S.No. : 04 **GH1_ME_A_040519**

Strength of Material

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

Subject : Strength of Material

Date of test : 04/05/2019

Answer Key

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)

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

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)

$$\tau_{max} = \frac{Pd}{4t} = \frac{4\times1000}{4\times10} = 100 \text{ MPa}$$

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.

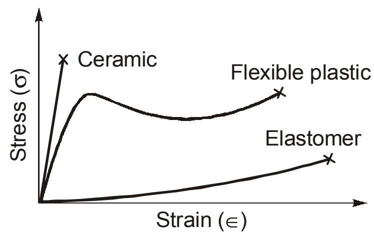
6. (c)

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

9. (a)

$$\text{Volumetric strain} = \frac{\sigma}{E}(1-2\nu) = \in(1-2\nu) = 0.02\,(1-2\times0.3) = 0.008$$

11. (c)



14. (d)

Strain energy for Case-I:

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

Strain energy for Case-II:

$$U_{II} = \left(\frac{\sigma}{4}\right)^2\times\frac{1}{2E}\times4A\times\frac{L}{4}\times2+\frac{\sigma^2}{2E}A\left(\frac{L}{2}\right)$$

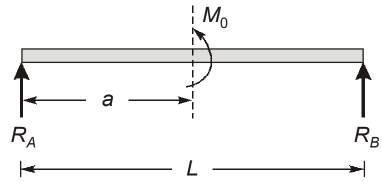
$$= \frac{\sigma^2}{2E}AL\left[\frac{1}{16}\times4\times\frac{1}{4}\times2\right]+\frac{\sigma^2}{2E}A\left(\frac{L}{2}\right) = \frac{\sigma^2}{2E}AL\left[\frac{1}{8}+\frac{1}{2}\right]=\frac{\sigma^2}{2E}A\left(\frac{5}{8}\right)=\left(\frac{5}{8}\right)U_I$$

Strain energy for Case-III:

$$U_{III} = \frac{\sigma^2}{2E}\times A\times\frac{L}{4}\times2+\left(\frac{\sigma}{4}\right)^2\times\frac{1}{2E}\times4A\times\frac{L}{2}$$

$$= \frac{\sigma^2}{2E}AL\left[\frac{1}{2}+\frac{1}{16}\times2\right] = \frac{\sigma^2}{2E}AL\left[\frac{1}{2}+\frac{1}{8}\right]=\left(\frac{5}{8}\right)U_I$$

15. (a)



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

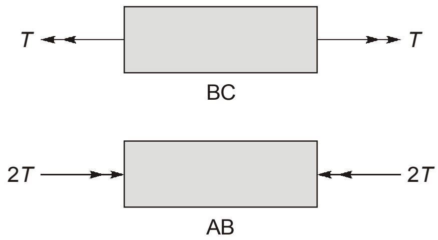
$$R_B = -\frac{M_o}{L}$$

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

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

So option I is correct representation of shear force diagram.

16. (a)



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

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

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

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

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

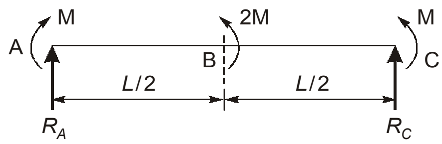
17. (c)

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

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)

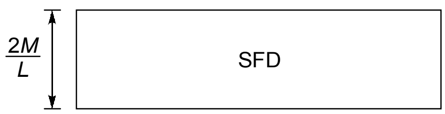


$$R_A + R_C = 0$$

$$R_A = -R_C$$

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

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



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, $$M_{max} = \frac{qL^2}{8} = \frac{5.8\times10^3\times16}{8} = 11.6 \times 10^3 \text{ N.m}$$

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)

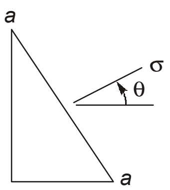
$$M_{max} = P(6b-2b) = 4Pb$$

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

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

22. (d)

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



Normal stress on plane $a-a$ at an angle θ

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

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

$$\sigma_{x1} = 0 = -9 + 41\cos 2\theta$$

$$\cos 2\theta = \frac{9}{41}$$

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

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:

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

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

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

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

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)

$$\epsilon_A = 520 \times 10^{-6}, \epsilon_B = 360 \times 10^{-6}, \epsilon_C = -80 \times 10^{-6}$$

$$\epsilon_{x1} = \frac{\epsilon_x + \epsilon_y}{2} + \frac{\epsilon_x - \epsilon_y}{2}\cos 2\theta + \frac{\gamma_{xy}}{2}\sin 2\theta$$

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

For B, $$\theta = 45°, \epsilon_B = \frac{\epsilon_x + \epsilon_y}{2} + \frac{\epsilon_x - \epsilon_y}{2}\cos 90° + \frac{\gamma_{xy}}{2}\sin 90°$$

$$\epsilon_B = \frac{\epsilon_x + \epsilon_y + \gamma_{xy}}{2} = 360 \times 10^{-6} \quad \text{...(ii)}$$

For C, $$\theta = 90°, \epsilon_C = \frac{\epsilon_x + \epsilon_y}{2} + \frac{\epsilon_x - \epsilon_y}{2}\cos 180° + \frac{\gamma_{xy}}{2}\sin 180°$$

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

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

$$\gamma_{xy} = 2\epsilon_B - \epsilon_A - \epsilon_C$$

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

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

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

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

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

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

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

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

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

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

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

28. (d)

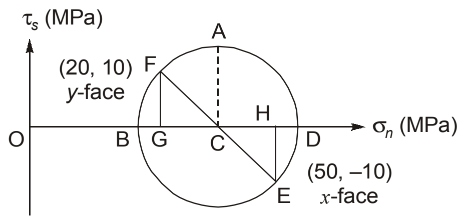
$$GC = CH = \frac{50 - 20}{2} = 15$$

$$OC = OG + GC$$

$$= 20 + 15 = 35$$

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

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

σ_T = 500 MPa, $\in_T = 0.16$

Taking log to both side:

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

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

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