S.No. : 07 SP1_ME_S_080719

Strength of Material

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# CLASS TEST 2019-2020

## MECHANICAL ENGINEERING

Date of Test : 08/07/2019

## ANSWER KEY ➤ Strength of Material

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

## DETAILED EXPLANATIONS

1. (c)

Thermal stress is produced only when it is restricted to expand and there exists temperature gradient.

3. (b)

$$\tau = \frac{16T}{\pi d^3} \quad \{T \to \text{torsional moment, } d \to \text{diameter}\}$$

For same $T$, we have

$$\tau_1 d_1^3 = \tau_2 d_2^3$$

$$\tau_2 = \tau_1\left(\frac{d_1}{d_2}\right)^3 = 128\left(\frac{1}{2}\right)^3 = \frac{128}{8} = 16 \text{ MPa}$$

4. (c)

$$\tau_{max} = \frac{Pd}{4t} = \frac{4\times 1000}{4\times 10} = 100 \text{ MPa}$$

5. (b)

In case of unsymmetrical bending, the equation of the neutral axis is found out by finding the locus of the points on which the resultant stress is zero.

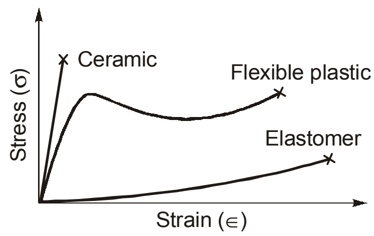
6. (c)

$$\sigma_1 + \sigma_2 = \sigma_x + \sigma_y = 40 + 60 = 100 \text{ MPa}$$

9. (a)

$$\text{Volumetric strain} = \frac{\sigma}{E}(1-2\nu) = \in(1-2\nu) = 0.02\,(1-2\times 0.3) = 0.008$$

11. (c)




14. (d)

Strain energy for Case-I:

$$U_I = \frac{\sigma^2}{2E}AL$$

Strain energy for Case-II:

$$U_{II} = \left(\frac{\sigma}{4}\right)^2 \times \frac{1}{2E}\times 4A \times \frac{L}{4}\times 2 + \frac{\sigma^2}{2E}A\left(\frac{L}{2}\right)$$

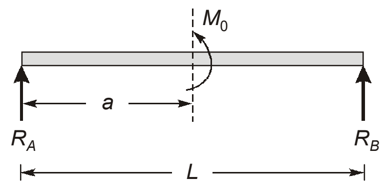
$$= \frac{\sigma^2}{2E}AL\left[\frac{1}{16}\times 4 \times \frac{1}{4}\times 2\right] + \frac{\sigma^2}{2E}A\left(\frac{L}{2}\right) = \frac{\sigma^2}{2E}AL\left[\frac{1}{8}+\frac{1}{2}\right] = \frac{\sigma^2}{2E}A\left(\frac{5}{8}\right) = \left(\frac{5}{8}\right)U_I$$

Strain energy for Case-III:

$$U_{III} = \frac{\sigma^2}{2E}\times A \times \frac{L}{4}\times 2 + \left(\frac{\sigma}{4}\right)^2 \times \frac{1}{2E}\times 4A \times \frac{L}{2}$$

$$= \frac{\sigma^2}{2E}AL\left[\frac{1}{2}+\frac{1}{16}\times 2\right] = \frac{\sigma^2}{2E}AL\left[\frac{1}{2}+\frac{1}{8}\right] = \left(\frac{5}{8}\right)U_I$$

15. (a)




$$\Sigma M_A = 0,\ R_B \times L + M_0 = 0$$

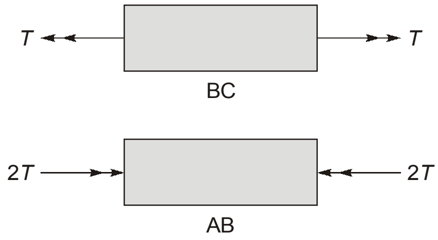
$$R_B = -\frac{M_o}{L}$$

$$\Sigma F_y = 0,\ R_A + R_B = 0$$

So, $$R_A = \frac{M_o}{L}$$

So option I is correct representation of shear force diagram.

16. (a)




$$\theta_{BC} = \frac{T\left(\frac{L}{2}\right)}{GJ} = \frac{1}{2}\frac{TL}{GJ}$$

$$\theta_{AB} = \frac{(2T)\left(\frac{L}{2}\right)}{GJ} = \frac{TL}{GJ}$$

$$\theta_C = \theta_{BC} + \theta_{AB} = \frac{TL}{GJ}(1+0.5) = 1.5\frac{TL}{GJ}$$

$$\theta_B = \frac{TL}{GJ} \quad (\text{As } \theta_A = 0)$$

$$\theta_B : \theta_C = 1 : 1.5$$

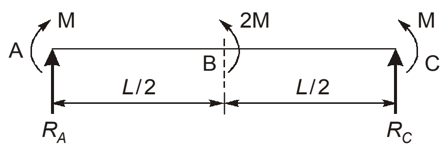
17. (c)

$$f = 12 \text{ Hz},\ P = 20 \text{ kW} = 20000 \text{ N.m/s}$$

Torque, $$T = \frac{P}{2\pi f} = \frac{20000}{2\pi \times 12} = 265.3 \text{ N.m}$$

$$\tau_{max} = \frac{16T}{\pi d^3} = \frac{16 \times 265.3 \times 10^3}{\pi \times (30)^3} \approx 50 \text{ MPa}$$

18. (a)

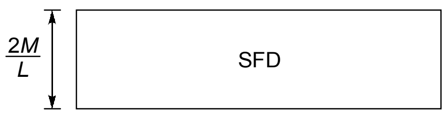



$$R_A + R_C = 0$$

$$R_A = -R_C$$

$$R_A = \frac{2M}{L}(\uparrow)$$

$$R_C = \frac{2M}{L}(\downarrow)$$




Shear force variation between AB and BC is constant.

$$M_A = M(\text{clockwise})$$

$$M_C = M(\text{anti-clockwise})$$

So option (a) is correct answer.

19. (b)

$$E = 200 \text{ GPa},\ d = 1.25 \text{ mm},\ R_0 = 500 \text{ mm}$$

$$\sigma = \frac{E\frac{d}{2}}{\rho} \quad (\rho - \text{radius of curvature})$$

$$\sigma_{max} = \frac{E\frac{d}{2}}{R_0 + \frac{d}{2}} \qquad \left(\rho_{max} = R_0 + \frac{d}{2}\right)$$

$$= \frac{200\times10^3\times1.25}{2\times500+1.25} = 249.688 \approx 250 \text{ MPa}$$

20. (a)

UDL, $q = 5.8$ kN/m, $b = 140$ mm, $h = 240$ mm, $L = 4$ m

Maximum bending moment, $M_{max} = \frac{qL^2}{8} = \frac{5.8\times10^3\times16}{8} = 11.6\times10^3$ N.m

Section modulus, $Z = \frac{I}{\frac{h}{2}} = \frac{bh^3}{12}\times\frac{2}{h} = \frac{bh^2}{6}$

$$\sigma_{max} = \frac{M_{max}}{Z} = \frac{6M_{max}}{bh^2} = \frac{6\times11.6\times10^6}{140\times(240)^2} = 8.63 \text{ MPa}$$

21. (c)

$$M_{max} = P(6b-2b) = 4Pb$$

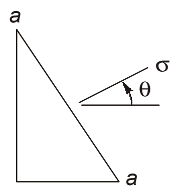
$$\sigma_a = \frac{M_{max}\left(\frac{d_{min}}{2}\right)}{\frac{\pi d_{min}^4}{64}} \Rightarrow d_{min} = \left(\frac{128Pb}{\pi\sigma_a}\right)^{1/3}$$

$$d_{min} = \left(\frac{128\times40\times37}{\pi\times30}\right)^{1/3} = 12.62 \text{ mm}$$

22. (d)

$$\sigma_x = 32 \text{ MPa}$$
$$\sigma_y = -50 \text{ MPa}$$
$$\tau_{xy} = 0$$

Normal stress on plane $a-a$ at an angle $\theta$




$$\sigma_{x1} = \frac{\sigma_x+\sigma_y}{2}+\frac{\sigma_x-\sigma_y}{2}\cos2\theta+\tau_{xy}\sin2\theta$$

$$= \frac{32-50}{2}+\frac{32+50}{2}\cos2\theta+0 = -9+41\cos2\theta$$

$$\sigma_{x1} = 0 = -9+41\cos2\theta$$

$$\cos2\theta = \frac{9}{41}$$

$$2\theta = 77.32° \text{ or } \theta = 38.66°$$

23. (a)

$$\tau_{max} = \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2+\tau_{xy}^2}$$

$$\sigma_{y1} = \sigma_x+2\sqrt{\tau_{max}^2-\tau_{xy}^2}$$

$$\sigma_{y2} = \sigma_x-2\sqrt{\tau_{max}^2-\tau_{xy}^2}$$

$$\sigma_{y1} = 42+2\sqrt{(35)^2-(33)^2} = 65.3 \text{ MPa}$$

$$\sigma_{y2} = 42 - 2\sqrt{(35)^2 - (33)^2} = 18.7 \text{ MPa}$$

So, $$\sigma_y = \begin{pmatrix} 65.3 \\ 18.7 \end{pmatrix} \text{MPa}$$

24. (c)

From stress-strain relations:

$$\in_x = \frac{\sigma_x}{E} - \frac{\nu}{E}(\sigma_y + \sigma_z)$$

$$\in_y = \frac{\sigma_y}{E} - \frac{\nu}{E}(\sigma_x + \sigma_z)$$

$$(-740 \times 10^{-6})E = -4.5 + 5.7\nu \quad \text{...(i)}$$

$$(-320 \times 10^{-6})E = -3.6 + 6.6\nu \quad \text{...(ii)}$$

Solving equation (i) and (ii), we get

$$E = 3000 \text{ MPa} = 3 \text{ GPa}, \nu = 0.4$$

Bulk modulus, $$K = \frac{E}{3(1-2\nu)} = \frac{3}{3(1-2\times 0.4)} = 5 \text{ GPa}$$

25. (b)

$$\in_A = 520 \times 10^{-6}, \in_B = 360 \times 10^{-6}, \in_C = -80 \times 10^{-6}$$

$$\in_{x1} = \frac{\in_x + \in_y}{2} + \frac{\in_x - \in_y}{2}\cos 2\theta + \frac{\gamma_{xy}}{2}\sin 2\theta$$

For A, $$\theta = 0°, \in_A = \in_x = 520 \times 10^{-6} \quad \text{...(i)}$$

For B, $$\theta = 45°, \in_B = \frac{\in_x + \in_y}{2} + \frac{\in_x - \in_y}{2}\cos 90° + \frac{\gamma_{xy}}{2}\sin 90°$$

$$\in_B = \frac{\in_x + \in_y + \gamma_{xy}}{2} = 360 \times 10^{-6} \quad \text{...(ii)}$$

For C, $$\theta = 90°, \in_C = \frac{\in_x + \in_y}{2} + \frac{\in_x - \in_y}{2}\cos 180° + \frac{\gamma_{xy}}{2}\sin 180°$$

$$\in_C = \in_y = -80 \times 10^{-6} \quad \text{...(iii)}$$

From equation (i), (ii) and (iii), we get

$$\gamma_{xy} = 2\in_B - \in_A - \in_C$$

$$= (2 \times 360 - 520 + 80) \times 10^{-6}$$

$$\gamma_{xy} = 280 \times 10^{-6}$$

Maximum shear strain, $$\frac{\gamma_{xy}}{2} = \sqrt{\left(\frac{\in_x - \in_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2}$$

$$\frac{\gamma_{xy} \times 10^6}{2} = \sqrt{\left(\frac{520+80}{2}\right)^2 + \left(\frac{280}{2}\right)^2}$$

$$\gamma_{xy} = 2\times 10^{-6}\sqrt{(300)^2 + (140)^2}$$

$$\gamma_{xy} = 662 \times 10^{-6}$$

26. (c)

Deflection due to point load, $$\delta_P = \frac{PL^3}{3EI} \text{ (downward)}$$

Deflection due to end moment, $\delta_M = \dfrac{ML^2}{2EI}$ (upward)

$$\delta = \delta_P + \delta_M = -\frac{PL^3}{3EI} + \frac{ML^2}{2EI}$$

$$= -\frac{100 \times 10^3 \times (9000)^3}{3 \times 81 \times 10^{12}} + \frac{900 \times 10^6 \times (9000)^2}{2 \times 81 \times 10^{12}} = -300+450=150 \text{ mm}$$

27. (b)

Engineering stress, $\sigma = \dfrac{4P}{\pi d_0^2} = \dfrac{4 \times 50 \times 10^3}{\pi \times 100} = 636.62 \text{ MPa}$

Engineering strain, $\in = \dfrac{\Delta l}{l_0} = \dfrac{1}{100} = 10^{-2}$

Engineering modulus, $E = \dfrac{\sigma}{\in} = 636.62 \times 10^2 \text{ MPa} = 63.662 \text{ GPa}$

$$E = 2G(1+\nu)$$

$$\nu = \frac{E}{2G} - 1 = \frac{63.662}{2 \times 25} - 1 = 0.273$$

28. (d)

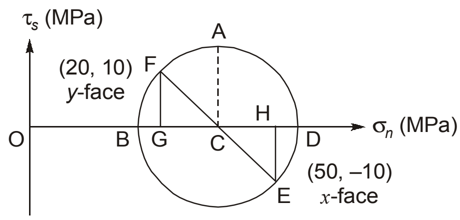
$$GC = CH = \frac{50-20}{2} = 15$$

$$OC = OG + GC$$

$$= 20 + 15 = 35$$

$$FC = \sqrt{15^2 + 10^2} = 18.03$$

Coordinates of $A \equiv (35, 18.03)$ MPa




29. (c)

When the temperature drops, wire tends to contract due to fall in temperature. A wire is constrained at the end A and B and wire will be subjected to tensile stress.

$$\Delta T = 20 - 0 = 20°\text{C}$$

$$\sigma = \sigma_1 + \sigma_2$$

[$\sigma_1$ = 42 MPa due to prestress, $\sigma_2 = E\alpha\Delta T$ due to temperature change]

$$= 42 + E\alpha\Delta T = 42 + 200 \times 10^3 \times 14 \times 10^{-6} \times 20$$

$$= 42 + 56 = 98 \text{ MPa}$$

30. (a)

The true stress-strain curve: $\sigma = K\in^n$

$n$ (strain-hardening exponent) = We have to find

$K$ (strength coefficient) = 825 MPa

$\sigma_T$ = 500 MPa, $\in_T = 0.16$

Taking log to both side:

$$\log\sigma = \log K + n\log\in$$

$$n = \frac{\log\sigma - \log K}{\log\in} = \frac{\log 500 - \log 825}{\log 0.16} = 0.273$$

■■■■