 is
   (A) 2 (B) 1/2
   (C) 1/4 (D) 1/16

9. Which one of the following is correct in respect of Poisson's ratio (μ) limits for an isotropic elastic solid?
   (A) $-\infty \le \mu \le \infty$ (B) $\frac{1}{4} \le \mu \le \frac{1}{3}$
   (C) $1 \le \mu \le \frac{1}{2}$ (D) $-\frac{1}{2} \le \mu \le \frac{1}{2}$

10. In a strained material one of the principal stress is thrice the other. The maximum shear stress in the same case is τ_{max}. Then, what is the value of the maximum principal stress?
    (A) τ_{max} (B) $1.5\tau_{max}$
    (C) $3\tau_{max}$ (D) $6\tau_{max}$

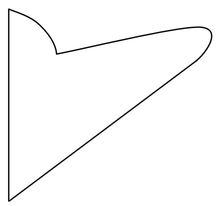
11. A weight falls on a collar rigidly attached to the lower end of a vertical bar 5 m long and 800 mm² in section. If the maximum instantaneous extension is 2 mm, then stress in the bar in MPa will be
    (Take *E* = 200 GPa)
    (A) 40 (B) 100
    (C) 160 (D) 80

12. A simply supported beam of 2 m span carries a triangular load of 20 kN. The magnitude of maximum shear force in kN will be
    (A) 10 (B) 20
    (C) 40 (D) 15

13. A grider of uniform section and constant depth is freely supported over a span of 5 m. If the point load at mid-span is 50 kN and $I_{XX} = 12 \times 10^{-6}$m⁴, then the central deflection in m will be
    (A) 0.079 (B) 0.084
    (C) 0.054 (D) 0.069

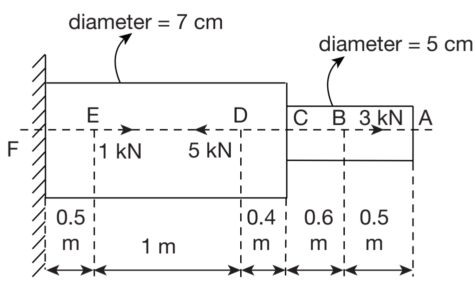
14. A hollow shaft is subjected to a torque of 40 kN-m and a bending moment of 60 kN-m. Equivalent torque in kN-m will be
(A) 50 (B) 56
(C) 40 (D) 72

15. The distribution of shear stress of a beam is shown in the given figure.



The cross–section of the beam is
(A) *I* (B) *T*
(C) *A* (D) Δ

16. Series of bar is shown in below figure. If $E = 200$ GPa, then the total change in length in m is



(A) 5.4×10^{-6} (B) 2.9×10^{-6}
(C) 6.49×10^{-6} (D) 4.9×10^{-6}

17. In a triaxial stress element, the principal stresses are 20, 0 and –50 MPa. Magnitude of maximum shear strain will be (in mm)
(Assume $E = 200$ GPa and $\mu = 0.3$)
(A) 0.5 (B) 0.22
(C) 0.455 (D) 0.105

18. A rectangular beam 400 mm deep is simply supported over a span of 5 m. If the bending stress is not to exceed 120 MPa and given $I = 230 \times 10^6 mm^4$ then the uniformly distributed load carried by the beam in kN/m will be
(A) 90 (B) 82
(C) 34 (D) 44

19. A hollow steel shaft of 400 mm external diameter and 250 mm internal diameter has to be replaced by a solid alloy shaft. Assuming the same values of polar modulus for both, the ratio of their torsional rigidities is [Assume $(G)_{steel} = 2.4(G)_{alloy}$]
(A) 1.44 (B) 0.44
(C) 2.536 (D) 2.412

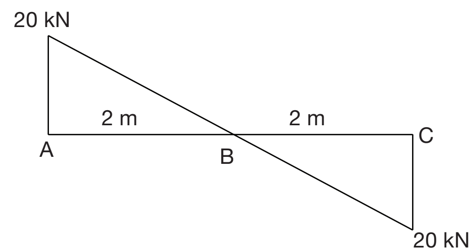
20. A thin spherical shell 2 m in diameter with its wall of 2.5 cm thickness is filled with a fluid at atmospheric pressure. If 200 cm^3 more fluid is pumped into the shell, then the circumferential stress in MPa will be

(Take $E = 200$ GN/m^2, $\frac{1}{m} = 0.3$)

(A) 6.68 (B) 4.55
(C) 9.89 (D) 5.67

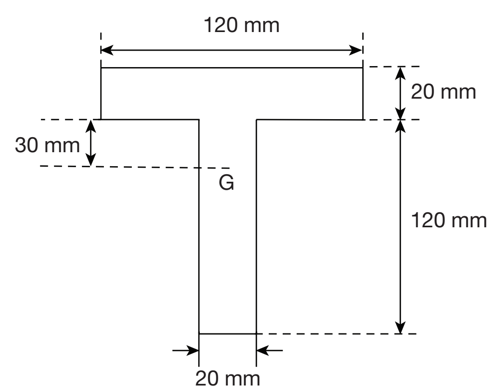
21. A cantilever beam of 5 m span carries a uniformly distributed load of 2 kN/m over its entire span and a point load of 3 kN at free end. If the same beam is simply supported at two ends, what point load at the centre should it carry to have same deflection as the cantilever?
(A) 146 kN (B) 138 kN
(C) 92 kN (D) 108 kN

22. A shear force diagram of a loaded beam is shown in figure. The maximum bending moment in the beam is (kN-m)



(A) 20 (B) 40
(C) 10 (D) 30

23. If the *T*- beam cross–section shown in the given figure has bending stress of 50 MPa in the top fibre, then the stress (MPa) in the bottom fibre would be
G is centroid



(A) 50 (B) 30
(C) –70 (D) Zero

24. A thin cylindrical tube 100 mm internal diameter and 6 mm thick, is closed at the ends and is subjected to an internal pressure of 8 MN/mm^2. If torsional shear stress applied to the tube is 40 MN/m^2, then the maximum shear stress in MN/m^2 will be
(A) 6.7 (B) 93.3
(C) 50 (D) 43.3

25. Two vertical rods, one of brass and the other of aluminium are rigidly fastened at upper ends at a horizontal distance of 800 mm apart. Each rod is 5 m long and cross–sectional area of $7 \times 10^{-4} m^2$. A horizontal cross–piece connects the lower end of the bars. Where should a load of 5 kN be placed from brass rod on the cross piece so that it remains horizontal after being loaded? (Assume $\sigma_{brass} = 2\sigma_{aluminium}$)

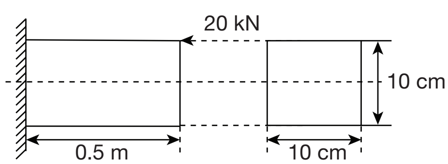
(A) 532.8 mm (B) 267.2 mm
(C) 432.3 mm (D) 367.2 mm

26. Match List – I with List – II and select the correct answer using the codes given below the lists.

	List – I		List – II
P	Brittleness	1	Absorption of energy at high stress without rupture
Q	Toughness	2	Failure without warning
R	Ductility	3	Drawn permanently over great changes of shape without rupture
S	Tenacity	4	High tensile strength

	P	*Q*	*R*	*S*
(A)	3	4	2	1
(B)	4	3	1	2
(C)	1	2	3	4
(D)	2	1	3	4

27. A beam of square cross-section is having eccentric loading as shown in below figure. A load of 20 kN is applied on the top fibre of beam axially.



Determine the maximum resistive stress (MPa) on top fibre if beam has not to fail.

(A) 8 (B) 2
(C) 6 (D) 4

28. When a 40 mm diameter rod is subjected to an axial pull of 5000 kN it was found that diameter changes to 39.8 mm but volume remains same. The value of Poisson's ratio will be approximately.

(A) 0.2 (B) 0.5
(C) 0.3 (D) 0.35

29. A 6 m long beam, simply supported at its ends carries a point load '*W*' at its centre. If the deflection at the centre of the beam is 69.813 mm, then the deflection at the end of the beam will be

(A) 1° (B) 3°
(C) 1.4° (D) 2°

30. A circular beam of 200 mm diameter is subjected to a shear force of 50 kN. The maximum shear stress in MPa will be

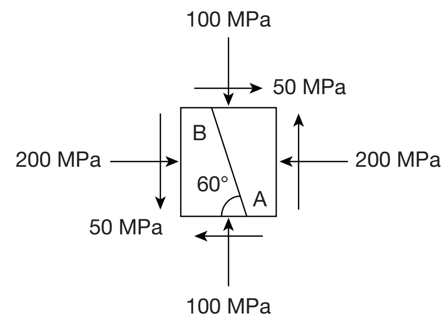
(A) 3.91 (B) 2.12
(C) 1.59 (D) 2.71

31. A closely coiled helical spring of round steel wire 6 mm in diameter having 15 complete coils of 60 mm mean diameter is subjected to an axial load of 200 N. The maximum shearing stress in the material (in MPa) will be

(A) 101.15 (B) 121.5
(C) 141.5 (D) 131.5

Common Data Questions 32 and 33:

A machine component is subjected to the stresses as shown in the figure.



32. The normal stress on the section *AB* in MPa will be

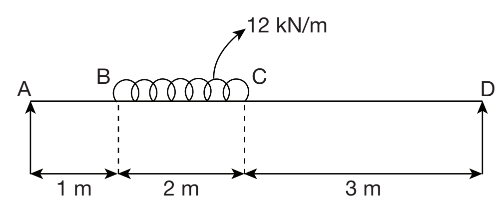
(A) +131.7 (B) –131.7
(C) –157.7 (D) 129.8

33. The shearing stress on the section *AB* in MPa will be

(A) –68.3 (B) +68.3
(C) +91.3 (D) –81.4

Linked Answer question 34 and 35:

A simply supported beam 6 m long is loaded with uniformly distributed load of 12 kN/m over a length of 2 m as shown



34. The reaction force at *A* in kN will be

(A) 24 (B) 8
(C) 16 (D) 12

35. The shear force at *D* in kN will be

(A) 0 (B) 16
(C) 12 (D) 8

Answer Keys

1. C	**2.** B	**3.** A	**4.** C	**5.** C	**6.** D	**7.** A	**8.** B	**9.** B	**10.** C
11. D	**12.** A	**13.** C	**14.** D	**15.** B	**16.** B	**17.** C	**18.** D	**19.** C	**20.** B
21. D	**22.** A	**23.** C	**24.** D	**25.** B	**26.** D	**27.** A	**28.** B	**29.** D	**30.** B
31. C	**32.** B	**33.** A	**34.** C	**35.** D					

Hints and Explanations

1. Choice (C)

2. Volumetric strain, $\varepsilon_V = 3\left(\frac{\delta D}{D}\right)$

$\therefore \quad \varepsilon_V = 3 \times \frac{10}{30} = 1$ Choice (B)

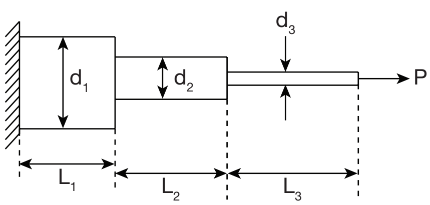
3. Under twisting moment

Modulus of resilience $= \frac{1}{2} \times \tau \times \gamma$ {Under elastic limit}

$\Rightarrow \quad \frac{\text{Proof resilience}}{\text{volume}} = \frac{1}{2} \times \tau \times \frac{\tau}{G} \left\{\gamma = \frac{R\theta}{L} = \frac{\tau}{G}\right\}$

$\therefore \quad$ Proof resilience $= \frac{\tau^2}{2G} \times$ volume Choice (A)

4. Case of compound Bar. Bars are connected in series.



Deflection $(\delta) = \delta_1 + \delta_2 + \delta_3$

Load $(P) = P_1 = P_2 = P_3$ Choice (C)

5. $\delta = \alpha \Delta T L = 12 \times 10^{-6} \times 60 \times 20 \times 1000$

$\therefore \quad \delta = 14.4$ mm Choice (C)

6. Choice (D)

7. $(\tau)_\theta = \frac{-1}{2}\left[\sigma_x - \sigma_y\right](\text{Sin}\, 2\theta) + \tau_{xy} \cos 2\theta$

$(\tau)_{90+\theta} = \frac{-1}{2}\left[\sigma_x - \sigma_y\right](-\text{Sin}\, 2\theta)$

$\therefore \quad -\tau = (\tau)_{90+\theta}$ Choice (A)

8. $P_1 = \frac{2\pi^2 E I_{\min}}{L^2}$ and $P_2 = \frac{\pi^2 E I_{\min}}{L^2}$

$\frac{P_2}{P_1} = \frac{1}{2}$ Choice (B)

9. Choice (B)

10. $\sigma_1 = 3\sigma_2$

$\tau_{\max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{\sigma_1 - \frac{\sigma_1}{3}}{2}$

$\therefore \quad 2\tau_{\max} = \frac{2}{3}\sigma_1$

$\therefore \quad \sigma_1 = 3\tau_{\max}$ Choice (C)

11. Instantaneous extension of the bar (δL),

$2 = \frac{\sigma \times L}{E}$

$\Rightarrow \quad \frac{\sigma \times 5 \times 10^3}{200 \times 10^3}$

$\therefore \quad \sigma = 80$ MPa Choice (D)

12. Reaction at supported end $= \frac{20}{2} = 10$ kN

Maximum shear force = 10 kN Choice (A)

13. $Y_{\max} = \frac{WL^3}{48EI} = \frac{50 \times 10^3 \times 5^3}{48 \times 200 \times 10^9 \times 12 \times 10^{-6}}$

$\therefore \quad Y_{\max} = 0.0542$ m Choice (C)

14. $T_e = \sqrt{M^2 + T^2}$

$T_e = \sqrt{40^2 + 60^2}$

$= 72.1$ kNm Choice (D)

15. Choice (B)

16. Total deflection, $\delta = \delta_{AB} + \delta_{BC} + \delta_{CD} + \delta_{DE} + \delta_{EF}$

Area of $AC = \frac{\pi}{4} \times 0.05^2 = 1.9635 \times 10^{-3}\text{m}^2$

Area of $CF = \frac{\pi}{4} \times 0.07^2 = 3.85 \times 10^{-3}\text{m}^2$

$\delta = 0 + \frac{3 \times 0.6}{\left(1.9635 \times 10^{-3} \times 200 \times 10^6\right)} +$

$\frac{3 \times 0.4}{\left(3.85 \times 10^{-3} \times 200 \times 10^6\right)}$

$\frac{2 \times 1}{\left(3.85 \times 10^{-3} \times 200 \times 10^6\right)} - \frac{1 \times 0.5}{\left(3.85 \times 10^{-3} \times 200 \times 10^6\right)}$

$\therefore \quad \delta = 2.9 \times 10^{-6}$m Choice (B)

17. $\sigma_1 = 20$ MPa; $\sigma_2 = 0$; $\sigma_3 = -50$ MPa

$\varepsilon_1 = \frac{\sigma_1}{E} - \mu\left[\frac{\sigma_2 + \sigma_3}{E}\right]$

$\Rightarrow \quad \varepsilon_1 = \frac{1}{\left(200 \times 10^3\right)}\left[20 - 0.3(-50)\right]$

$\Rightarrow \quad \varepsilon_1 = 1.75 \times 10^{-4}$ m or 0.175 mm

$$\varepsilon_2 = \frac{\sigma_2}{E} - \mu\left[\frac{\sigma_3 + \sigma_1}{E}\right]$$

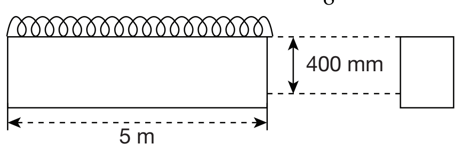
$$\Rightarrow \quad \varepsilon_2 = -0.3\left[\frac{-30}{200\times10^3}\right] = 0.045 \text{ mm}$$

$$\varepsilon_3 = \frac{\sigma_3}{E} - \mu\left[\frac{\sigma_2 + \sigma_1}{E}\right]$$

$$\Rightarrow \quad \varepsilon_3 = \frac{-50}{\left(200\times10^3\right)} - 0.3\left[\frac{20}{200\times10^3}\right] = -0.28 \text{ mm}$$

Maximum shear strain = $\varepsilon_1 - \varepsilon_3$
= 0.175 – (–0.28)
= 0.455 mm Choice (C)

18. Maximum bending moment, $M = \dfrac{wL^2}{8}$



$$M = \sigma_{max} \times Z = \frac{120\times230\times10^6\times2}{400}$$

$M = 138 \times 10^6$ N-mm

$$\therefore \quad 138 \times 10^6 = \frac{w\times(5000)^2}{8}$$

$\therefore \quad$ w = 44.16 N/mm Choice (D)

19. $(Z)_{steel} = (Z)_{alloy}$

$$\frac{\pi}{16\times400}\left[400^4 - 250^4\right] = \frac{\pi}{16}\times D_A^3$$

$\therefore \quad D_A = 378.522$ mm

Torsional rigidity = G × J

$$\therefore \quad \frac{(\text{Torsional rigidity})_{steel}}{(\text{Torsional rigidity})_{alloy}}$$

$$= \frac{2.4G\times\frac{\pi}{32}\left[400^4 - 250^4\right]}{G\times\frac{\pi}{32}(378.522)^4} = 2.536$$ Choice (C)

20. Volumetric strain, $\varepsilon_V = \dfrac{\delta V}{V} = \dfrac{200\times10^{-6}}{\frac{4}{3}\times\pi\times(1)^3}$

$\therefore \quad \varepsilon_V = 4.77465 \times 10^{-5}$

$\varepsilon_V = 3\varepsilon \Rightarrow \varepsilon = 1.59155 \times 10^{-5}$

Now, $\varepsilon = \dfrac{\sigma_c}{E}\left[1 - \dfrac{1}{m}\right]$

$$\therefore \quad 1.59155\times10^{-5} = \frac{\sigma_C}{\left(200\times10^9\right)}[1-0.3]$$

$\therefore \quad \sigma_c = 4.55$ MPa Choice (B)

21. Cantilever : $y_{max} = \dfrac{WL^3}{8EI} + \dfrac{WpL^3}{3EI}$

$$Y'_{max} = \frac{L^3}{EI}\left[\frac{10}{8} + \frac{3}{3}\right] = \frac{2.25L^3}{EI}$$

SSB: $y'_{max} = \dfrac{WL^3}{48EI} = \dfrac{2.25L^3}{EI}$ $\{y'_{max} = y'_{max}\}$

$$\Rightarrow \quad \frac{2.25L^3}{EI} \quad \frac{WL^3}{48EI}$$

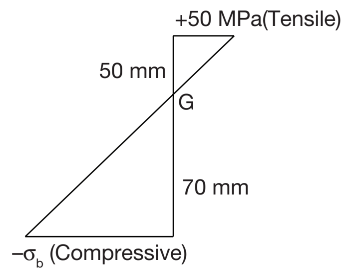
$\Rightarrow \quad W = 108$ kN Choice (D)

22. Bending moment is maximum at B

$M_B - M_A$ = Area of SFD between B and A

$\therefore \quad M_B = \dfrac{1}{2}\times20\times2 = 20$ kN-m Choice (A)

23.



$$\frac{50}{50} = \frac{-\sigma_b}{70}$$

$\therefore \quad \sigma_b = -70$ MPa

or $\sigma_b = 70$ MPa (Compressive) Choice (C)

24. Hoop stress, $\sigma_c = \dfrac{pd}{2t} = \dfrac{8\times10^6\times0.1}{2\times0.006}$

$\Rightarrow \quad \sigma_c = 66.67$ MPa $= \sigma_x$

Longitudinal stress, $\sigma_L = \dfrac{pd}{4t} = 33.34$ MPa

$\therefore \quad \sigma_L = \sigma_y = 33.34$ MPa

$\tau_{xy} = 40$ MPa (Given)

Maximum shear stress, $\tau_{max} = \sqrt{\left(\dfrac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^{\ 2}}$

$$\therefore \quad \tau_{max} = \sqrt{\left(\frac{66.67 - 33.34}{2}\right)^2 + 40^2}$$

$\Rightarrow \quad \tau_{max} = 43.33$ MPa Choice (D)

25. $\sigma_b = 2\sigma_a$

$P = P_b + P_a$

$P = \sigma_b A_b + \sigma_a A_a$

$5 \times 10^3 = 2\sigma_a A_a + \sigma_a A_a$

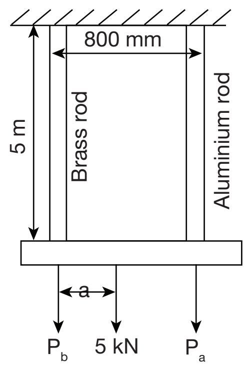
$$\therefore \quad \sigma_a = \frac{\left(5\times10^3\right)}{3A_a}$$

$$\Rightarrow \quad \sigma_a = \frac{(5\times10^3)}{(3\times7\times10^{-4})}$$

$\sigma_a = 2.381\text{MPa}$

$P_a = \sigma_a A_a = 2.381 \times 7 \times 10^{-4}$

$\Rightarrow \quad P_a = 1.67$ kN



Taking moment from line of P_B we get

$P_a \times 0.8 = 5 \times a$

$$\Rightarrow \quad \frac{1.67\times0.8}{5} = a$$

$\therefore \quad a = 267.2$ mm Choice (B)

26. Choice (D)

27. Top fibre is having compressive stress due to eccentric loading.

$$\sigma_{\max} = \frac{P}{A} + \frac{M}{Z}$$

$$\Rightarrow \quad \sigma_{\max} = \frac{(20\times10^3)}{(0.1\times0.1)} + \frac{20\times10^3\times.05\times.05\times12}{0.1^4}$$

$\sigma_{\max} = 8$ MPa (Compressive) Choice (A)

28. Initial volume = Final volume

$$\frac{\pi}{4}\times40^2\times L_i = \frac{\pi}{4}\times39.8^2\times L_f$$

$$\therefore \quad \frac{L_f}{L_i} = 1.010075$$

$$\text{or} \quad \frac{L_f}{L_i} - 1 = \frac{\delta L}{L_i} = 0.010075$$

$$\frac{\delta D}{D_i} = \frac{39.8-40}{40} = -0.005$$

$$\mu = \left|\frac{-\delta D/D_i}{\delta L/L_i}\right| = 0.4963 \sim 0.5$$ Choice (B)

29. Maximum deflection, $y = \frac{WL^3}{48EI}$

Maximum slope, $\theta = \frac{WL^2}{16EI}$

$$\therefore \quad \theta = \frac{3y}{L} = \frac{3\times0.06981}{6}\times\frac{180}{\pi}$$

$\therefore \quad \theta = 2°$ Choice (D)

30. $\tau_{avg} = \frac{F}{A} = \frac{50\times10^3}{\pi/4\times0.2^2} = 1.59155$ MPa

$\tau_{maximum} = 1.33 \times \tau_{avg}$

$= 2.11676$ MPa

~ 2.12 MPa Choice (B)

31. $W \times R = \frac{\pi}{16}\times\tau\times d^3$

$200 \times 30 = \frac{\pi}{16}\times\tau\times6^3$

$\tau = 141.5$ MPa Choice (C)

32. $\sigma_n = \frac{\sigma_x+\sigma_y}{2} - \frac{\sigma_x-\sigma_y}{2}\cos2\theta - \tau_{xy}\,\text{Sin}\,2\theta$

$$\sigma_n = \frac{-200+(-100)}{2} - \frac{-200-(100)}{2}\cos(2\times60°) - [-50\times\text{Sin}(2\times60°)]$$

$\Rightarrow \quad \sigma_n = -131.7$ MPa Choice (B)

33. $\tau = \frac{\sigma_x-\sigma_y}{2}\text{Sin}\,2\theta - \tau_{xy}\cos2\theta$

$$= \frac{-200-(-100)}{2}\times\text{Sin}(120°) - [-50\times\text{Cos}120°]$$

$= -68.3$ MPa Choice (A)

34. Moment about D we get

$R_A \times 6 - 24 \times 4 = 0$

$\therefore \quad R_A = 16$ kN Choice (C)

35. Shear force

$F_A = +R_A = 16$ kN

$F_B = 16$ kN

$F_C = 16 - (12 \times 2) = -8$ kN

$F_D = -8$ kN Choice (D)