ZONE TECH

समीक्षा

RSSB JE 2026

HYBRID TEST SERIES

SOLUTION

Paper ID

501

Stream

Civil Engineering (B.Tech)

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26 JULY 2026

Subject
SOM + TOS

|| आपकी सफलता, हमारी प्रतिबद्धता ||

1. Answer A

Solution.

Volumetric strain is the sum of strains in all three mutually perpendicular directions:

$$\varepsilon_v = \varepsilon_x + \varepsilon_y + \varepsilon_z$$

$$\varepsilon_v = \varepsilon - \frac{\varepsilon}{m} - \frac{\varepsilon}{m}$$

$$\varepsilon_v = \varepsilon\left(1 - \frac{2}{m}\right)$$

So the volumetric strain is:

$$\boxed{\varepsilon_v = \varepsilon\left(1 - \frac{2}{m}\right)}$$

2. Answer A

Solution.

In a composite bar, two materials with different coefficients of thermal expansion (CTE) are rigidly joined together, which forces both materials to undergo the *same* change in length — even though each material naturally "wants" to expand or contract by a different amount.

- On cooling, the part with the higher CTE wants to shrink (contract) more than the part with the lower CTE.
- Since both parts are joined together, the high-CTE part is restrained from shrinking as much as it wants by the low-CTE part.
- This restraint effectively stretches it relative to its natural (free) contracted length, which induces tensile stress in the high-CTE part.
- Conversely, the low-CTE part is pulled inward more than it naturally would contract, inducing compressive stress in it.

So, on cooling: the high CTE part experiences tensile stress, and the low CTE part experiences compressive stress.

3. Answer B

Solution.

The bar has two contributions to elongation — one from its own self-weight, and one from the applied axial load P.

1. Elongation due to self-weight (W):

Self-weight acts as a distributed load, with the internal force varying from 0 at the bottom to W at the top. Since the internal force isn't constant along the length, we integrate:

$$\delta_w = \frac{WL}{2AE}$$

This gives the well-known result: elongation due to self-weight is half of what it would be if the entire weight acted as a point load

2. Elongation due to **applied load P:**

P acts as a point load at the bottom, so the entire bar experiences constant internal force P throughout its length:

$$\delta_p = \frac{PL}{AE}$$

3. Total elongation:

$$\delta_{total} = \delta_w + \delta_p = \frac{WL}{2AE} + \frac{PL}{AE}$$

$$\boxed{\delta_{total} = \frac{WL}{2AE} + \frac{PL}{AE}}$$

4. Answer A

Solution.

Due to uniformly distributed horizontal load, the cable takes a parabolic shape. However, due to its own weight, it takes a shape of catenary.

5. Answer C

Solution.

The relation between elastic constants E, K, C, and Poisson's ratio (m) comes from two standard formulas:

$$E = 3K(1 - 2\mu) \qquad \ldots(i)$$

$$E = 2C(1+\mu) \qquad \ldots(ii)$$

Derivation:

Since both expressions equal E, equate them:

$$3K(1-2\mu) = 2C(1+\mu)$$

$$3K - 6K\mu = 2C + 2C\mu$$

$$3K - 2C = \mu(6K+2C)$$

$$\mu = \frac{3K-2C}{6K+2C}$$

6. Answer A

Solution.

The Maximum Shear Stress theory (also called Tresca's criterion or Guest's theory) states that yielding in a material begins when the maximum shear stress in the complex stress system equals the maximum shear stress at yielding in a simple uniaxial tension test.

Derivation:

In a simple tensile test, when the material reaches yield stress (σ_y), the specimen is under uniaxial stress:

$$\sigma_1 = \sigma_y,\ \sigma_2 = 0,\ \sigma_3 = 0$$

The maximum shear stress in this uniaxial conditions is:

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{\sigma_y - 0}{2}$$

$$\tau_{max} = \frac{\sigma_y}{2}$$

Result:

$$\boxed{\tau_{max} = \frac{1}{2} \times \text{yield stress}}$$

7. Answer C

Solution.

Shear stress at neutral axis = $\frac{4}{3}\tau_{avg}$

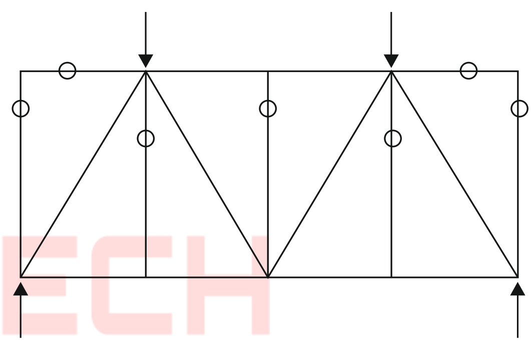
$$= \frac{4}{3} \times \frac{F}{\frac{1}{2}bh}$$

$$= \frac{8}{3}\frac{F}{bh}$$

8. Answer C

Solution.

- If only two non-collinear members meet at a joint and threre is no external load at that joint, then both members are zero force members.
- If three members meet at a joint, where two are collinear and one is non- collinear, and threee is no external load at that joint, then the non- collinear member is a zero force member.



7 members carry zero force

9. Answer B

Solution.

Elongation due to self-weight of a bar hanging freely:

$$\delta = \frac{WL}{2AE}$$

Where W = self-weight = $\rho \times A \times L \times g$ (ρ = density, A = cross-sectional area, L = length)

Derivation:

Substituting W = ρALg into the elongation formula:

$$\delta = \frac{(\rho ALg) \times L}{2AE} = \frac{\rho g L^2}{2E}$$

Notice that A cancels out – elongation due to self-weight depends only on "L^2", not on the cross-sectional area at all.

Now, if all dimensions are doubled:

- New length L′ = 2L
- New elongation:

$$\delta' = \frac{\rho g (2L)^2}{2E} = \frac{4\rho g L^2}{2E} = 4\delta$$

$$\boxed{\delta' = 4\delta \Rightarrow \text{enongation increases four times}}$$

10. Answer C

Solution.

Statement 1: "Maximum normal stress = external load / maximum cross-sectional area" (Incorrect)

- Normal stress = Load/Area is a general formula, but maximum normal stress actually occurs at the minimum cross-sectional area (weakest section), not the maximum area. A larger area gives lower stress, not higher. So this statement is wrong.

Statement 2: "Shear stress is zero on the plane where normal stress is maximum" (Correct)

- In uniaxial loading, the maximum normal stress occurs on the plane perpendicular to the load axis ($\theta = 0°$). On this plane:

$$\tau = \frac{\sigma}{2}\sin(2\theta) = \frac{\sigma}{2}\sin(0°) = 0$$

So shear stress is indeed zero where normal stress is maximum - this is a principal plane.

Statement 3: "Normal stress on planes of maximum shear stress is less than the maximum normal stress (Correct)

- Maximum shear stress occurs at θ = 45°, where:

$$\sigma_{45°} = \frac{\sigma}{2}(1+\cos 90°) = \frac{\sigma}{2}$$

$$\tau_{max} = \frac{\sigma}{2}$$

Since σ /2 < σ (maximum normal stress), the normal stress on the max-shear plane is indeed less than the maximum normal stress. Correct.

11. Answer B

Solution.

Here, the load is applied through the centroid (not through the shear center), in a plane perpendicular to the plane of symmetry.

1. Bending moment- Any transverse load on a beam causes bending moment.
2. Twisting moment- Since the load passes through the centroid but not through the shear center (channel sections have shear center offset from centroid, outside the web), the load's line of action doesn't align with the shear center

   This creates an additional torque (twisting moment) = Load × (distance between centroid and shear center).
3. Shear force- A transverse concentrated load always induces shear force in the beam.
4. Axial thrust- Since the load is applied through the centroid (not offset axially) and is purely transverse (perpendicular to the beam axis), there is no axial force component.

12. Answer B

Solution.

Williot- Mohr diagram is used for trusses only.

13. Answer B

Solution.

Given:

$E_A = 2E_B$

$\alpha_A = 2\alpha_B$

ΔT is same for both bars

σ_A

$= E_A.\alpha_A.\Delta T = (2E_B)(2\alpha_B)(\Delta T) = 4 \times (E_B \alpha_B \Delta T) = 4\sigma_B$

$\frac{\sigma_A}{\sigma_B} = 4$

14. Answer B

Solution.

For a hollow circular column subjected to an eccentric compressive load, the condition for no tension anywhere in the section (i.e., load must lie within the "core" or "kern" of the section) gives the limiting eccentricity:

$$e_{max} = \frac{D^2 + d^2}{8D}$$

Where D = external diameter, d = internal diameter.

Given values:

- Internal diameter = d

  External diameter D = 1.5d

Derivation:

$$e_{max} = \frac{(1.5d)^2 + d^2}{8(1.5d)}$$

$$e_{max} = \frac{2.25d^2 + d^2}{12d}$$

$$e_{max} = \frac{3.25d^2}{12d}$$

$$e_{max} = \frac{3.25d}{12} = \frac{13d}{48}$$

Result:

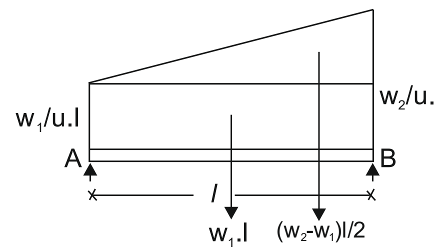
$$\boxed{e_{max} = \frac{13d}{48}}$$

15. Answer C

Solution.

Shear force at support B = Reaction at B (R_B). To find R_B, split the trapezoidal load into two simpler parts and take moments about support A.

split the trapezoidal load:



1. Rectangular part (uniform intensity w_1 throughout the span):
- Total load $w_1 \times l$
- Acts at centroid = $\frac{l}{2}$ from A

2. Triangular part (intensity increasing from 0 at A to (w_2 - w_1) at B):
- Total load = ½(w_2-w_1)×l
- Acts at centroid = 2l/3 from A (since the triangle peaks at B)

Derivation:

Taking moments about A $(\Sigma M_A = 0)$ to find R_B:

$$R_B \times l = w_1 l \times \frac{l}{2} + \frac{(w_2 - w_1)l}{2} \times \frac{2l}{3}$$

$$R_B \times l = \frac{w_1 l^2}{2} + \frac{(w_2 - w_1)l^2}{3}$$

$$R_B = l\left[\frac{w_1}{2} - \frac{w_1}{3} + \frac{w_2}{3}\right]$$

$$R_B = l\left[\frac{w_1}{6} + \frac{w_2}{3}\right]$$

Result:

$$\boxed{R_B = \frac{w_1 l}{6} + \frac{w_2 l}{3}}$$

16. Answer C

Solution.

Maxwells theorem

$$w_1\delta_1 = w_2\delta_2$$

$$\frac{\delta_1}{\delta_2} = \frac{W_2}{W_1}$$

17. Answer D

Solution.

For a beam of uniform strength, the bending stress (f) remains constant throughout the beam length, even though the bending moment varies - this is achieved by varying the depth (d) while keeping width (b) constant.

Bending stress relation:

$f = \frac{M}{Z}$ (where Z = section modulus = $bd^2/6$ (for rectangular section))

At the fixed end (x = L from free end), the bending moment is maximum:

$$M_{max} = WL$$

At this section, depth = d (maximum depth, occurring at the fixed end for a cantilever of uniform strength since M = 0 at the free end, the theoretical depth there is zero).

Applying the bending equation at the fixed end:

$$f = \frac{M_{max}}{Z} = \frac{WL}{\frac{bd^2}{6}}$$

$$f = \frac{6WL}{bd^2}$$

Solving for d:

$$d^2 = \frac{6WL}{bf}$$

$$\boxed{d = \sqrt{\frac{6WL}{bf}}}$$

18. Answer A

Solution.

Analysis of each statement:

Statement 1: "Flitched beam has a composite section of two or more materials joined together such that they behave as a unit piece and each material bends to the same radius of curvature" **Correct.**

- This is the fundamental definition of a flitched (composite) beam — e.g., a timber beam reinforced with steel plates. Since the materials are joined and act as one unit, they undergo the **same curvature (1/R)** at any section, even though their individual stresses differ (due to different E values).

Statement 2: "Total moment of resistance = sum of moments of resistance of individual sections" **Correct.**

- Since both materials bend to the same radius, and each contributes its own moment of resistance based on its own E and I:

$$M_{total} = M_1 + M_2 = \frac{E_1 I_1}{R} + \frac{E_2 I_2}{R}$$

This additive property of moments of resistance holds true for flitched beams.

Statement 3: "Flitched beams are used when a beam of one material alone would require quite a large cross-sectional area" **Correct.**

This is the practical motivation for flitched beams - e.g., reinforcing a timber beam with steel plates allows a smaller, more economical section to carry the same load compared to using timber alone (which would need to be much larger/bulkier).

19. Answer D

Solution.

On a stress-strain curve, the yield point is the stress level at which the material begins to deform plastically — beyond this point, a large increase in strain (extension) occurs for a very small (or negligible) increase in stress (load).

20. Answer C

Solution.

Euler's critical buckling load for a column is-

$$P = \frac{\pi^2 EI}{(L)^2}$$

Here L = Effective Length

Effective length for different end coditions.

	End condition	Effective Length
i	Both end hinged	L
ii	one end fixed and the other hinged	$\frac{L}{\sqrt{2}}$
iii	One end Fixed and other free	2L
iv	Both end fixed	L/2

In given question, column is fixed at one end and free at other end.

$$P = \frac{\pi^2 ET}{(2L)^2} = \frac{\pi^2 EI}{4L^2}$$

21. Answer B

Solution.

- True Stress = Load / Actual Area
- Nominal Stress = Load / Original Area
- In a tensile test, the actual area decreases, so True Stress > Nominal Stress.
- UTM grips cause stress concentration, but this is not the reason for the difference.
- Therefore, both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

22. Answer A

Solution.

In a **mild steel tensile specimen**, failure occurs in the form of a **cup-and-cone fracture**. The fracture plane is inclined at **45° to the longitudinal axis**.

Maximum shear plane is at an angle **θ** with the normal to the principal plane.

When **2θ = 90°**,

θ = 45°

Thus, **maximum shear stress acts at 45° to the axis.**

Hence, the **Reason is also correct**, and it is the **correct justification for the Assertion**

23. Answer D

Solution.

Elongation in bar due to load P

$$\Delta = \Sigma \frac{PL}{AE}$$

$$= \frac{10 \times 100}{E}\left[\Sigma \frac{4}{\pi d^2}\right]$$

$$= \frac{1000}{E} \times \frac{4}{\pi}\left[\frac{1}{(40)^2} + \frac{1}{(50)^2} + \frac{1}{(60)^2}\right]$$

$$= \frac{40}{\pi E}\left[\frac{1}{16} + \frac{1}{25} + \frac{1}{36}\right] \text{mm}$$

24. Answer C

Solution.

Member	Stiffness	Distribution factor
BA	$\frac{4EI}{6} = \frac{2}{3}EI$	$\frac{2/3\ EI}{2/3\ EI + EI} = 0.4$
BC	$\frac{4(2EI)}{8} = EI$	$1 - 0.4 = 0.6$

25. Answer C

Solution.

Metal	Poisson's ratio (μ)
Aluminium	0.334
Cast iron	0.26
Steel	0.303

$\mu_{\text{aluminium}} > \mu_{\text{steel}} > \mu_{\text{cast iron}}$

26. Answer A

Solution.

For bending moment M to be maximum

$$\frac{dM}{dx} = 0$$

We know $\frac{dM}{dx} = V$

Hence shear force at a section is given by the rate of change of bending moment and value of bending moment is maximum at the section where shear force is zero or changes sign.

27. Answer D

Solution.

Load can be transferred through bending also hence option (1) is incorrect

option (2) is correct

out of option (3) and (4) option 4 is most. appropriate because definition of complicated loading is vague.

28. Answer D

Solution.

$$\frac{dV}{dx} = w$$

Slope of SFD = Load intensity

Slope of SFD is constant in portion CE which shows a udl is acting on the portion CE.

Sudden change in SFD shows that a concentrated load is acting at the point.

Hence, statement 1 and 3 are correct.

29. Answer B

Solution.

- BM is maximum under the load
- Deflection will be maximum, where slope of elastic curve is zero.
- Deflection under the load will be maximum – false because for an unsymmetrically placed point load, the point of maximum deflection does not occur under the load. It occurs at the point where the slope of the deflected beam becomes zero.
- Slope at the nearer support will be maximum – true since the load is closer to one support (say the nearer support), that support carries a larger reaction force, and consequently experiences a steeper slope of the deflected beam at that end compared to the farther support.

30. Answer C

Solution.

Symmetrical frame having symmetrical loading about its central line will not cause any sway.

31. Answer C

Solution.

Method area moment proves advantageous for

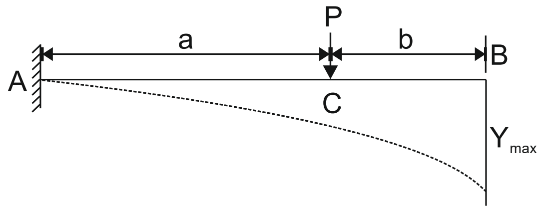
(1) Cantilever beam → Slope at fixed end is zero

(2) Symmetrically simply supported beams slope at mid point is zero

(3) Fixed beam → slopes at fixed support are zero

32. Answer A

Solution.



$$Y_{max} = \delta_B = \delta_C + \theta_C * b$$

$$Y_{max} = \frac{Pa^3}{3EI} + \frac{Pa^2}{2EI} * b$$

$$= \frac{Pa^2}{6EI}(2a + 3b)$$

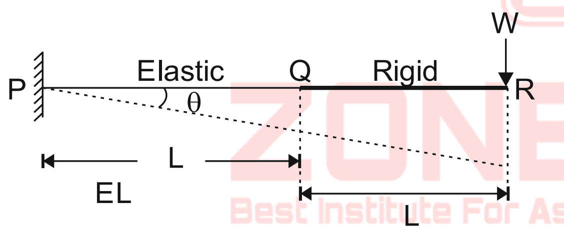
$$= \frac{Pa^2}{6EI}(3(a+b) - a)$$

$$= \frac{Pa^2}{6EI}(3l - a)$$

33. Answer A

Solution.

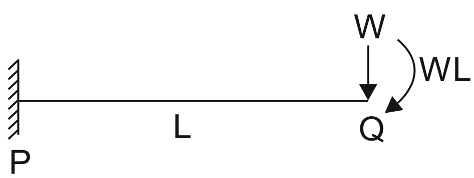
Rigid - No elastic deflection



This is equivalent to δ_Q

$$= \frac{WL^3}{3EI} + \frac{(WL)L^2}{2EI} = \frac{5WL^3}{6EI}$$

$$\theta_Q = \frac{WL^2}{2EI} + \frac{(WL)L}{EI} = \frac{3WL^2}{2EI}$$



34. Answer C

Solution.

$$\delta_R = \delta_Q + (\theta_Q \times L)$$

$$= \frac{5WL^3}{6EI} + \frac{3WL^3}{2EI} = \frac{7}{3}\frac{WL^3}{EI}$$

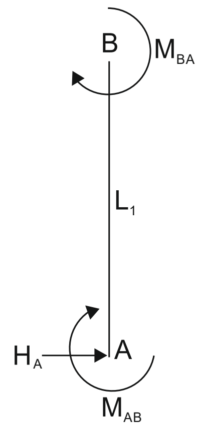
35. Answer A

Solution.

Shear equation for the portal frame is

$H_A + H_D + P = 0$

where H_A and H_D are reactions at A and D in rightward direction.



Taking moment about B

$H_A \times L_1 = M_{BA} + M_{AB}$

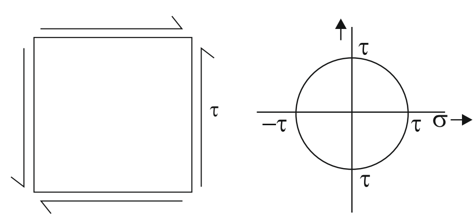
$$H_A = \frac{M_{BA} + M_{AB}}{L_1}$$

$$\text{Similarly, } H_D = \frac{M_{CD} + M_{DC}}{L_2}$$

$$\frac{M_{BA} + M_{AB}}{L_1} + \frac{M_{CD} + M_{DC}}{L_2} + P = 0$$

36. Answer C

Solution.



Principal stresses are τ and -τ.

37. Answer D

Solution.

Modulus of rupture : In case of bending, maximum normal stress σ is called modulus of rupture

$\sigma = \frac{M_u . y}{I}$ where M_u is the ultimate moment that causes failure in the member.

Hence modulus of rupture is related to moment of inertia

- Elongation $= \frac{\text{Tensile stress} \times \text{length}}{E}$
- At neutral axis longitudinal stress is zero.
- At outermost surface shear stress is zero so at top fibre shear stress is zero

38. Answer C

Solution.

$$M_{21} = M_{F21} + \frac{2EI}{L}\left(2\theta_2 + \theta_1 - \frac{3\delta}{L}\right)$$

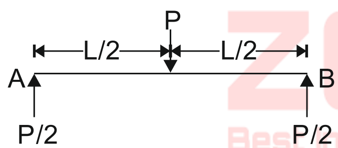
Fixed end moment, $M_{F21} = 0$

End 1 is fixed so $\theta_1 = 0$

$$\therefore \quad M_{21} = \frac{2EI}{L}\left(2\theta_2 - \frac{3\delta}{L}\right)$$

39. Answer C

Solution.



Bending moment at a distance x from end A

$$M(x) = \frac{P}{2}x; \qquad x < \frac{L}{2}$$

For a beam of uniform strength BM at any section is equal to moment of resistance of beam.

M.O.R. = σ . z

$$\frac{P}{2}x = \sigma \frac{b_x d^2}{6}$$

$b_x \propto x$

40. Answer D

Solution.

- In theory of bending, strain developed in any fibre is directly proportional to the distance of fibre from NA, also valid

during inelastic actions, because linear strain variation is derived from the assumption of plane section before bending remains plane after bending.

- NA coincides with centroid only when hook's law is valid i.e., linear elastic action.
- However if there is symmetry about the axis of bending then even in inelastic conditions N.A will lie at the C.G only. For example in case of rectangular section N.A does not shift even in case of inelastic action and remains at the same location as in case of elastic condition.

41. Answer B

Solution.

At the top and bottom shear stress will be zero and it will increase parabolically upto neutral axis after that shear stress will decrease in parabolic shape but in the bottom portion as width increases suddenly, shear stress will reduce suddenly.

42. Answer B

Solution.

Force method uses force as basic unknown variable which is a function as static indeterminacies so, force method is preferred when there is less no. of static and more numbers of kinematic indeterminacies.

43. Answer A

Solution.

For a 2D state of stress $\left(\sigma_x, \sigma_y, \tau_{xy}\right)$, the centre of Mohr's Circle on the normal stress (s) axis is:

$$C = \left(\frac{\sigma_x + \sigma_y}{2}, 0\right)$$

Hence, the distance of the centre from the y-axis (t-axis) is:

$$\boxed{\frac{\sigma_x + \sigma_y}{2}}$$

44. Answer C

Solution.

Resilience is the total strain energy stored in a body within the elastic limit.

- Impact Energy → Energy due to a suddenly applied load.
- Resilience → Total strain energy stored in the elastic range.
- Proof Resilience → Maximum strain energy stored up to the elastic limit.
- Modulus of Resilience → Proof resilience per unit volume.

45. Answer B

Solution.

For a triangular section of b and height h:

- Moment of Inertia about C.G. (parallel to the base):

$$I_G = \frac{bh^3}{36}$$

- Area of triangle

$$A = \frac{1}{2}bh$$

- Distance between the vertex axis and C.G. axis:

$$d = \frac{2h}{3}$$

Using the parallel Axis Theorem,

$$I_V = I_G + Ad^2$$

$$= \frac{bh^3}{36} + \frac{1}{2}bh\left(\frac{2h}{3}\right)^2$$

$$= \frac{bh^3}{36} + \frac{2bh^3}{9} = \frac{9bh^3}{36} = \frac{bh^3}{4}$$

Therefore,

$$\frac{I_V}{I_G} = \frac{\frac{bh^3}{4}}{\frac{bh^3}{36}} = 9$$

46. Answer B

Solution.

Shear stress is given by:

$$\tau = \frac{FQ}{Ib}$$

The first moment of area Q is maximum at the neutral axis; therefore, the maximum shear stress occurs at neutral axis.

47. Answer A

Solution.

Correct Answer:

Both Assertion (A) and Reason (R) are true, and Reason (R) correctly explains Assertion (A).

For pin-jointed plane frames, the degree of static indeterminacy is generally smaller than the number of kinematic degrees of freedom. Therefore, the force method involves fewer unknowns and requires less computation than the displacement method.

48. Answer C

Solution.

For an eccentrically loaded square column,

$$\sigma = \frac{W}{A} \pm \frac{MY}{I}$$

Where,

M = W.e

A = b^2

$$I = \frac{b^4}{12}$$

$$Y = \frac{b}{2}$$

Maximum bending stress:

$$\frac{MY}{I} = \frac{We\left(\frac{b}{2}\right)}{\frac{b^4}{12}} = \frac{6We}{b^3} = \frac{6We}{b^3} = \frac{W}{A}\cdot\frac{6e}{b}$$

Therefore,

$$\boxed{\sigma_{max} = \frac{W}{A}\left(1 + \frac{6e}{b}\right)}$$

49. Answer B

Solution.

For a simply supported beam carrying a UDL w:

- Deflection at the centre due to UDL:

$$\delta_{UDL} = \frac{5wL^4}{384EI}$$

- Deflection at the centre due to an upward prop reaction R:

$$\delta_R = \frac{RL^3}{48EI}$$

Since the prop prevents deflection at midpoint,

$$\delta_{UDL} = \delta_R$$

$$\frac{5wL^4}{384EI} = \frac{RL^3}{48EI}$$

$$R = \frac{5wL}{8}$$

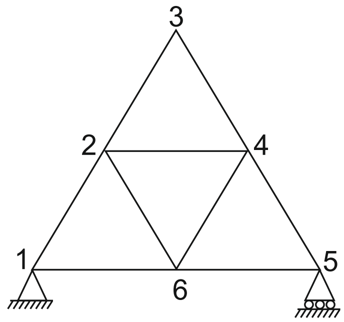
50. Answer D

Solution.

A continuous beam is subjected to a couple in one (or more) of the spans. Such a beam is also analyses in the similar manner. The couple will cause negative moments in one part and positive moments in the other part of the span. While taking moment of the bending moment diagram. due care should be taken for the positive and negative bending moments

51. Answer C

Solution.



D_s = m+r-2j

= 9+3 -2 × 6

= 12 – 12 = 0

D_{se}= r- 3

= 3 – 3 = 0 (Externally determinate)

D_{si} = D_s - D_{se} = 0 (Internally determinate)

r = number of reactions

52. Answer B

Solution.

$$\boxed{U = \frac{\tau^2}{4C}\left(\frac{D^2 + d^2}{D^2}\right)}$$

For a hollow shaft, strain energy per unit volume is:

$$U = \frac{\tau^2}{4C}\left(1 + \frac{d^2}{D^2}\right)$$

Where C is the modulus of rigidity.

53. Answer B

Solution.

For mild steel, Rankine's constant is:

$$\boxed{\alpha = \frac{1}{7500}}$$

Note:- $\frac{1}{9000}$ is generally used for wrought iron.

54. Answer A

Solution.

Given:

- Length of shaft, L = 5 m
- Applied torque, T = 200 kN.m
- Torsional rigidity, GJ = 50000 kN.m²/rad

1. Angle of Twist

Using the torsion equation,

$$\frac{T}{J} = \frac{G\theta}{L}$$

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

$$\theta = \frac{200 \times 5}{50000} = 0.02 \text{ rad}$$

2. Strain Energy Stored

The strain energy stored in a shaft is

$$U = \int_0^L \frac{T^2}{2GJ} dx$$

Since the torque is constant throughout the length,

$$U = \frac{T^2 L}{2GJ}$$

Substituting the given values,

$$U = \frac{(200)^2 \times 5}{2 \times 50000}$$

U = 2 kN.m

55. Answer D

Solution.

Plane frame: D_s = 3m + r - 3n

- Space truss: D_s = m + r - 3n
- Space frame: D_s = 6m + r - 6n

Answer: (d) 4, 1, 2

56. Answer C

Solution.

Shear Centre

The shear centre is the point on the cross-section of a beam through which the resultant shear force must pass so that the beam bends without twisting.

- The shear centre is also known as the centre of twist.

- For sections symmetric about both axes, the shear centre coincides with the centroid.
- For sections symmetric about one axis only, the shear centre lies on the axis of symmetry.
- When the external load passes through the shear centre, the beam undergoes pure bending only, and no twisting (torsion) occurs.

57. Answer B

Solution.

For a rectangular section of width b and depth d:

To ensure that no tensile stress is produced in the section,

$$e \le \frac{k^2}{y}$$

Where,

- e = eccentricity of the load
- k = radius of gyration of the section
- $y = \frac{d}{2}$ = distance from the centroid to the extreme fibre

For a rectangular section,

$$k^2 = \frac{I}{A} = \frac{bd^3/12}{bd} = \frac{d^2}{12}$$

Substituting,

$$e \le \frac{d^2/12}{d/2} = \frac{d}{6}$$

Final Answer:

$$\boxed{e \le \frac{d}{6}}$$

Where k is the radius of gyration of the section.

58. Answer C

Solution.

Hooke's Law	Elastic Material
One-dimensional stress	Stress varies linearly with distance from the neutral axis.
Curvature of a beam	Varies linearly with the bending moment
Bending Stress	Varies inversely with the moment of inertia

59. Answer C

Solution.

In case of determinate structures, reactions are more

$\Rightarrow$ greater sections are required, Uneconomical Indeterminate structures

$\Rightarrow$ Lesser forces, reactions, deflections and Economical

$\therefore$ Statement 1 is wrong.

If $D_s = 0$, structure is not necessary unstable

If D_s = (-)ve, we consider it unstable

$\therefore$ Statement 2 is wrong

60. Answer A

Solution.

Failure Theory	**Proposed By**
Maximum Principal Stress Theory	Rankine
Maximum Principal Strain Theory	Saint-Venant
Maximum Shear Stress Theory	Tresca
Maximum Strain Energy Theory	Beltrami-Haigh

61. Answer D

Solution.

Maximum Principal Stress (Maximum Normal Stress)

$$\boxed{\sigma_{max} = \frac{16}{\pi D^3}\left[M + \sqrt{M^2 + T^2}\right]}$$

Maximum Shear Stress

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

Where:

M = Bending Moment

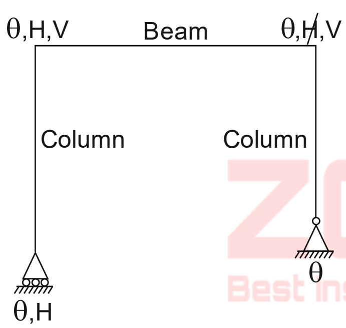
T = Torque

D = Diameter of the shaft

62. Answer B

Solution.

Beam is axially rigid. Hence, m = 1.



$3j - r - m = 3 \times 4 - 3 - 1 = 8$

m = No. of inextensible members

63. Answer B

Solution.

Rankine's formula is applicable to both short and long columns because it considers both crushing and buckling failures.

Let,

1. Crushing Load: $P_c = \sigma_c A$

2. Euler Buckling Load: $P_E = \dfrac{\pi^2 EI}{L_e^2}$

Rankine's formula $\boxed{P = \dfrac{\sigma_c A}{1 + a\left(\dfrac{L_e}{K}\right)^2}}$

Where, $\lambda = \dfrac{L_e}{K}$

64. Answer C

Solution.

- For a circular shaft, the strength can be increased by approximately 0.7% by removing the excess material and converting in into a hollow section.
- Depth of removed portion should be 0.011 times the external diameter d.

65. Answer B

Solution.

Flexural stiffness is defined as the moment required to produce unit rotation.

$$\boxed{k = \frac{M}{\theta}}$$

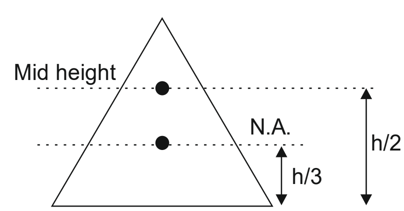
where:

M = Bending moment

θ = Rotation (radians)

66. Answer D

Solution.



For a triangular cross-section, the shear stress distribution is parabolic, with:

- Zero shear stress at the apex.
- Maximum shear stress at $\boxed{\dfrac{h}{2}}$ from the base (or $\boxed{\dfrac{h}{6}}$ from the centroid).

67. Answer C

Solution.

$R_A + R_B = P$ ...(i)

Taking moments about point A,

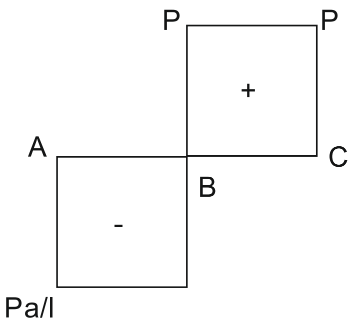
$R_B \times L - P(L + a) = 0$

$$R_B = \frac{P(L+a)}{L} = P + \frac{Pa}{L}$$

Substituting the value of R_B in Equatin (i),

$$R_A = P - P - \frac{Pa}{L}$$

$$R_A = -\frac{Pa}{L}$$



Shear force change sign at point B so maximum bending moment occure at point B.

68. Answer A

Solution.

From the equilibrium of vertical forces,

$$\Sigma F_y = 0$$

$R_A = 2$ kN

Shear Force on the Beam

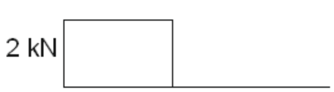
At point A, $(SF)_A = +2$ kN

At point B, $(SF)_B = +2$ kN

A downward 2 kN at point B so SFD sudden drawdown 2 kN.

Shear force in portion BC = 0

Shear Force Diagram (S.F.D.)



69. Answer A

Solution.

Rotational stiffness of joint

$$\Sigma K_0 = K_{0A} + K_{0B} + K_{0C} + K_{OD}$$

$$= \frac{4EI}{L} + \frac{3EI}{L} + \frac{4EI}{L} + 0 = \frac{11EI}{L}$$

70. Answer A

Solution.

Strain Energy Due to Bending

$$U = \frac{M^2L}{2EI} = \frac{M^2L}{2E\left(\frac{bd^3}{12}\right)}$$

$$U \propto \frac{1}{d^3}$$

If the depth of the beam is reduced to half, then

$$U \propto \frac{1}{\left(\frac{d}{2}\right)^3} = \frac{8}{d^3}$$

Therefore,

$$\frac{U'}{U} = \frac{\frac{8}{d^3}}{\frac{1}{d^3}} = 8$$

$$\boxed{U' = 8U}$$

71. Answer D

Solution.

Volumetric Strain:

Volumetric Strain is defined as the ratio of the change in volume to the original volume of a body.

- Volumetric Strain is also known as Bulk Strain.

Shear Strain:

Shear Strain is the angular deformation produced when forces act parallel to the surface of a body.

Linear Strain:

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Linear Strain is the ratio of the change in length to the original length of a body when a force is applied along its axis.

72. Answer B

Solution.

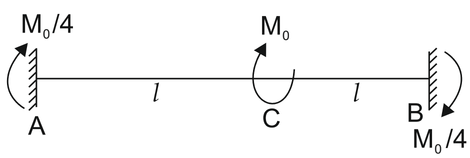
1. On principal planes, shear stress is zero - Correct.
2. Shear stresses on mutually perpendicular planes are equal in magnitude - Correct.
3. Maximum shear stress is:

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}$$

It is half the difference, not half the sum - Incorrect.

73. Answer C

Solution.



Final end moment of A $= \frac{M}{4}$

74. Answer B

Solution.

Impulse $\rightarrow$ Large force applied in short Time

Torsion "T" $\rightarrow$ 'G' (related)

Plane of loading $\rightarrow$ Shear centre

Instantaneous centre of rotation $\rightarrow$ Plane motion

75. Answer C

Solution.

$$P = T.\omega$$

$$P = \frac{2\pi NT}{60}$$

$$\frac{P_A}{P_B} = \frac{N_A}{N_B} \times \frac{T_A}{T_B} = 2 \times \frac{1}{2} = 1$$

76. Answer B

Solution.

Assertion (A):

A moment applied perpendicular to the axis of a circular beam produces pure bending. In pure bending, normal (bending) stress is induced, while shear stress is zero.

Assertion is Correct.

Reason (R):

If the moment is applied along the axis of the beam, it produces torsion (twisting). A circular shaft under pure torsion develops only shear stress and no bending (normal) stress.

Reason is also Correct.

Hence, the **Reason is also correct**, and it is the **correct justification for the Assertion**

77. Answer B

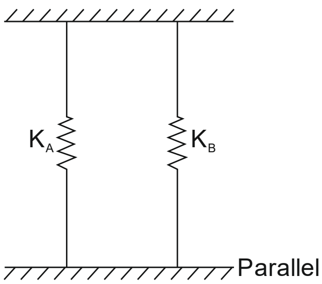
Solution.

Castigliano's 1st theorem	**Castigliano's 2nd theorem**
1. The first partial derivative of total internal energy (strain energy) in a structure with respect to any particular deflection component at a point is equal to the force applied at that point and in the direction corresponding to that deflection component. i.e. $\frac{\partial U}{\partial \delta} = P$ or $\frac{\partial U}{\partial \theta} = M$	1. The first partial derivative of total internal energy in a structure w.r.t the force applied at any point is equal to the deflection at the point of application of that force in the direction of its line of action. i.e. $\frac{\partial U}{\partial P} = \delta$ or $\frac{\partial U}{\partial M} = \theta$
2. Castigliano's 1st theorem is applicable to linearly or non-	2. Castigliano's 2nd theorem is applicable to linearly elastic

linearly elastic structures in which the temperature is constant and the supports are unyielding.	(Hookean material) structures with constant temperature & unyielding supports.

78. **Answer D**

Solution.



$$P = P_A + P_B$$

$$\delta_A = \delta_B = \delta$$

$$K = \frac{F}{\delta}$$

$$K.\delta = K_A\delta + K_B\delta$$

$$K = K_A + K_B$$

79. **Answer D**

Solution.

Cylinder $\sigma_h = \frac{Pd}{2t}$

$$\sigma_l = \frac{Pd}{4t}$$

$$\frac{\Delta d}{d} = \varepsilon_h = \frac{\sigma_h - \mu\sigma_l}{E}$$

$$\Delta d = \frac{Pd^2}{4tE}(2-\mu)$$

80. **Answer B**

Solution.

For inextensible members:

- Independent joint rotations = 8
- Independent lateral sway displacement at the top storey = 1
- The lower storey cannot sway due to the lateral support.

Degree of Freedom = 8 + 1 = 9