S.No. : 06 SP1_ME_T_280619
Strength of Material

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

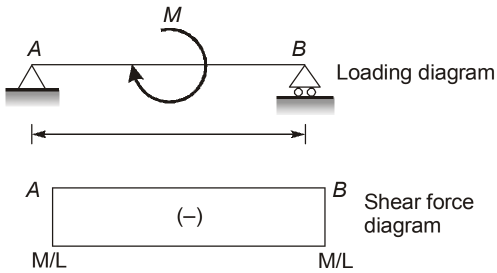
Date of Test : 28/06/2019

ANSWER KEY ➤ Strength of Material

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

DETAILED EXPLANATIONS

1. (c)



2. (b)

$$\text{Load } (P) = 5 \text{ kN} = 5 \times 10^3 \text{ N}$$

$$\text{Stress} = 100 \text{ MPa} = 100 \text{ N/mm}^2$$

We know that, $\sigma_{impact} = \sigma_{static} \times \text{Impact factor}$

For suddenly applied load,

$$\text{Impact factor} = 2$$

Here for safety σ_{impact} should not exceed 100 MPa.

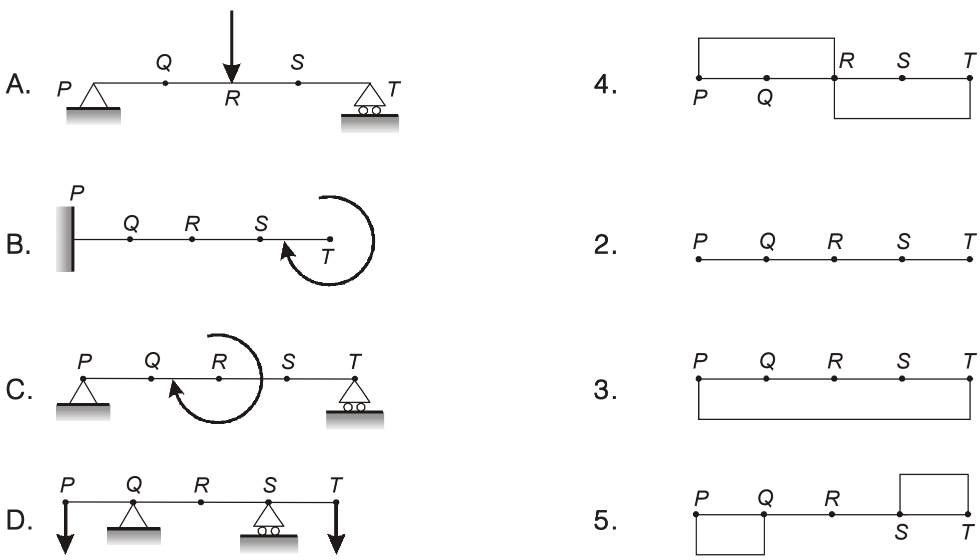
$$\Rightarrow \quad \sigma_{static} = \frac{\sigma_{Impact}}{\text{Impact factor}} = \frac{100}{2}$$

$$= 50 \text{ N/mm}^2$$

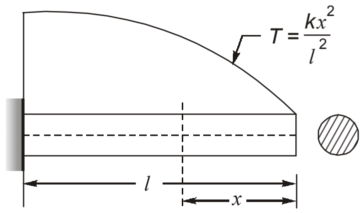
$$\Rightarrow \quad 50 = \frac{P}{A} = \frac{5\times 10^3}{\frac{\pi}{4}\times d^2} = \frac{6366.1977}{d^2}$$

$$\Rightarrow \quad d = 11.28 \text{ mm}$$

3. (d)



4. (a)



$$T = \frac{kx^2}{l^2}$$

$$\theta = \int \frac{Tdx}{GJ}$$

$$= \frac{1}{GJ}\int Tdx = \frac{1}{GJ}\int_0^l \frac{kx^2}{l^2}dx$$

$$= \frac{k}{GJl^2}\left|\frac{x^3}{3}\right|_0^l = \frac{kl}{3GJ}$$

5. (b)

$$M = Pe$$

$$(\sigma_b)_{AB} = \frac{My}{I_{xx}} = \frac{5Pe}{I_{xx}}\text{(tensile)}$$

$$(\sigma_a)_{AB} = \left(\frac{P}{A}\right)\text{(compressive)}$$

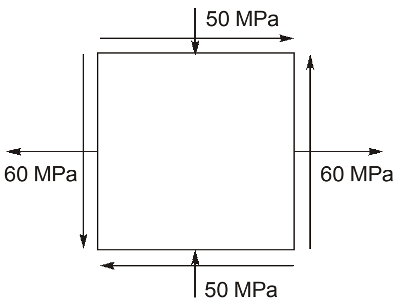
$$\text{Total stress at } AB = \frac{P}{A} - \frac{5Pe}{I_{xx}}\text{ (compressive)}$$

6. (c)

For beam of uniform strength, maximum bending stress remains constant throughout.

7. (c)

According to the given conditions



$$\sigma_{1,2} = \frac{1}{2}\left[(\sigma_x + \sigma_y) \pm \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^{\ 2}}\right]$$

$$\sigma_1 = \frac{1}{2}\left[(\sigma_x + \sigma_y) + \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^{\ 2}}\right]$$

$$125 = \frac{1}{2}\left[(60-50)+\sqrt{(60+50)^2+4\tau_{xy}^{\ 2}}\right]$$

$$\Rightarrow \qquad \tau_{xy} = 106.65 \text{ MPa}$$

8. (c)

$$\frac{Pd}{2t} = \sigma_{per}$$

$$\frac{P\times(1750-2\times16)}{2\times16} = \left(\frac{450}{5}\right)$$

Internal pressure, $P = \dfrac{450\times2\times16}{(1750-32)\times5} = 1.67 \text{ MPa}$

9. (c)

$$P_e = \frac{\pi^2 EI}{(L_e)^2}$$

L_e = Effective length of column

For both end fixed, $L_e = \dfrac{l}{2}$

$$\Rightarrow \qquad P_e = \frac{4\pi^2 EI}{l^2}$$

10. (c)

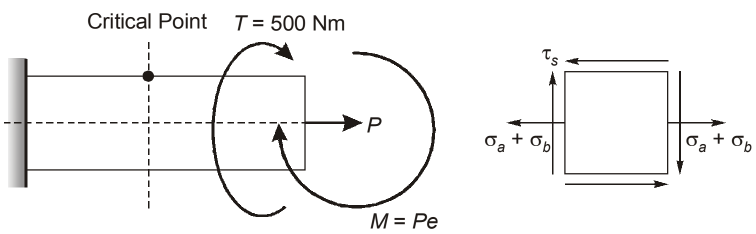
Average force, $F = \dfrac{d\vec{P}}{dt} = \dfrac{m(v-u)}{t}$

$$= \frac{20000(50-10)}{20}\times\frac{1000}{3600} = 11111.11 \text{ N or } 11.11 \text{ kN}$$

11. (b)

Cross-section remains plane and undistorted for circular shaft only but not for non-circular shaft.

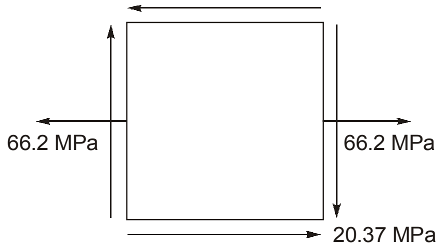
12. (b)



$$\sigma_a = \frac{P}{A} = \frac{50\times10^3}{\frac{\pi}{4}\times50^2} = 25.46 \text{MPa}$$

$$\sigma_b = \frac{My}{I_{NA}} = \frac{50\times10^3\times10\times25\times64}{\pi\times(50)^4} = 40.74 \text{ MPa}$$

$$\tau_s = \frac{16T}{\pi d^3} = \frac{16 \times 500 \times 10^3}{\pi \times (50)^3} = 20.37\,\text{MPa}$$

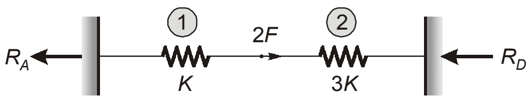


According to MDET,

$$\sqrt{\sigma_x{}^2 + 3\tau_{xy}{}^2} = \frac{S_{yt}}{N}$$

$$N = 2.67$$

13. (d)



$$P_1 = R_A,$$

$$P_2 = R_A - 2F \text{ or } - R_D$$

$$= R_A + R_D = 2F$$

$$\delta_1 + \delta_2 = 0$$

$$\frac{P_1}{K_1} + \frac{P_2}{K_2} = 0$$

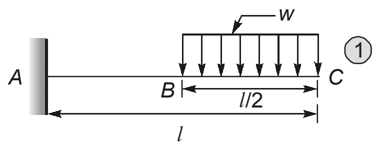
$$\frac{R_A}{K} + \frac{(R_A - 2F)}{3K} = 0$$

$$R_A = \frac{F}{2}$$

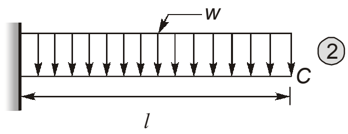
$$U_1 = \frac{1}{2}P_1\delta_1 = \frac{1}{2} \times \frac{F}{2} \times \left[\frac{P_1}{K_1}\right]$$

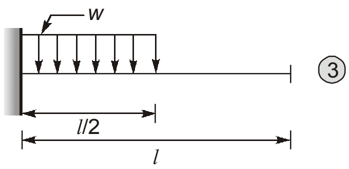
$$= \frac{1}{2} \times \frac{F}{2} \times \left[\frac{F}{2 \times K}\right] = \frac{F^2}{8K}$$

14. (b)



By use of superposition principle

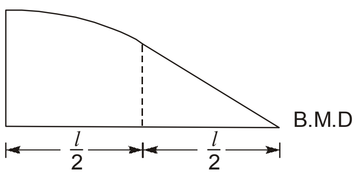




$$\delta_1 = \delta_2 - \delta_3$$

We know that $$\delta_2 = \left(\frac{wl^4}{8EI}\right)$$

For case (3)



$$\delta_3 = \left[\frac{w\left(\frac{l}{2}\right)^3}{6EI} \times \frac{l}{2} + \frac{w\left(\frac{l}{2}\right)^4}{8EI}\right] = \left(\frac{wl^4}{96EI} + \frac{wl^4}{128EI}\right)$$

$\Rightarrow$ $$\delta_1 = (\delta_2 - \delta_3) = \frac{wl^4}{8EI} - \frac{wl^4}{96EI} - \frac{wl^4}{128EI}$$

$$= \frac{48wl^4 - 4wl^4 - 3wl^4}{384EI}$$

$$= \frac{41wl^4}{384EI}$$

15. (b)

$$\frac{16T_e}{\pi d^3} \le \tau_{\text{allowable}}$$

$$\frac{16 \times 20 \times 10^6}{\pi d^3} \le 50$$

$\Rightarrow$ $$d \ge 126.7 \text{ mm} \qquad \text{...(i)}$$

and $$\frac{32M_e}{\pi d^3} \le \sigma_{\text{allowable}}$$

$$\frac{32 \times 14 \times 10^6}{\pi d^3} \le 100$$

$\Rightarrow$ $$d \ge 112.56 \text{ mm} \qquad \text{...(ii)}$$

From (i) and (ii), we get

$$d \ge 126.7 \text{ mm}$$

17. (b)

$$\text{diameter (d)} = 10 \text{ mm}$$
$$\text{radius (r)} = 5 \text{ mm}$$
$$\theta = 2\pi \text{ radian}$$
$$\tau = 40 \text{ N/mm}^2$$
$$G = 2.7 \times 10^4 \text{ N/mm}^2$$

We know that, $$\frac{\tau}{r} = \frac{G\theta}{L}$$

$\Rightarrow$ $$L = \left(\frac{G\theta r}{\tau}\right) = \frac{2.7\times10^4\times2\pi\times5}{40}$$
$$= 21205.75 \text{ mm} = 21.205 \text{ m} \simeq 21.21 \text{ m}$$

18. (a)

The extension of the rod is given by,

$$\delta = \frac{4Pl}{\pi E d_1 d_2}$$

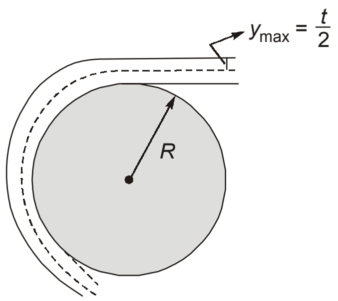
$\Rightarrow$ $$\delta = \frac{4\times6000\times300}{\pi\times2\times10^5\times60\times30}$$
$$= 6.366 \ \mu\text{m} \simeq 6.37 \ \mu\text{m}$$

19. (a)

Given: $$E = 300 \times 10^3 \text{ N/mm}^2$$

$$y_{max} = \frac{2}{2} = 1 \text{ mm}$$

$$R = \frac{2000}{2} = 1000 \text{ mm}$$



Maximum bending stress:

$$(\sigma_b)_{max} = \frac{Ey_{max}}{R_1} = \frac{Ey_{max}}{R+\frac{t}{2}} \approx \frac{Ey_{max}}{R} \qquad \left[R >>> \frac{t}{2}\right]$$

$$= \frac{300\times10^3\times1}{1000}$$

$$= 300 \text{ N/mm}^2$$

20. (b)

Change in volume i.e. dilatation,

$$\in_v = \frac{\sigma_x+\sigma_y+\sigma_z}{E}(1-2\mu)$$

Dilatation $\propto$ (sum of normal stresses)

$$\text{Dilatation} \propto \frac{1}{E}$$

$E = 2G(1+\mu) \leftarrow$ Relationship between E and G

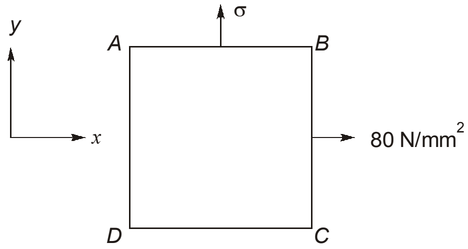
$\mu = 0.1$: for concretes

$$\mu = 0.25 - 0.35 : \text{for elastic materials}$$
$$\mu = 0.5 : \text{rubber}$$

Largest possible value of μ is 0.5.

$$G = \frac{E}{2(1+\mu)} \text{; As } (1 + \mu) > 0,\ G < E$$

21. (d)



For zero strain in *BC*,

$$\in_y = \frac{\sigma_y}{E} - \mu\frac{\sigma_x}{E}$$
$$0 = \frac{\sigma}{E} - \frac{0.3 \times 80}{E}$$
$$\sigma = 24 \text{ N/mm}^2$$

22. (c)

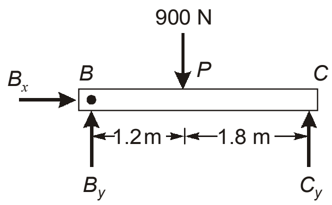
for aluminium, $\mu = 0.33$

for rubber, $\mu = 0.48$ to 0.5

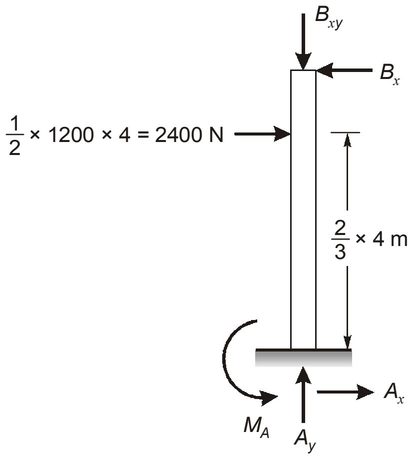
As $\mu_{Al} < \mu_r$, aluminium resists lateral deformation more effectively than rubber.

23. (d)

Let us draw Free Body Diagram of *AB* and *BC* separately :



$$\Sigma M_B = 0,$$
$$900 \times 1.2 = C_y \times 3$$
$$C_y = \frac{900 \times 1.2}{3} = 360 \text{ N}$$



Sum of all moments at A for entire frame:

$$M_A + 360 \times 3 - 900 \times 1.2 - 2400 \times \frac{8}{3} = 0$$

$$M_A = -1080 + 1080 + 6400$$

$$M_A = 6400 \text{ Nm}$$

24. (b)

$$\sigma_1 = 100 \text{ N/mm}^2, \sigma_2 = 50 \text{ N/mm}^2, \sigma_3 = 0$$

According to maximum principal stress theory,

$$\sigma_1 \le \frac{\sigma_y}{FOS}$$

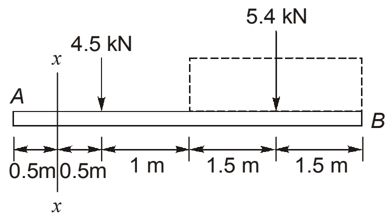
$$\text{FOS} = \frac{250}{100} = 2.5$$

According to maximum shear stress theory,

$$\tau_{\text{max, absolute}} \le \frac{\sigma_y}{2 \times FOS}$$

$$\text{FOS} = 2.5$$

25. (d)



$$M_x = 4.5 \times 0.5 + 5.4(1.5 + 1.0 + 0.5)$$

$$M_x = 2.25 + 16.2$$

$$M_x = 18.45 \text{ kNm}$$

27. (c)

$$U = \frac{1}{2} W \times \delta$$

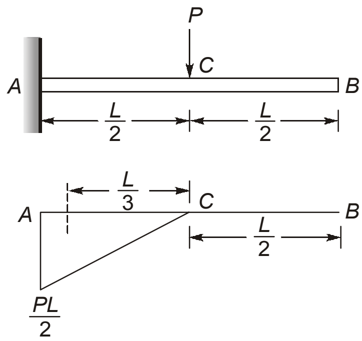
$$W = \frac{2U}{\delta} = \frac{2 \times 72000}{60} = 2400 \text{ N}$$

$$\delta = \frac{8 \times 2400 \times 1000 \times 8}{82000 \times 60} = 31.2 \text{ mm}$$

$$D = 312 \text{ mm}$$

Maximum shear stress, $\tau_{max} = \frac{8WD}{\pi d^3} = \frac{8 \times 2400 \times 312}{\pi \times (31.2)^3} = 62.8 \text{ MPa}$

28. (c)



Area of bending moment,

$$A = \frac{1}{2} \times \frac{PL}{2} \times \frac{L}{2}$$

$$= \frac{PL^2}{8}$$

$$\bar{x} = \frac{L}{2} + \frac{L}{3}$$

$$\bar{x} = \frac{5L}{6}$$

$$\delta_B = \frac{A\bar{x}}{EI} = \frac{PL^2}{8} \times \frac{5L}{6} \times \frac{1}{EI} = \frac{5PL^3}{48EI}$$

29. (a)

Given, $\sigma_1 = 100$ MPa

$\sigma_2 = 50$ MPa,

$\sigma_3 = 25$ MPa

$S_{yt} = 220$ MPa,

For maximum shear strain energy theory,

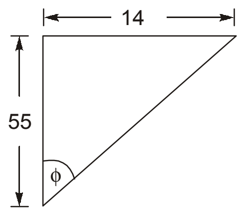
$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \le 2\left(\frac{S_{yt}}{N}\right)^2 \text{ [Where, } N = \text{factor of safety]}$$

$$(100 - 50)^2 + (50 - 25)^2 + (25 - 100)^2 = 2\left(\frac{220}{N}\right)^2$$

After solving,

$\because$ Factor of safety, $N = 3.326 \simeq$ **3.33**

30. (d)



$$\text{Shear strain, } \phi = \tan^{-1}\left[\frac{14}{55}\right] = 14.28^\circ = 0.25 \text{ radian}$$

$$\tau = \frac{P}{ab} = \frac{16000}{150 \times 225} = 0.474 \text{ MPa}$$

$$\text{Shear modulus, } G = \frac{\tau}{\phi} = \frac{0.474}{0.25} = 1.896 \approx 1.90 \text{ MPa}$$

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