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**ESE- 2018 (Prelims) - Offline Test Series** **Test-1**

**CIVIL ENGINEERING**

# SUBJECT: SOLID MECHANICS, CONSTRUCTION PRACTICE, PLANNING AND MANNAGEMENT
# SOLUTIONS

**01. Ans: (b)**

**Sol:** $\Delta_s = \Delta_h$

$$\frac{PL}{A_s E} = \frac{PL}{A_h E}$$

$$A_s = A_h$$

$$d^2 = D^2 - \left(\frac{D}{2}\right)^2 \Rightarrow d^2 = \frac{3D^2}{4}$$

$$d = \frac{\sqrt{3}}{2} D$$

**02. Ans: (a)**

**Sol:** $\delta_s = \delta_c$

$$\Rightarrow \frac{\sigma_s}{E_s} = \frac{\sigma_c}{E_c} \qquad (\because L_s = L_c)$$

$$\sigma_c = \frac{\sigma_s}{E_s} \times E_c$$

$$\sigma_c = \frac{\sigma_s}{2} = \frac{100}{2} = 50\,\text{MPa}$$

**03. Ans: (b)**

**Sol:** $$\left(\frac{P}{100} \times 1000\right) = 2 \times 10^5 \times 0.75$$

$10\,P = 150000$

$P = 15$ kN

**04. Ans: (b)**

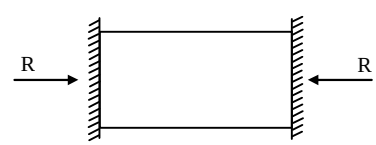
**Sol:** $\sigma = E(\alpha t) = 200 \times 10^3 \times 10^{-3} \times 30$

$\sigma = 6000$ N/mm$^2$ (compressive)

Compressive force is exerted by the supports which prevents increase in length due to increase in temperature

**05. Ans: (c)**

**Sol:**




$\Delta_{act} = 0$

$\Delta_{temp\ change} = \Delta_{compressive\ reaction\ force}$

$$L\alpha\Delta T = \frac{RL}{AE}$$

$R = \alpha.\ \Delta T.\ AE$

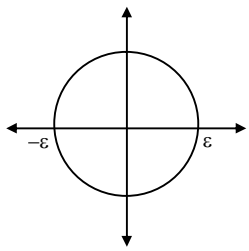
$= 10 \times 10^{-6} \times 50 \times 20 \times 10^{-4} \times 200 \times 10^{9}$

$R = 200 \times 10^{3}$ N

$R = 200$ kN

**06. Ans: (b)**

**Sol:**




**07. Ans: (d)**

**Sol:** For plastic deformation

$\mu = 0.5$

$$\varepsilon_1 = \frac{\sigma_1}{E} - \frac{\mu\sigma_2}{E} - \frac{\mu\sigma_3}{E}$$

$$\varepsilon_1 = \frac{30 - (0.5\times 10) - (0.5\times 5)}{E} = \frac{22.5}{E}$$

$$\varepsilon_2 = \frac{\sigma_2}{E} - \frac{\mu\sigma_1}{E} - \frac{\mu\sigma_3}{E}$$

$$\varepsilon_2 = \frac{10 - (0.5\times 30) - (0.5\times 5)}{E} = \frac{-7.5}{E}$$

$$\varepsilon_3 = \frac{\sigma_3}{E} - \frac{\mu\sigma_1}{E} - \frac{\mu\sigma_2}{E}$$

$$\varepsilon_3 = \frac{5 - (0.5\times 30) - (0.5\times 10)}{E} = \frac{-15}{E}$$

$\therefore \varepsilon_1 : \varepsilon_2 : \varepsilon_3 = 22.5 : -7.5 : -15$

$= 15 : -5 : -10$

**08. Ans: (c)** **09. Ans: ( b)**

**10. Ans: (b)**

**Sol:** $$\delta = \frac{wL^3}{48EI}$$

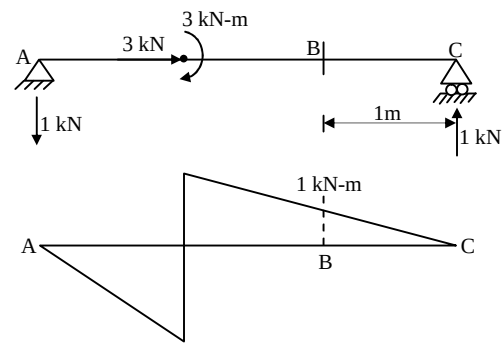
$$\delta\alpha\frac{1}{I}$$

y $$\delta \times \frac{bd^3}{12} = \delta_2 \times \frac{b^3 d}{12}$$

Ĝ $$\delta_2 = \left(\frac{d}{b}\right)^2 \delta$$

**11. Ans: (c)**

**Sol:**




**12. Ans: (b)**

**Sol:** $$\sigma = \frac{M}{Z}$$

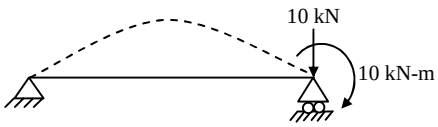
$Z_{squ} > Z_{curcular}$ in case of bending

$\therefore \sigma_{circle} > \sigma_{square}$

Since 'I' (moment of inertial) will be different for square and circular section. Deformation will not be same.

**13. Ans: (c)**

**Sol:**




$$\Delta_C = \frac{10\times 1^3}{3EI} + \frac{10\times 3}{3EI}\times 1$$

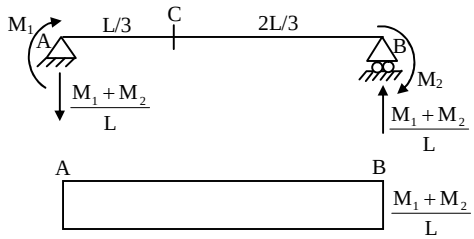
$$\Delta_C = \frac{40}{3EI}$$

**14. Ans: (c)**

**Sol:** Unit load method can be applied to plastic range also but $d\theta$ will not be equal to $\frac{M}{EI}dx$

**15. Ans: (b)**

**Sol:**




$\Rightarrow M_c = 0$ inflection point at C

$$\therefore \quad M_1 - \left(\frac{M_1 + M_2}{L}\right)\frac{L}{3} = 0$$

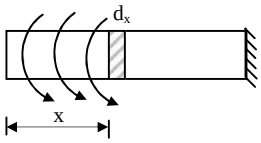
$\Rightarrow 3M_1 - (M_1 + M_2) = 0$

$\Rightarrow 2M_1 = M_2$

$$\frac{M_2}{M_1} = 2$$

**16. Ans: (b)**

**Sol:**




$$d\phi = \frac{T dx}{GJ} \qquad T = T_o x$$

$$d\phi = \frac{T_o x dx}{GJ}$$

$$\phi = \frac{1}{GJ}\int_o^L T_o x dx$$

$$\phi = \frac{T_o L^2}{2GJ}$$

**17. Ans: (b)**

**Sol:**

$$\tau = \frac{16T}{\pi d^3} \Rightarrow T = \frac{\pi}{16}\tau d^3$$

$$\theta = \frac{TL}{GJ} \Rightarrow L = \theta \times \frac{GJ}{T}$$

$$L = \frac{0.01 \times 0.84 \times 10^5 \times \frac{\pi}{32}(25)^4}{42 \times (25)^3 \times \frac{\pi}{16}}$$

L = 250 mm

**18. Ans: (d)**

**Sol:**

$$Z_p \propto d^3$$

$\therefore$ Shaft B is 8 times stronger than A

**19. Ans: (a)**

**20. Ans: (d)**

**Sol:** B = b+2mt

= 200 + 2(10)20

= 200 + 400 = 600 mm

**21. Ans: (a)**

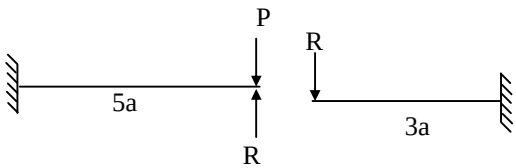
**Sol:**

$$\tau_{max} = \frac{16}{\pi d^3}\sqrt{T^2 + M^2}$$

$$= \frac{16}{\pi 20^3}\sqrt{30^2 + 40^2} = \frac{1}{10\pi}\text{kN/m}^2$$

**22. Ans: (b)**

**Sol:**




$$\frac{P(5a)^3}{3EI} - \frac{R(5a)^3}{3EI} = \frac{R(3a)^3}{3EI}$$

$P\times 5^3 - 125\,R = 27R$

$P\times 125 = 152\,R$

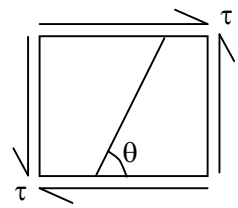
$$R = \frac{125P}{152} \quad \delta = \frac{125P(3a)^3}{152\times 3EI} = \frac{1125Pa^3}{152EI}$$

**23. Ans: (c)**

**Sol:** Ductile material is weak in shear, so it fails in a plane where maximum shear stress occurs. Brittle material is weak in tension, so it fails in a plane where maximum tensile stress occurs.

**Torsion test:**

It is a case of pure shear.

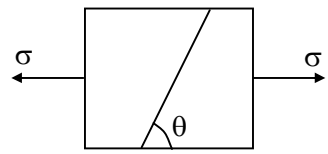



$\tau = \tau_{max}$, at $\theta = 90°$ (maximum shear stress which causes failure of ductile material)

$\sigma_1 = \sigma_{max}$, at $\theta = 45°$ (maximum normal stress which causes failure of brittle material)

**Tensile test:**

It is a case of uniaxial stress.



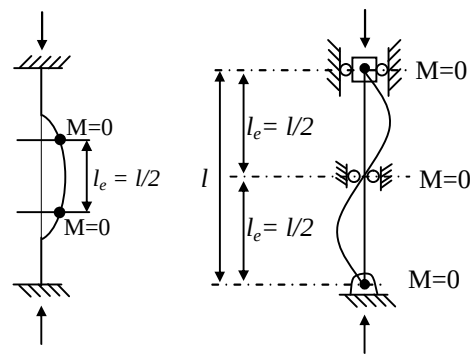

$\tau = \tau_{max}$, at $\theta = 45°$ (maximum shear stress which causes failure of ductile material)

$\sigma_1 = \sigma_{max}$, at $\theta = 90°$ (maximum normal stress which causes failure of brittle material)

So, from the given options, only option (C) is correct.

**24. Ans: (d)**

**Sol:**



$$(P_{cr1})_{fixed-fixed} = \frac{\pi^2 EI}{\ell_e^{\,2}} = \frac{\pi^2 EI}{\left(\frac{\ell}{2}\right)^2} = 4 \times \frac{\pi^2 EI}{\ell^2}$$

$$(P_{cr2})_{pin-pin} = \frac{\pi^2 EI}{\ell_e^{\,2}} = \frac{\pi^2 EI}{\left(\frac{\ell}{2}\right)^2} = 4 \times \frac{\pi^2 EI}{\ell^2}$$

So, $\frac{P_{cr(1)}}{P_{cr(2)}} = 1$

**25. Ans: (c)**

**26. Ans: (b)**

**Sol:** Length of rod- 5m, pitch of thread = 2.5 mm

Axial movement on both sides of screw

$$= \frac{2.5}{3} = 0.833 \text{ mm}$$

Strain in each rod = $\frac{0.833}{5000} = 1.6 \times 10^{-4}$

$E = 200 \times 10^3$ N/mm$^2$

($\sigma_1$)stress in each rod

$= 0.16 \times 10^{-3} \times 200 \times 10^3$

$= 33.33$ N/mm$^2$

$$A = \frac{\pi}{4} \times (30)^2 = 225\pi \text{mm}^2$$

$T = 225\pi \times 33.33 = 7500\ \pi$ N $= 7.5\pi$ kN

**27. Ans: (a)**

**Sol:**

$$EI\frac{dy}{x} = \frac{-w}{24l}(L-x)^4 + \frac{WL^3}{24}$$

Differentiation of slope = bending moment at X

$$EI\frac{d^2y}{dx^2} = \frac{-W}{24L}4(l-x)^3(-1) + 0$$

$$EI\frac{d^3y}{dx^3} = \frac{W}{6L}3(L-x)^2(-1)$$

$$EI\frac{d^3y}{dx^3} = \frac{-W}{2L}(L-x)^2$$

Shear force at distance x from fixed end A

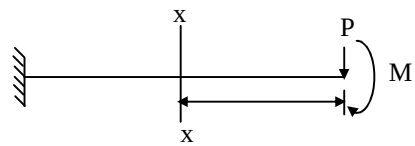
$$F = \frac{-W}{2L}(L-x)^2$$

At $x = \frac{L}{2}$

$$F = \frac{-W}{2L}\left(\frac{L}{2}\right)^2 = \frac{-WL}{8}$$

**28. Ans: (d)**

**Sol:**




$M_x = P_x + M$

Strain energy $U = \int \frac{M_x^2 dx}{2EI}$

$$= \int_0^L \frac{(Px + M)^2 dx}{2EI}$$

$$= \frac{1}{2EI}\int_0^L (P^2x^2 + M^2 + 2PMx)dx$$

$$= \frac{1}{2EI}\left(P^2\frac{x^3}{3} M^2x + 2PM\frac{x^2}{2}\right)_O^L$$

$$= \frac{P^2L^3}{6EI} + \frac{M^2L}{2EI} + \frac{PML^2}{2EI}$$

Principle of super position is applicable when there is a linear relationship between external loads and corresponding structural displacements.

**29. Ans: (d)**

**Sol:** Mile stone chart is modification of bar chart.

**30. Ans: (a)**

**31. Ans: (b)**

**Sol:** "Pipe laid" is completion of an activity i.e. an event.

**32. Ans: (c)**

**Sol:** Critical path for the given network is


$\therefore$ Project completion time = 28 weeks

**33. Ans: (a)**

**Sol:** Optimistic time occurs when conditions are better than normal

**34. Ans: (b)**

**Sol:** Standard deviation of the network ending event $(\sigma_{t_E}) = \sqrt{\sigma_1^2 + \sigma_2^2 + ..... + \sigma_n^2}$

where, $\sigma_1$, $\sigma_2$, ……$\sigma_n$ are the standard deviations of each of the activities.

$$\sigma_{11-12} = \frac{8-4}{6} = 0.667$$

$$\sigma_{12-13} = \frac{11-5}{6} = 1$$

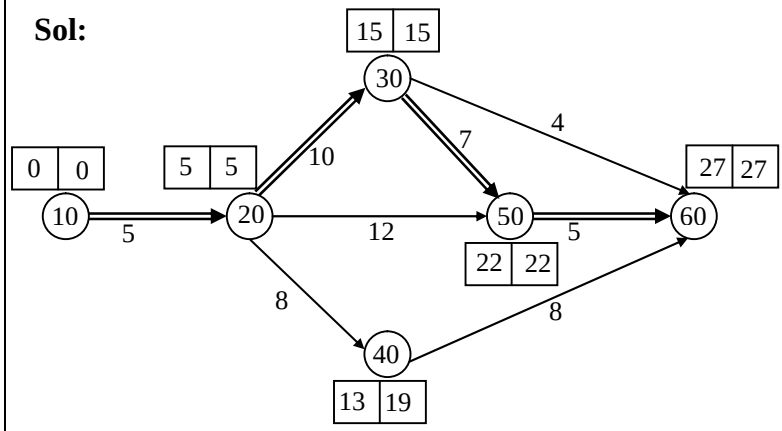
$$\sigma_{13-14} = \frac{12-4}{6} = 1.337$$

$$(\sigma_{t_E}) = \sqrt{(0.667)^2 + 1^2 + (1.337)^2}$$

$$= 1.795$$

**35. Ans: (c)**

**Sol:**




Double line represents critical path

$\therefore$ Slack at event (40) = 19 – 13 = 6 days

**36. Ans: (d)**

**Sol:**

Another cause of rolling resistance is slippage between tyres and surface.

**37. Ans: (c)**

**38. Ans: (b)**

**39. Ans: (c)**

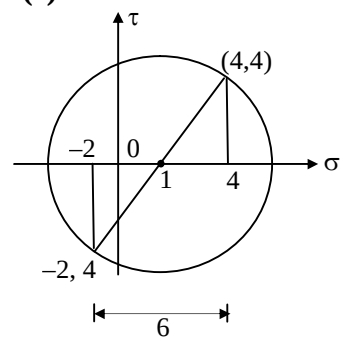
**Sol:** P = W × rolling resistance × slope

100 = 10 × R ×4%

R = 25 kgf/ton

**40. Ans: (c)**

**Sol:**



Radius of Mohr's circle is maximum shear stress

$\tau_{max} = \sqrt{3^2 + 4^2} = 5$ units

(OR)

From Mohr's circle

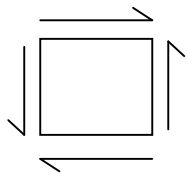
$\sigma_x = 4, \quad \sigma_y = -2$

$\tau_{xy} = 4$

$\therefore \tau_{max} = 5$ units

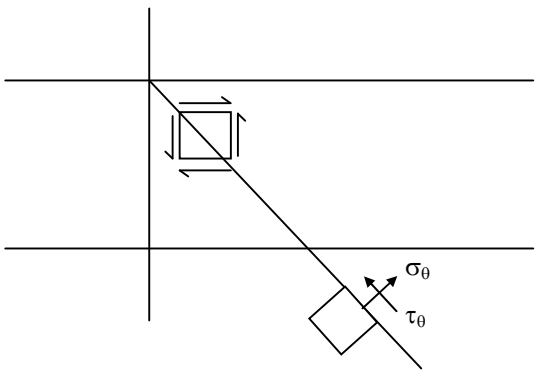
**41. Ans: (c)**

**Sol:** Material is subjected to pure shear



Normal stress

$$\sigma_\theta = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$$




$\sigma_\theta = \tau\sin 2\theta = \tau$

Shear stress $\tau_\theta = -\tau\cos 2\theta = 0$

$\therefore$ Normal force $F_n = \sigma_\theta \dfrac{A}{\cos\theta} = \sqrt{2}\tau A$

$\therefore$ Shear force $F_s = \tau_\theta \dfrac{A}{\cos\theta} = \tau_\theta \times \dfrac{A}{\frac{1}{\sqrt{2}}} = 0$

**Another Method**

As this is pure shear condition, maximum principle plane will be at 45° to vertical and on maximum principal plane, shear stress will be zero.

In pure shear maximum principle stress is $\tau$

Normal force on the plane = $\tau \times$ Area of plane

$$= \tau \times \frac{A}{\cos\theta} = \sqrt{2}\tau A$$

**42. Ans: (b)**

**Sol:** Power, $P = \dfrac{2\pi NT}{60}$

$P = 2\pi fT$

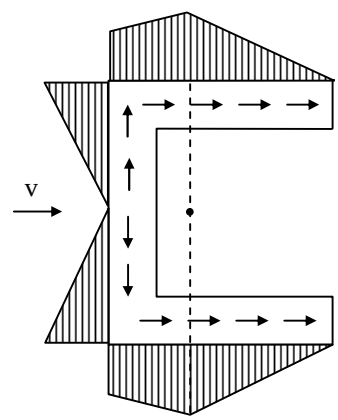
$(\dfrac{N}{60} = f$ , f = rotation per sec)

$50 \times 10^3 = 2\pi \times 10 \times T$

$T = \dfrac{2500}{\pi}$

**43. Ans: (d)**

**Sol:**




At NA, shear stress should be maximum.

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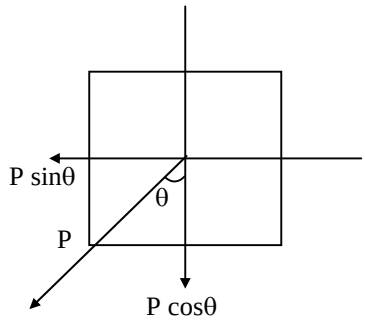
**44. Ans: (c)**

**Sol:**




$M_z = 50\cos\theta(7)$

$M_y = 50\sin\theta(7)$

$$\tan\beta = \frac{M_y}{M_z}\frac{I_z}{I_y}$$

$$\tan\beta = \frac{1}{\sqrt{3}}.3 = \sqrt{3}$$

$$\beta = 60^o$$

**45. Ans: (c)**

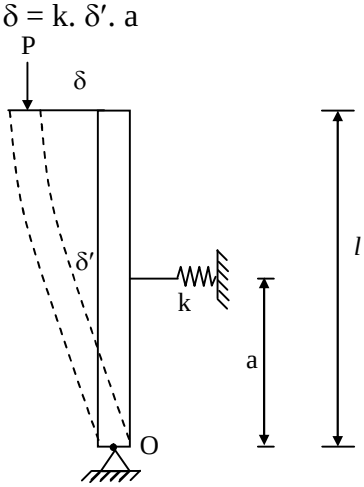
**Sol:** At neutral condition

$M_o = M_R$

$P_{cr}.\ \delta = F.\ a$

$\Rightarrow F = k.\delta'$

$P_{cr}.\ \delta = k.\ \delta'.\ a$

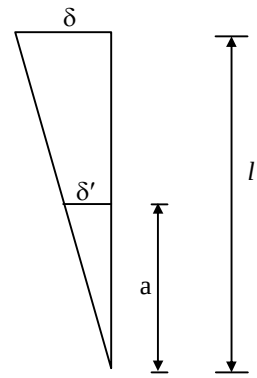



By similar triangle

$$\frac{\delta}{\ell} = \frac{\delta'}{a} \Rightarrow \delta' = \frac{\delta}{\ell}.a$$

$$P_{cr}.\delta = k.\frac{\delta}{\ell}.a^2$$

$$P_{cr} = k.\frac{a^2}{\ell}$$




**46. Ans: (a)**

**Sol:** $\tau_{max} = \dfrac{16PR}{\pi d^3}\left[1+\dfrac{d}{4R}\right]$

$$\text{Spring index} = \frac{D}{d} = 10$$

$D = 10 \times 10 = 100$ mm

$R = 50$ mm

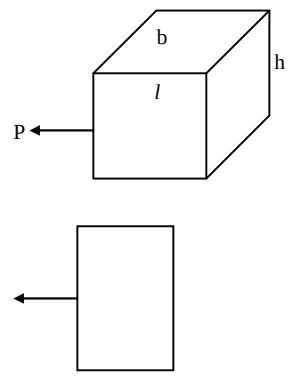
$$50 = \frac{16P[50]}{\pi(10)^3}\left[1+\frac{10}{4\times 50}\right]$$

$P = 59.52\ \pi$ N

$P \simeq 60\pi$ N

**47. Ans: (a)**

**Sol:**




$$\frac{\delta\ell}{\ell} = e$$

$\delta l = (le)$

Total length elongation after application of load

$l' = l + le$

$l' = l\,(1 + e)$

Change in breadth direction $\Rightarrow b' = b - \mu\, be$

$= b\,(1 - \mu e)$

Similarly,

$h' = h\,(1 - \mu e)$

Total changed volume $\Rightarrow l'b'h'$

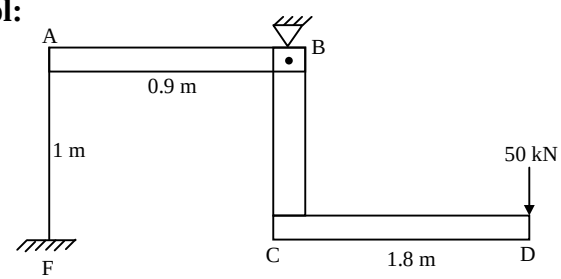
$V' = l(1 + e)\, b(1 - \mu e)\, h\,(1 - \mu e)$

$= lbh\,(1 + e)\,(1 - \mu e)^2$

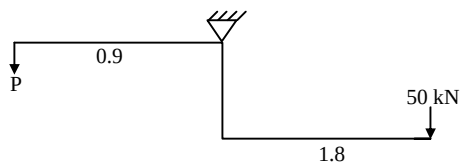
$V' = V\,(1 + e)\,(1 - \mu e)^2$

**48. Ans: (c)**

**Sol:**



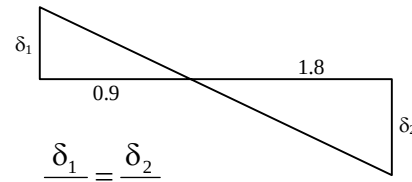

FBD:




$P \times 0.9 = 50 \times 1.8$

$P = 100$ kN

$$\delta_{AF} \Rightarrow \frac{P\ell}{AE} = \frac{100\times1000\times1000}{100\times2\times10^5} = 5 \text{ mm}$$




$$\frac{\delta_1}{0.9} = \frac{\delta_2}{1.8}$$

$\delta_2 = 10$ mm

**49. Ans: (c)**

**Sol:** $M_Q = 0$

$10\times12\times6 = W\times4$

$W = 180$ kN

**50. Ans: (c)**

**51. Ans (c)**

**Sol:** Load carrying capacity of beam $\propto Z$

Where Z = section modulus $= \dfrac{I}{y_{max}}$

For vertical beam, b = 120 mm, d = 60 mm

$$Z_{vertical} = \frac{\left(\frac{bd^3}{12}\right)}{\frac{d}{2}} = \frac{bd^2}{6} = \frac{120\times60^2}{6}$$

For horizontal beam, b = 60 mm,

d = 120mm

$$Z_{horizontal} = \frac{bd^2}{6} = \frac{60\times120^2}{6}$$

$$\frac{Z_{vertical}}{Z_{horizontal}} = \frac{\left(\frac{120\times60^2}{6}\right)}{\left(\frac{60\times120^2}{6}\right)} = 0.5$$

**52. Ans: (c)**

**Sol:** $y = \dfrac{3a^2 \times E_1 \times (2a + a/2) + 6a^2 \times 2E_1 \times a}{3a^2E_1 + 12E_1}$

$= \dfrac{3a^2E_1 \times 2.5a + 12a^3E_1}{15a^2E_1} = 1.3a$

**53. Ans: (c)**

**54. Ans: (c)**

**Sol:**

We know that

$\dfrac{E}{R} = \dfrac{M}{I} = \dfrac{f}{y}$

$f = \dfrac{M}{Z}$

$M = 20 \times 4 = 80$ kN-m

$Z = \dfrac{\pi d^3}{32} = \dfrac{\pi}{32}(0.1)^3$

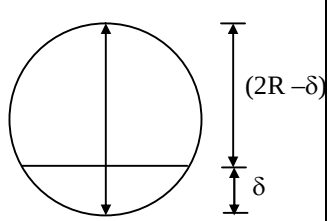
$\therefore f = \dfrac{80 \times 32}{\pi(0.1)^3} = \dfrac{2560}{\pi} \times 10^3$ kN/m$^2$

**55. Ans: (d)**

**56. Ans: (b)**

**Sol:**

$(2R - \delta)\delta = \dfrac{L^2}{4}$




$R = \left(\dfrac{L^2}{8\delta}\right) \quad \rightarrow (1)$

$\dfrac{f}{y} = \dfrac{E}{R}$

$\dfrac{f}{y} \Rightarrow \dfrac{\varepsilon.E}{y} = \dfrac{E}{R}$

$\dfrac{\varepsilon}{y} = \dfrac{1}{R}$

$\varepsilon = \left(\dfrac{y}{R}\right)$

$\varepsilon = \dfrac{8\delta y}{L^2}$

$\varepsilon = \dfrac{8 \times 0.4 \times 1}{(400)^2} = 2 \times 10^{-5}$

**57. Ans: (d)**

**Sol:** Modulus of elasticity is constant.

Modulus of elasticity is depends on the properties of material

**58. Ans: (a)**

**Sol:** Strain energy $(U) = \dfrac{1}{2}P.\delta$

$= \dfrac{1}{2} \times 30 \times 10^3 \times 0.05 \times 10^{-3}$

$= 15 \times 0.05 = 0.75$ N–m

**59. Ans: (c)**

**Sol:** For two dimensional systems

As per maximum shear stress theory, failure occurs if

$\dfrac{\sigma_1 - \sigma_2}{2} \geq \dfrac{\sigma_y}{2} \Rightarrow (\sigma_1 - \sigma_2) \geq \sigma_y$

**60. Ans: (d)**

**Sol:** For No tension

$$e = \frac{Z}{A} = \frac{\frac{D^3}{6\sqrt{2}}}{D^2} = \frac{D}{6\sqrt{2}}$$

$$\left( \text{where } Z = \frac{I}{y_{max}} = \frac{D^3}{6\sqrt{2}} \right)$$

**61. Ans: (b)** **62. Ans: (b)**

**63. Ans: (a)**

**64. Ans: (c)**

**Sol:** Area under load deformation curve with elastic limit is modulus of resilience

**65. Ans: (a)**

**Sol:** $P_{cr} = \frac{\pi^2 EI}{L^2}$

**66. Ans: (c)** **67. Ans: (b)**

**68. Ans: (a)**

**69. Ans: (d)**

**Sol:** EPC contract doesn't involve detailed estimate. It is based on line estimate.

**70. Ans: (b)**

**71. Ans: (d)**

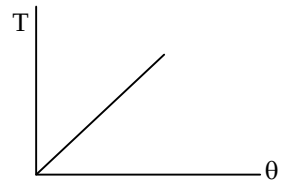
**Sol:** "Float is not associated with events"

Assertion is wrong.

**72. Ans: (a)** **73. Ans: (b)**

**74. Ans: (a)**

**Sol:**




Area under torque-rotation curve is strain energy

$$U = \frac{T\theta}{2}$$

$$\theta = \frac{TL}{GI_p}$$

$$\therefore U = \frac{T^2 L}{2GI_p}$$

**75. Ans: (a)**