

# CLASS TEST

S.No. : 05 GH1\_ME\_D\_080619

Strength of Material



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# CLASS TEST 2019-2020

## MECHANICAL ENGINEERING

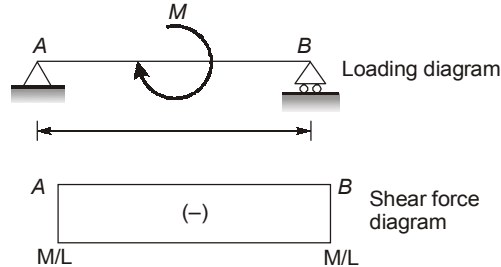
Date of Test : 08/06/2019

### 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,  $\sigma_{\text{impact}} = \sigma_{\text{static}} \times \text{Impact factor}$

For suddenly applied load,

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

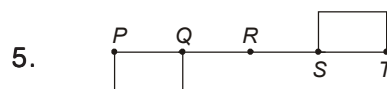
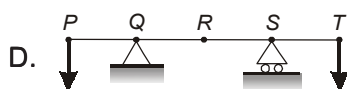
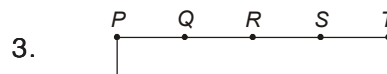
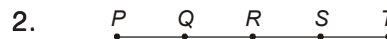
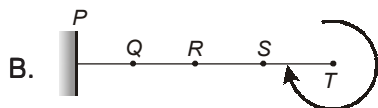
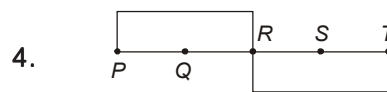
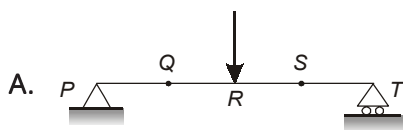
Here for safety  $\sigma_{\text{impact}}$  should not exceed 100 MPa.

$$\Rightarrow \sigma_{\text{static}} = \frac{\sigma_{\text{Impact}}}{\text{Impact factor}} = \frac{100}{2} = 50 \text{ N/mm}^2$$

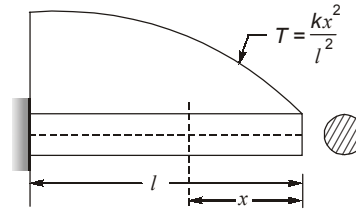
$$\Rightarrow 50 = \frac{P}{A} = \frac{5 \times 10^3}{\frac{\pi}{4} \times d^2} = \frac{6366.1977}{d^2}$$

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

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)

$$M = Pe$$

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

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

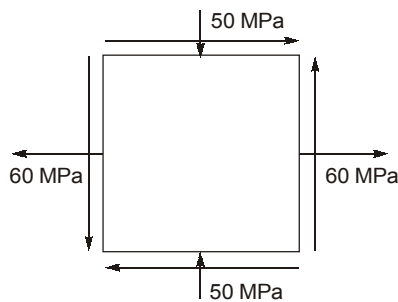
$$\text{Total stress at AB} = \frac{P}{A} - \frac{5Pe}{I_{xx}} \text{ (compressive)}$$

6. (c)

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

7. (c)

According to the given conditions



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

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

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

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

8. (c)

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

$$\frac{P \times (1750 - 2 \times 16)}{2 \times 16} = \left( \frac{450}{5} \right)$$

Internal pressure,  $P = \frac{450 \times 2 \times 16}{(1750 - 32) \times 5} = 1.67 \text{ MPa}$

9. (c)

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

$L_e$  = Effective length of column

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

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

10. (c)

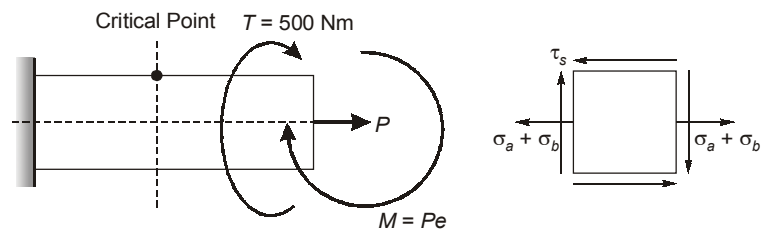
Average force,  $F = \frac{d\bar{P}}{dt} = \frac{m(v-u)}{t}$

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

11. (b)

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

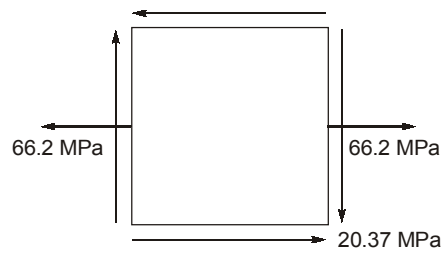
12. (b)



$$\sigma_a = \frac{P}{A} = \frac{50 \times 10^3}{\frac{\pi}{4} \times 50^2} = 25.46 \text{ MPa}$$

$$\sigma_b = \frac{My}{I_{NA}} = \frac{50 \times 10^3 \times 10 \times 25 \times 64}{\pi \times (50)^4} = 40.74 \text{ MPa}$$

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

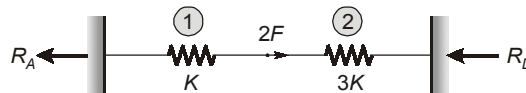


According to MDET,

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

$$N = 2.67$$

13. (d)



$$P_1 = R_A$$

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

$$= R_A + R_D = 2F$$

$$\delta_1 + \delta_2 = 0$$

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

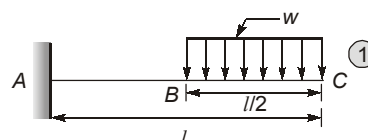
$$\frac{R_A}{K} + \frac{(R_A - 2F)}{3K} = 0$$

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

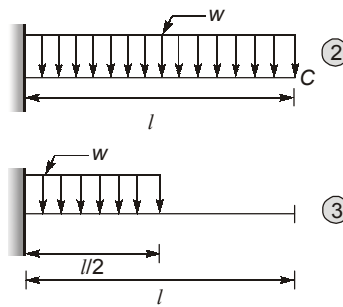
$$U_1 = \frac{1}{2} P_1 \delta_1 = \frac{1}{2} \times \frac{F}{2} \times \left[ \frac{P_1}{K_1} \right]$$

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

14. (b)



By use of superposition principle

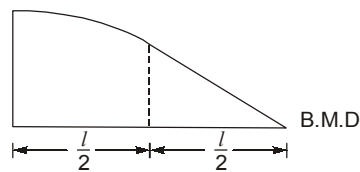


$$\delta_1 = \delta_2 - \delta_3$$

We know that

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

For case (3)



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

⇒

$$\begin{aligned} \delta_1 &= (\delta_2 - \delta_3) = \frac{wl^4}{8EI} - \frac{wl^4}{96EI} - \frac{wl^4}{128EI} \\ &= \frac{48wl^4 - 4wl^4 - 3wl^4}{384EI} \\ &= \frac{41wl^4}{384EI} \end{aligned}$$

15. (b)

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

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

⇒

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

...(i)

and

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

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

⇒

$$d \geq 112.56 \text{ mm}$$

...(ii)

From (i) and (ii), we get

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

17. (b)

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

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

$$\begin{aligned} \Rightarrow L &= \left( \frac{G\theta r}{\tau} \right) = \frac{2.7 \times 10^4 \times 2\pi \times 5}{40} \\ &= 21205.75 \text{ mm} = 21.205 \text{ m} \simeq 21.21 \text{ m} \end{aligned}$$

18. (a)

The extension of the rod is given by,

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

$$\begin{aligned} \Rightarrow \delta &= \frac{4 \times 6000 \times 300}{\pi \times 2 \times 10^5 \times 60 \times 30} \\ &= 6.366 \mu\text{m} \simeq 6.37 \mu\text{m} \end{aligned}$$

19. (a)

Given:

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

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

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

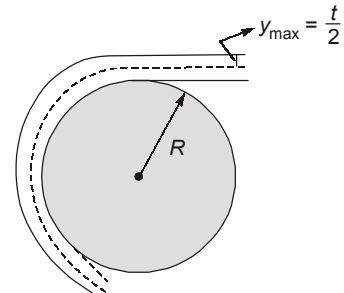
Maximum bending stress:

$$(\sigma_b)_{\max} = \frac{E y_{\max}}{R_1} = \frac{E y_{\max}}{R + \frac{t}{2}} \approx \frac{E y_{\max}}{R}$$

$$\left[ R \gg \frac{t}{2} \right]$$

$$= \frac{300 \times 10^3 \times 1}{1000}$$

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



20. (b)

Change in volume i.e. dilatation,

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

Dilatation  $\propto$  (sum of normal stresses)

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

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

$$\mu = 0.1 : \text{ for concretes}$$

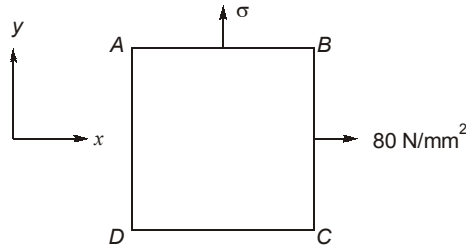
$\mu = 0.25 - 0.35$  : for elastic materials

$\mu = 0.5$  : rubber

Largest possible value of  $\mu$  is 0.5.

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

21. (d)



For zero strain in  $BC$ ,

$$\begin{aligned} \epsilon_y &= \frac{\sigma_y}{E} - \mu \frac{\sigma_x}{E} \\ 0 &= \frac{\sigma}{E} - \frac{0.3 \times 80}{E} \\ \sigma &= 24 \text{ N/mm}^2 \end{aligned}$$

22. (c)

for aluminium,  $\mu = 0.33$

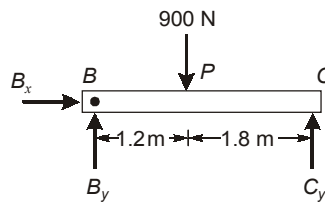
for rubber,  $\mu = 0.48$  to  $0.5$

As

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

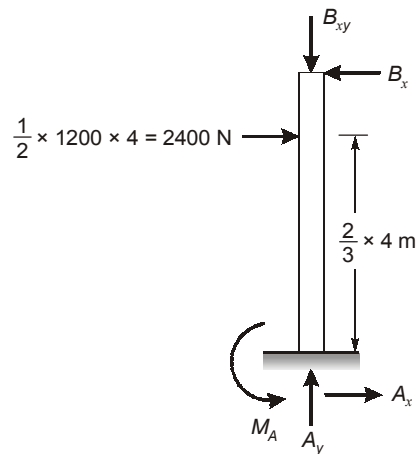
23. (d)

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



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





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,

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

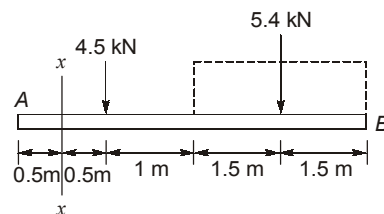
$$FOS = \frac{250}{100} = 2.5$$

According to maximum shear stress theory,

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

$$FOS = 2.5$$

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)

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

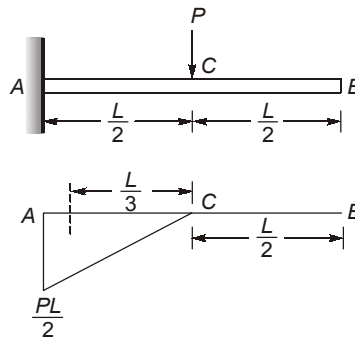
$$W = \frac{2U}{\delta} = \frac{2 \times 72000}{60} = 2400 \text{ N}$$

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

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

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

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,

$$\sigma_1 = 100 \text{ MPa}$$

$$\sigma_2 = 50 \text{ MPa,}$$

$$\sigma_3 = 25 \text{ MPa}$$

$$S_{yt} = 220 \text{ MPa,}$$

For maximum shear strain energy theory,

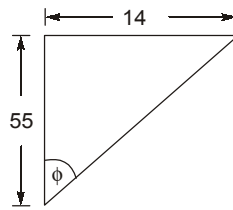
$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \leq 2 \left( \frac{S_{yt}}{N} \right)^2 \quad [\text{Where, } N = \text{factor of safety}]$$

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

After solving,

$$\therefore \text{Factor of safety, } N = 3.326 \approx \mathbf{3.33}$$

30. (d)



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

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

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

