DETAILED SOLUTIONS

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ESE 2023 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 6

Section A : Design of Steel Structure + Surveying and Geology [All Topics]
Section B : Solid Mechanics-I [Part Syllabus]
Section C : Geo-technical & Foundation Engg-II + Environmental Engg-II [Part Syllabus]

1.	(d)	16.	(b)	31.	(a)	46.	(c)	61.	(b)
2.	(a)	17.	(c)	32.	(b)	47.	(d)	62.	(d)
3.	(d)	18.	(c)	33.	(b)	48.	(c)	63.	(c)
4.	(c)	19.	(d)	34.	(d)	49.	(c)	64.	(b)
5.	(c)	20.	(b)	35.	(c)	50.	(b)	65.	(d)
6.	(a)	21.	(b)	36.	(b)	51.	(c)	66.	(b)
7.	(d)	22.	(b)	37.	(a)	52.	(b)	67.	(c)
8.	(d)	23.	(b)	38.	(c)	53.	(c)	68.	(c)
9.	(d)	24.	(c)	39.	(a)	54.	(c)	69.	(b)
10.	(c)	25.	(b)	40.	(d)	55.	(c)	70.	(b)
11.	(b)	26.	(b)	41.	(c)	56.	(b)	71.	(c)
12.	(c)	27.	(d)	42.	(a)	57.	(d)	72.	(d)
13.	(d)	28.	(b)	43.	(a)	58.	(b)	73.	(d)
14.	(c)	29.	(b)	44.	(c)	59.	(b)	74.	(a)
15.	(b)	30.	(b)	45.	(a)	60.	(c)	75.	(c)

- **Revised key / solution 22-11-2022 [Q.19, 72]**

DETAILED EXPLANATIONS

1. (d)

Reduction factor, $\beta_{pk} = 1 - 0.0125\, t_{pk}$

IS 800 : 2007 Clause 10.3.3.3

2. (a)

The value of maximum equivalent stress $\leq \dfrac{f_u}{\sqrt{3}\,\gamma_{mw}}$

$$\Rightarrow \quad f_e \leq \frac{f_u}{\sqrt{3}\,\gamma_{mw}}$$

$$\Rightarrow \quad f_e \leq \frac{410}{\sqrt{3} \times 1.25} \leq 189.37 \text{ MPa}$$

3. (d)

In laced columns, due to shear deformations, slenderness ratio gets increased.

4. (c)

Non-dimensional effective slenderness ratio

$$\lambda = \sqrt{\frac{f_y}{f_{cc}}}$$

$$f_{cc} = \frac{\pi^2 E}{\left(\frac{kl}{r}\right)^2}$$

Refer IS 800 : 2007 Clause 7.1.2.1

5. (c)

(a) Gross section yielding: Excessive deformation of the member in longitudinal direction before fracture.

(b) Net section rupture: Fracture of the member when the net cross-section of the member reaches ultimate stress.

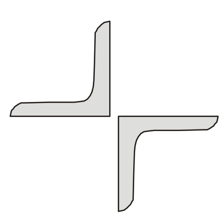
(c) Block shear: A segment of block of material at end of member gets shear out.

6. (a)

Flexural buckling: Any cross-sectional shape

Torsional buckling: Thin walled members with open cross-sectional shapes

Cruciform section:



Flexural-torsional buckling: Unsymmetrical cross-sections both with one axis of symmetry and no axis of symmetry.

7. (d)

For semi-compact section (Both high and low shear case)

$$M_d = \frac{\beta_b Z_p f_y}{\gamma_{mo}}$$

$$\beta_b = \frac{Z_e}{Z_p}$$

$$\therefore \quad M_d = \frac{Z_e f_y}{\gamma_{mo}} \le \frac{1.5 Z_e f_y}{\gamma_{mo}}$$

$$\Rightarrow \quad M_d = \frac{751.9 \times 10^3 \times 250}{1.1} \text{ N.mm} = 170.89 \text{ kNm} \simeq 170.9 \text{ kNm}$$

8. (d)

As per IS 800 : 2007 Clause 16.4.1

$$\frac{(f_y)_T}{(f_y)_{20}} = \frac{905 - T}{905}$$

$$\Rightarrow \quad \frac{(f_y)_{100}}{(f_y)_{20}} = \frac{905 - 100}{905} = 0.8895$$

$$\therefore \quad \text{Reduction in yield strength,} \quad R = \frac{(f_y)_{20} - (f_y)_{100}}{(f_y)_{20}} \times 100$$

$$= (1 - 0.8895) \times 100 = 11.05\% \simeq 11.1\%$$

10. (c)

Bearing stiffeners are used to transfer concentrated loads. They are required when the web has insufficient strength for web yielding and web crippling.

11. (b)

The vertical deflection δ of a gantry girder of span length L should not exceed the values specified below:

(i) When the cranes are manually operated, $\delta = \frac{L}{500}$.

(ii) When the cranes are travelling overhead and operated electrically up to 500 kN, $\delta = \frac{L}{750}$.

(iii) When the cranes are travelling overhead and operated electrically over 500 kN, $\delta = \frac{L}{1000}$.

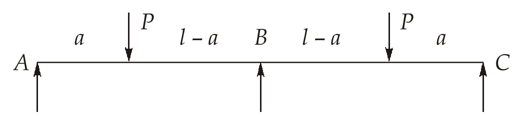
(iv) Other moving loads, such as charging cars, etc. where, L = Span of gantry girder, $\delta = \frac{L}{600}$.

12. (c)

$$LL = 750 - 20(\theta - 10)$$

$\Rightarrow$ $$LL = 750 - 20(25 - 10)$$
$$= 750 - 20 \times 15$$
$$= 750 - 300 = 450 \text{ N/m}^2$$

13. (d)

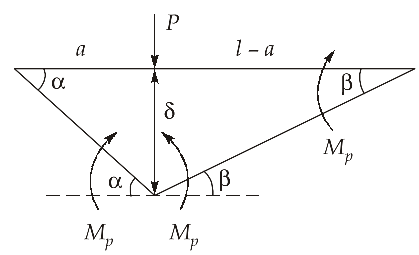


$$D_s = 3 - 2 = 1$$
$$n = D_s + 1 = 1 + 1 = 2$$

Mechanism possible

$$\delta = a\,\alpha = (l - a)\,\beta$$

$\therefore$ $$P \times \delta = M_p\,\alpha + M_p\,\beta + M_p\,\beta$$



$\Rightarrow$ $$P \times \delta = M_p\,\alpha + 2M_p \times \frac{a\alpha}{l - a}$$

$\Rightarrow$ $$P \times a\alpha = M_p\left[\frac{\alpha(l - a) + 2a\alpha}{l - a}\right]$$

$\Rightarrow$ $$P \times a\alpha = \frac{M_p[\alpha l + a\,\alpha]}{l - a}$$

$\Rightarrow$ $$P \times a\alpha = M_p\,\alpha\frac{(l + a)}{(l - a)}$$

$\Rightarrow$ $$P = \frac{M_p}{a}\,\frac{(l + a)}{(l - a)}$$

14. (c)

Shape factor of triangular section is 2.34 which is highest among all the given sections. Shape factor represents reserve strength.

15. (b)

True length of line = 300 m

Measured length = 303 m

Clearly the actual length of tape will be less than 30 m.

Let the actual length be l.

As per given data,

$$\frac{l}{30} \times 303 = 300$$

$\Rightarrow$ $$l = \frac{300 \times 30}{303} = \frac{300}{10.1} \approx 29.7 \text{ m}$$

16. (b)

Let the accuracy in linear measurement = $\frac{1}{r}$

and the length of offset be 'l'

So, $$\text{Linear error} = \frac{l}{r}$$

$$\text{Angular error} = l \sin \alpha$$

$\therefore$ $$\frac{l}{r} = l \sin \alpha$$

$\Rightarrow$ $$r = \text{cosec } \alpha$$

So accuracy in linear measurement = 1 in cosec α

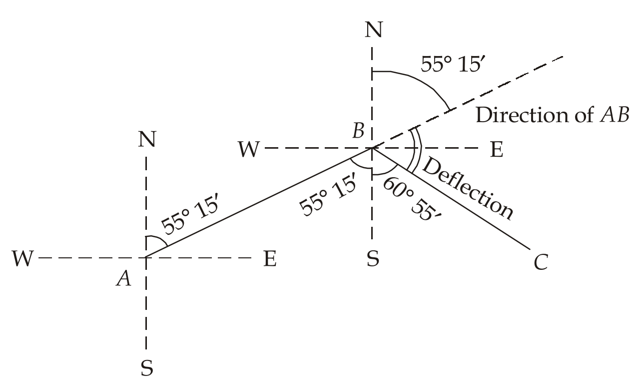
17. (c)

$$\text{Weight of } A + B + C = \frac{1}{\frac{1}{2}+\frac{1}{4}+\frac{1}{4}} = 1$$

18. (c)

A concave or positive lens has surface that are round to spherical surfaces of a certain curvature. Due to this, the thickness of the lens is not uniform across its length. Hence, rays of light falling near the edges are refracted more and fall closer to the lens as compared to rays passing through the lower layers. This is known as spherical aberration.

19. (d)



$$\text{Deflection} = 180° - (55° 15' + 60° 55') = 63° 50'$$

$$\text{Internal angle i.e. } \angle ABC = 60° 55' + 55° 15' = 116° 10'$$

$\therefore$ $$\text{Included angle} = 360° - 116° 10' = 243° 50'$$

20. (b)

In order to help surveyors determine declination at a place, isogonic charts are published. These charts show:

(a) Isogonic lines connecting places of equal declinations.

(b) Agonic lines showing places having zero declination.

(c) Lines connecting places having equal variations in declination.

21. (b)

Station A is free from local attraction. So fore bearing of AB and back bearing of DA is correct.

$\therefore$ Correct back bearing of AB = 30° + 180° = 210°

So, add 1° to readings of station 'B' (210° – 209° = 1°)

(i) Correct fore bearing of BC = 119° + 1° = 120°

$\therefore$ Correct back bearing of BC = 120° + 180° = 300°

So, subtract 2° from readings at station 'C' (300° – 302° = –2°)

(ii) Correct fore bearing of CD = 242° – 2° = 240°

$\therefore$ Correct back bearing of CD = 240° – 180° = 60°

So, subtract 1° from readingsz at station 'D' (60° – 61° = –1°)

(iii) Correct fore bearing of DA = 321° – 1° = 320°

Back bearing of DA is already correct and same can be verified as 320° – 180° = 140°

22. (b)

Let us assume the line of sight shifts downwards and let the collimination error 'E_{cl}' = e m

When staff is nearer to A, reading at A is unaffected by collimination error and when staff is near to station B, station B is unaffected by collimination error. Also as distance is less and hence effect of curvature and refraction will be insignificant.

When staff is near to A

Correct reading at A = 2.285

Correct reading at B = 3.625 + e

When staff is near to B

Correct reading at A = 1.225 + e

Correct reading at B = 2.465

$$\Delta H = 3.625 + e - 2.285 = 2.465 - 1.225 - e$$

$$\Rightarrow \quad 2e = (2.465 - 1.225) - (3.625 - 2.285)$$

$$\Rightarrow \quad 2e = 1.24 - 1.34$$

$$\Rightarrow \quad 2e = -0.1$$

$$\Rightarrow \quad e = -0.05 \text{ m}$$

(–) sign implies that due to collimination error, light of sight has shifted upwards (opposite to the assumed direction)

and ΔH = 3.625 + e – 2.285

= 1.34 – 0.05 = 1.29 m

23. (b)

Sensitivity of a bubble tube increases with

1. Decrease in viscosity.

2. Decrease in roughness at internal surface.

3. Increase in smoothness of internal surface.

4. Increase in radius of curvature.

5. Increase in diameter of tube.

6. Increase in length of tube.

24. (c)

If P, Q and R are the three stations whose plotted positions p, q and r are available on the plan and S is the station where the plane table is to be set up, then the accuracy with which the point s (plotted position of S on plane table) can be determined which is known as strength of fix. The strength of fix is good when

(a) S lies within the triangle PQR.

(b) The middle station is much nearer compared to the other two stations.

(c) The angle subtended by PQ and QR at S is such that one is large while the other is small.

26. (b)

Let the horizontal distance between point Q and tower be 'B' and take the difference in elevation between P and Q as 'D'.

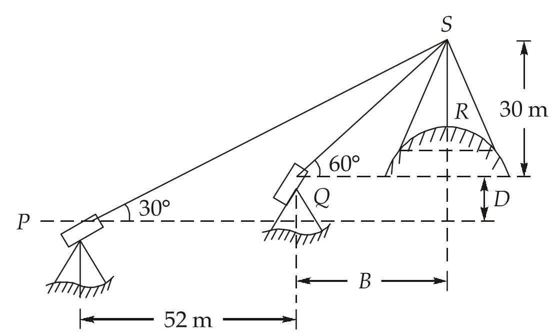
For instrument station P,

$$\tan 30° = \frac{30+D}{52+B} \quad \text{...(i)}$$

For instrument station Q,

$$\tan 60° = \frac{30}{B} \quad \text{...(ii)}$$

$$\Rightarrow \quad B = \frac{30}{\sqrt{3}} = 10\sqrt{3} \text{ m}$$



Substituting B in (i)

$$\frac{1}{\sqrt{3}} = \frac{30+D}{52+10\sqrt{3}}$$

$$\Rightarrow \quad \frac{52}{\sqrt{3}}+10 = 30 + D$$

$$\Rightarrow \quad \frac{52}{\sqrt{3}}+10-30 = D$$

$$\Rightarrow \quad D \approx 10 \text{ m}$$

So, R.L of S = H.I at P + D + H

= 100.5 + 10 + 30 = 140.5 m

27. (d)

$$K = 100 \text{ and } C = 0.5 \text{ m}$$

$$K = \frac{f}{i} \quad (\text{where, } f = 25 \text{ cm})$$

$$\Rightarrow \quad i = \frac{f}{k} = \frac{25}{100} \text{ cm} = 0.25 \text{ cm} = 2.5 \text{ mm}$$

$$C = f + d$$

$$\Rightarrow \quad d = C - f$$

$$= 0.5 - 0.25$$

$$= 0.25 \text{ m} = 25 \text{ cm}$$

28. (b)

$$\text{Longitude of } P = 87^\circ\ 30'\ \text{E}$$

$$\text{Standard meridian} = 72^\circ\ \text{E}$$

$$\text{Difference in longitude} = 87^\circ\ 30' - 72^\circ$$

$$= 15^\circ\ 30' = 1\ \text{h}\ 2\ \text{min} \qquad \left(\frac{15^\circ 30'}{15}\right)$$

$$\text{Standard time} = 9\ \text{h}\ 48\ \text{m}\ 20\ \text{sec}$$

$$\therefore \quad \text{Local mean time at } P = 9\ \text{h}\ 48\ \text{m}\ 20\ \text{s} + 1\ \text{h}\ 2\ \text{min}$$

$$= 10\ \text{h}\ 50\ \text{m}\ 20\ \text{s}$$

29. (b)

$$\text{Relief displacement } (d) = \frac{\text{Radial distance} \times h}{(H - h_{\text{avg}})}$$

$$\Rightarrow \quad 5 = \frac{50 \times h}{(2700 - 900)}$$

$$\Rightarrow \quad \frac{5 \times 1800}{50} = h$$

$$\Rightarrow \quad h = 180\ \text{m}$$

30. (b)

$$\text{Apex distance} = R\left(\sec\frac{\Delta}{2} - 1\right)$$

$$R = 200\ \text{m}$$

$$\Delta = 120^\circ$$

So,

$$\text{Apex distance} = 200\ (\sec 60^\circ - 1)$$

$$= 200\ (2 - 1) = 200\ \text{m}$$

31. (a)

Shear lag occurs when some elements of the member cross-section are not connected. Unconnected part is under-stressed and connected part is over-stressed. Therefore unequal lengths are preferred.

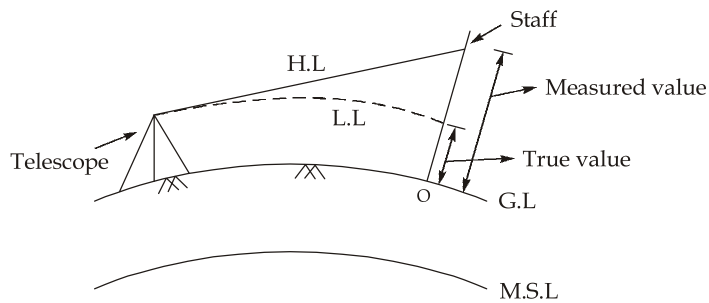
32. (b)

Web buckling is due to thin section of the web.

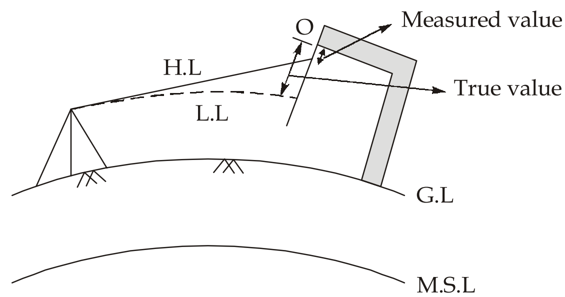
Web crippling is due to large stresses generated due to stress concentration at the junction of web and flange.

33. (b)

Correction = True value – Measured value



H.L → Horizontal line, L.L → Level line, G.L → Ground level
M.S.L → Mean sea level, O → Zero staff reading



For an inverted staff, magnitude of true value is more but as readings are taken with a negative sign, combined correction remains negative here also.

34. (d)

The magnetic lines of force are perfectly horizontal around the equator while they are perpendicular to the horizontal surface at the poles. Thus the angle of dip is zero at the equator and 90° at the poles.

35. (c)

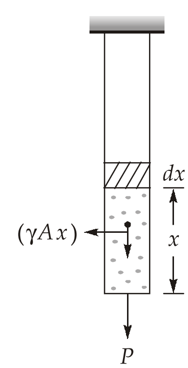
$$U = \int_0^L \frac{(\gamma Ax + P)^2\, dx}{2AE}$$

$$U = \frac{1}{2AE}\int_0^L (\gamma^2 A^2 x^2 + P^2 + 2\gamma A x P)\, dx$$

$$U = \frac{1}{2AE}\left[\frac{\gamma^2 A^2 x^3}{3} + P^2 x + 2\gamma A \frac{Px^2}{2}\right]_0^L$$

$$U = \frac{1}{2AE}\left[\frac{\gamma^2 A^2 L^3}{3} + P^2 L + \gamma APL^2\right]$$

$$U = \frac{\gamma^2 AL^3}{6E} + \frac{\gamma PL^2}{2E} + \frac{P^2 L}{2AE}$$



Note: Principle of superposition cannot be used since strain energy is not a linear function of the load.

36. (b)

Let the unknown weight be 'P'

$$\delta_{max} = 2 \text{ mm}$$

$$\sigma_{max} = E \times \frac{\delta_{max}}{L} = 200 \times 10^3 \times \frac{2}{5000} = 80 \text{ N/mm}^2$$

$$\sigma_{max} = \sigma_{st}\left[1 + \sqrt{1 + \frac{2h}{\delta_{st}}}\right] \qquad \left\{\delta_{st} = \frac{PL}{AE}\right\}$$

$$\Rightarrow \quad 80 = \frac{P}{600}\left[1 + \sqrt{1 + \frac{2 \times 10 \times 600 \times 200 \times 10^3}{P \times 5000}}\right]$$

$$\Rightarrow \quad \frac{48000}{P} = 1 + \sqrt{1 + \frac{480000}{P}}$$

$$\Rightarrow \quad \left(\frac{48000}{P} - 1\right)^2 = 1 + \frac{480000}{P}$$

$$\Rightarrow \quad \left(\frac{48000}{P}\right)^2 + 1 - \frac{96000}{P} = 1 + \frac{480000}{P}$$

$$\Rightarrow \quad \left(\frac{48000}{P}\right)^2 = \left(\frac{48000}{P}\right)(10 + 2)$$

$$\Rightarrow \quad \frac{48000}{P} = 12$$

$$\Rightarrow \quad P = \frac{48000}{12} = 4000 \text{ N}$$

37. (a)

$$\epsilon_x' = \left(\frac{\epsilon_x + \epsilon_y}{2}\right) + \left(\frac{\epsilon_x - \epsilon_y}{2}\right)\cos 2\theta + \left(\frac{\gamma_{xy}}{2}\right)\sin\theta$$

$$\Rightarrow \quad \left(\epsilon_x' - \left(\frac{\epsilon_x + \epsilon_y}{2}\right)\right) = \left(\frac{\epsilon_x - \epsilon_y}{2}\right)\cos 2\theta + \left(\frac{\gamma_{xy}}{2}\right)\sin\theta$$

$$\Rightarrow \quad (\epsilon_x' - a) = \left(\frac{\epsilon_x - \epsilon_y}{2}\right)\cos 2\theta + \left(\frac{\gamma_{xy}}{2}\right)\sin\theta \qquad \text{...(i)}$$

Centre of Mohr's circle, $a = \dfrac{\epsilon_x + \epsilon_y}{2}$

$$\frac{\gamma_{xy}'}{2} = -\left[\left(\frac{\epsilon_x - \epsilon_y}{2}\right)\sin 2\theta - \left(\frac{\gamma_{xy}}{2}\right)\cos 2\theta\right] \qquad \text{...(ii)}$$

Squaring (i) and (ii) on both sides and adding

$$(\epsilon_x' - a)^2 + \left(\frac{\gamma_{xy}'}{2}\right)^2 = \left(\frac{\epsilon_x - \epsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2$$

$$\Rightarrow \quad (\in_x' - a)^2 + \left(\frac{\gamma_{xy}'}{2}\right)^2 = r^2, \quad \text{where} \quad r = \text{radius}$$

$\therefore$ Equation of Mohr's circle is

$$(\in_x' - a)^2 + \left(\frac{\gamma_{xy}'}{2}\right)^2 = r^2$$

Substituting the given values,

$$(\in_x' - 225 \times 10^{-6})^2 + \left(\frac{140 \times 10^{-6}}{2}\right)^2 = (100 \times 10^{-6})^2$$

$$\Rightarrow \quad \left(\frac{\in_x'}{10^{-6}} - 225\right)^2 + 70^2 = 100^2$$

$$\Rightarrow \quad \frac{\in_x'}{10^{-6}} - 225 = \pm 10\sqrt{51} = \pm 71.4$$

$$\Rightarrow \quad \in_x' = 296.4 \times 10^{-6}, \quad \in_y' = 153.6 \times 10^{-6}$$

38. **(c)**

Plane stress:

- **Stress:** $\sigma_z = 0, \quad \tau_{xz} = 0, \quad \tau_{yz} = 0$

  σ_x, σ_y and τ_{xy} may have non-zero values.
- **Strains:** $\gamma_{xz} = 0, \quad \gamma_{yz} = 0$

  $\in_x$, $\in_y$, $\in_z$ and γ_{xy} may have non-zero values.

Plane strain:

- **Stress:** $\tau_{xz} = 0, \quad \tau_{yz} = 0$

  σ_x, σ_y, σ_z and τ_{xy} may have non-zero values.
- **Strains:** $\in_x = 0, \quad \gamma_{xz} = 0, \quad \gamma_{yz} = 0$

  $\in_x$, $\in_y$, γ_{xy} may have non-zero values.

39. **(a)**

Upper part:

Outer diameter = 30 mm

Inner diameter = 30 – (2 × 12) = 6 mm

$$\text{Compressive stress in upper part, } \sigma_1 = \frac{P_1}{\frac{\pi}{4}(30^2 - 6^2)}$$

Lower part:

Outer diameter = 60 mm

Inner diameter = 60 – (2 × 9) = 42 mm

Compressive load on lower part = $(P_1 + P_2)$

Compressive stress in lower part, $\sigma_2 = \dfrac{(P_1 + P_2)}{\frac{\pi}{4}(60^2 - 42^2)}$

For $\sigma_1 = \sigma_2$

$P_2 = ?$

$$\Rightarrow \quad \frac{P_1}{\frac{\pi}{4}(30^2 - 6^2)} = \frac{(P_1 + P_2)}{\frac{\pi}{4}(60^2 - 42^2)}$$

$$\Rightarrow \quad \frac{P_1 \times 1836}{864} = P_1 + P_2$$

$$\Rightarrow \quad \frac{16 \times 1836}{864} = 16 + P_2$$

$$\Rightarrow \quad 34 = 16 + P_2$$

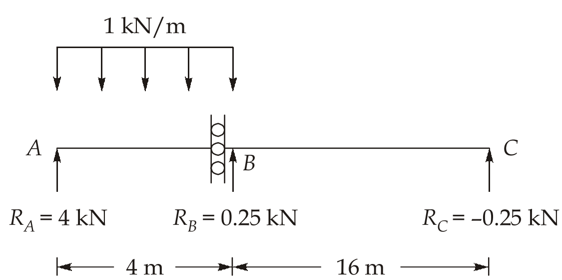
$$\Rightarrow \quad P_2 = 18 \text{ kN}$$

40. (d)

Given that it is a statically determinate beam and from the given options, it is clear that the beam is supported at *A*, *B* and *C*.

For this beam to be statically determinate there must be a moment release or shear release or an axial release in the beam.

As the shear force just to the left of *B* is zero, there is a shear release present just to the left of *B*.



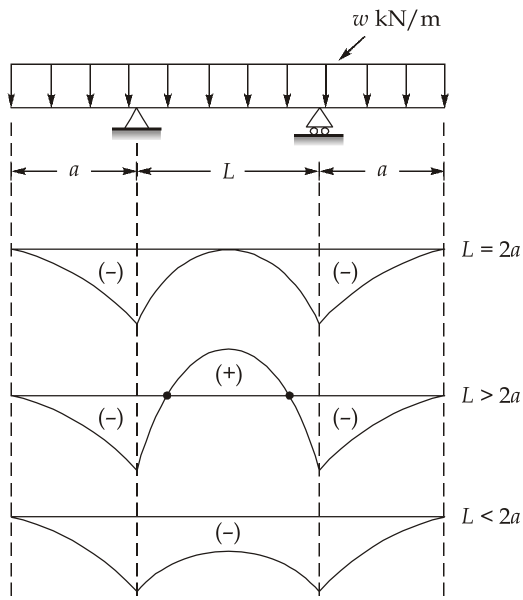
$$\Sigma M_c = 4 \times 20 - 1 \times 4 \times 18 + 0.25 \times 16$$
$$= 12 \text{ kN-m}$$

$\because \quad \Sigma M_c \neq 0$ (Not balanced)

$\therefore$ There is a concentrated moment of 12 kN-m.

Hence jump in the bending moment diagram.

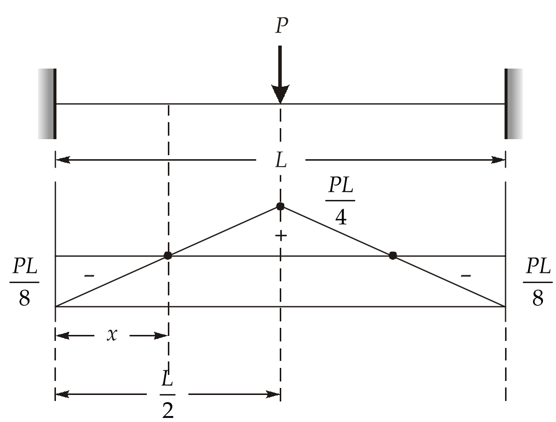
41. (c)



BMD

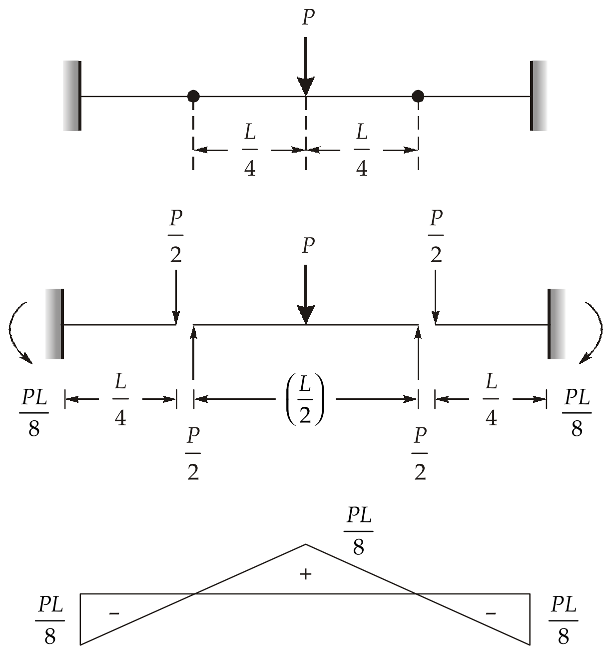
42. (a)

If hinges are introduced at the points of contraflexure of the fixed beam, the bending moment diagram and the elastic curve will be same as that of fixed beam.

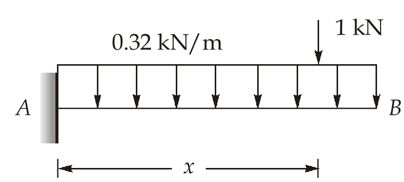


$$\frac{PL}{4\times\frac{L}{2}} = \frac{PL}{8\times x}$$

$$\Rightarrow \quad x = \frac{L}{4}$$



43. (a)



$$M_A = \frac{0.32 \times 2.5^2}{2} + 1 \times x$$

$\Rightarrow$ $M_A = (1 + x)$ kN-m

Maximum tensile stress (which occurs at top) = 27 MPa

$$\frac{M}{I} = \frac{\sigma_t}{y}$$

$$\Rightarrow \quad \sigma_f = \frac{(1+x) \times 10^6}{130 \times 10^4} \times 15 = 27 \text{ MPa (given)}$$

$$\therefore \quad \frac{27 \times 130 \times 10^4}{10^6 \times 15} = 1 + x$$

$\Rightarrow$ $x = 1.34$ m

Maximum compressive stress = 100 MPa (given)

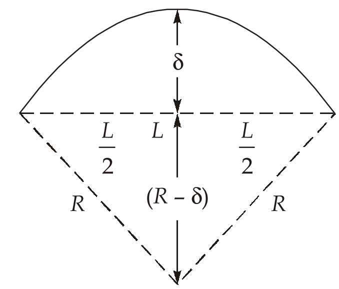
$$\frac{(1+x) \times 10^6}{130 \times 10^4} = \frac{100}{55}$$

$\Rightarrow$ $x = 1.36$ m

$\therefore$ Place the concentrated load at $x = 1.34$ m

44. (c)

For the given loading, the beam will be in pure bending between the supports.



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

$$\Rightarrow \quad R^2 = R^2 + \delta^2 - 2R\delta + \frac{L^2}{4}$$

$$\Rightarrow \quad \delta \simeq \frac{L^2}{8R}$$

Also, $\in_{max} = \dfrac{y_{max}}{R}$

Given, $\in_{max} = 0.0006$

$$y_{max} = \frac{120}{2} = 60 \text{ mm}$$

$$\therefore \quad R = \frac{y_{max}}{\in_{max}} = \frac{60\times10^{-3}}{0.0006} = 100 \text{ m}$$

$$\therefore \quad \delta = \frac{L^2}{8R}$$

$$\Rightarrow \quad 5\times10^{-3} = \frac{L^2}{8\times100}$$

$$\Rightarrow \quad L^2 = 4$$

$$\Rightarrow \quad L = 2 \text{ m}$$

45. (a)

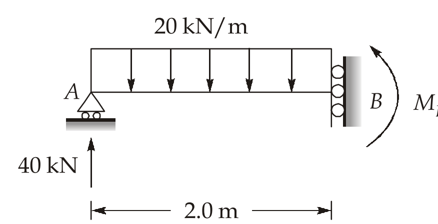
$$\Sigma F_y = 0$$

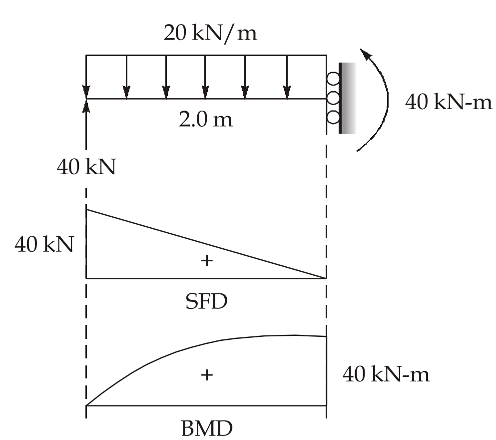
$$\Rightarrow \quad F_A = 20 \times 2 = 40 \text{ kN}$$

$$\Sigma M_A = 0$$

$$\Rightarrow \quad M_B - 20 \times 2 \times 1 = 0$$

$$\Rightarrow \quad M_B = 40 \text{ kN-m}$$





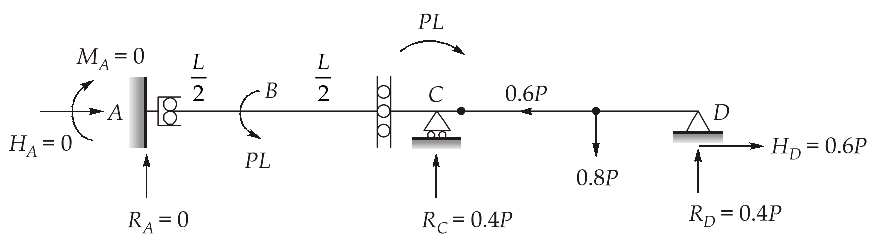
$\therefore$ Maximum bending moment = 40 kN-m

Now, $$\frac{M}{I} = \frac{\sigma_{max}}{y}$$

$$\Rightarrow \quad \sigma_{max} = \frac{M}{I} \cdot y = \frac{M}{z} = \frac{40 \times 10^6 \times 6}{150 \times 300^2}$$

$$\Rightarrow \quad \sigma_{max} = 17.78 \text{ N/mm}^2$$

46. (c)



$$R_A + R_C + R_D = 0.8P \qquad \text{...(i)}$$

Just right of C, $\Sigma M = 0$

$$\Rightarrow \quad R_D \times \frac{L}{2} - 0.8P \times \frac{L}{4} = 0$$

$$\Rightarrow \quad R_D = 0.4P$$

At the shear release, S.F = 0

$\therefore$ SF just left of C = 0

$$\Rightarrow \quad -R_C - R_D + 0.8P = 0$$

$$\Rightarrow \quad R_C = 0.4P$$

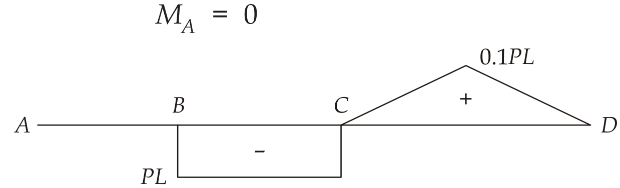
$\therefore$ $R_A = 0$ {from (i)}

Considering the equilibrium of whole beam,

$$\Sigma M_A = 0$$

$$\Rightarrow \quad 0.4P \times \frac{3L}{2} - 0.8P \times \frac{5L}{4} + 0.4P \times L + PL - PL + M_A = 0$$

$$\Rightarrow \quad M_A = 0$$



BMD

47. (d)

The principle of superposition is valid whenever the quantity to be determined is a linear function of applied loads. This is ensured if the material obeys Hooke's law and the deformations are sufficiently small having negligible effect on the geometry.

Strain energy is not a linear function of the load.

48. (c)

In manufacturing industries, materials are deformed to ensure yield point phenomenon is over and strain ageing time is printed on the material. The material should be consumed within this time period. Otherwise yield point phenomenon reappears. The time period after which yield point phenomenon reappears in the material is called strain ageing time.

49. (c)

- Formation of white precipitate indicates absence of dissolved oxygen.
- Formation of brown precipitate indicates presence of dissolved oxygen.
- Titration is done with $\frac{N}{70}$ sodium thiosulphate ($Na_2S_2O_3$) using starch as an indicator.

50. (b)

If decolorization of standard methylene blue solution takes place in less than 4 days at 20°C and in less than 2 days and 37°C, then the effluent is considered unstable.

Also relative stability, $S = 100\left[1-0.794^{t_{20}}\right]$

For, $t_{20} = 4$ days, $S \approx 60\%$

$S = 100\left[1-0.794^{t_{37}}\right]$

For, $t_{37} = 2$ days, $S \approx 60\%$

Thus if $S > 60\%$, then effluent is considered stable.

Here Effluent I is unstable (got decolourized only after 3 days at 20°C) and Effluent II is stable (got decolourized after 3 days at 37°C).

52. (b)

$$\text{Discharge } 'Q' = 3 \times 10^6\ l/\text{day}$$

$$\text{BOD} = 250\ \text{mg}/l$$

$$\text{Volume of filter } (V) = 0.075\ \text{ha.m} = 750\ \text{m}^3$$

$$\text{Efficiency } '\eta' = \frac{100}{1+0.44\sqrt{u}}$$

$$\text{Organic loading rate } u = \frac{Q \times \text{BOD}}{V}$$

$$= \frac{3\times10^6 \times 250 \times 10^{-6}}{750} = 1\ \text{kg/day/m}^3$$

$$\therefore \quad \eta = \frac{100}{1+0.44\sqrt{1}} = \frac{100}{1.44} = 69.44\% \approx 70\%$$

53. (c)

Volume of settled sludge = 300 ml

Weight of suspended solids in 60 ml mixed liquor = 0.18 g

$\therefore$ Weight of suspended solids in 1000 ml mixed liquor = $\frac{0.18}{60} \times 1000$

$$\text{SVI} = \frac{\text{Volume of settled sludge (ml)}}{\text{Weight of suspended solids in mixed liquor (gm)}}$$

$$= \frac{300}{\frac{0.18}{60} \times 1000} = \frac{300 \times 60 \times 100}{18 \times 1000} = 100 \text{ ml/gm}$$

54. (c)

Sludge age, $\theta_c = \frac{VX}{Q_w X_u}$

V = Volume of aeration basin = 360 m^3

X = MLSS concentration in aeration basin = 3900 mg/l

Q_w = Wasted sludge discharge = 26 m^3/day

X_u = Underflow concentration = 15000 mg/l

Putting values, $\theta_c = \frac{360 \times 3900}{26 \times 15000} = \frac{360 \times 300}{2 \times 15000} = 3.6 \text{ days}$

55. (c)

Maximum allowable rate of application of sewage onto soil,

$$q = \frac{204}{\sqrt{t}} \; l/\text{m}^2/\text{day}$$

where t is the percolation rate in min/cm

So, $q = \frac{204}{\sqrt{t}} = \frac{204}{5} \; l/\text{m}^2/\text{day}$

Flow of effluent in dispersion trench (Q_0) = 1.7 l/min

= 1.7 × 60 × 24 l/day

Required area of dispersion trench $= \frac{Q_0}{q} = \frac{1.7 \times 60 \times 24}{204} \times 5 = \frac{60 \times 24 \times 5}{120} = 60 \text{ m}^2$

56. (b)

Contributing population	Peak factor
Upto 20000	3
20001 to 50000	2.5
50001 to 75000	2.25
Above 75000	3

57. (d)

Total solids = x kg

Volatile solids = $0.7x$ kg

Total gases produced = $0.7 \times 0.7x$ kg

Amount of methane produced = $0.7 \times 0.7 \times 0.7x$ kg

Volume of methane produced = $(0.7)^3 \times x \times 0.9 \text{ m}^3 = 3087 \text{ m}^3$ (given)

$$\Rightarrow \quad (0.7)^3 \times x \times 0.9 = 3087$$

$$\Rightarrow \quad x = \frac{3087}{0.9 \times (0.7)^3} = 10000 \text{ kg}$$

58. (b)

Sewer 1 is running half full

Sewer 2 is running completely full

For same degree of self cleansing,

$$(\gamma RS)_1 = (\gamma RS)_2$$

Here γ will be same as sewage is same

$$R_1 = \frac{A_1}{P_1} = \frac{\frac{1}{2}\frac{\pi}{4}D^2}{\frac{1}{2}\pi D} \quad \text{(Half full)}$$

$$= \frac{D}{4}$$

$$R_2 = \frac{A_2}{P_2} = \frac{\frac{\pi}{4}D^2}{\pi D} \quad \text{(Completely full)}$$

$$= \frac{D}{4}$$

$$\therefore \quad \gamma R_1 S_1 = \gamma R_2 S_2$$

$$\Rightarrow \quad \frac{D}{4}S_1 = \frac{D}{4}S_2$$

$$\Rightarrow \quad \frac{S_1}{S_2} = 1$$

59. (b)

Upon heating in closed container in oxygen free atmosphere, most of the organic substances of solid waste can be split through a combination of thermal cracking and condensation reactions into gaseous, liquid and solid fractions. This process is known as pyrolysis. It is a highly endothermic process and is also known as destructive distillation.

60. (c)

Trap	Seal depth
Floor trap	50 mm
Gully trap	50 - 75 mm
Intercepting traps	About 100 mm

61. (b)

Nitrosomonas bacteria $\rightarrow$ NH_3 to NO_2^-

Nitrobacter bacteria $\rightarrow$ NO_2^- to NO_3^-

Paracoccus denitrificant $\rightarrow$ NO_3^- to N_2

62. (d)

Wastewater stream

$Q_W = 2\ m^3/s$,

$BOD_{u_W} = 155\ mg/l$,

River

$Q_R = 100\ m^3/s$

$BOD_{u_R} = 2\ mg/l$

$$BOD_{mix} = \frac{Q_W \times BOD_{u_W} + Q_R \times BOD_{u_R}}{Q_W + Q_R}$$

$$= \frac{2 \times 155 + 100 \times 2}{2 + 100} = \frac{510}{102} = 5\ mg/l$$

But BOD_{mix} can not exceed 4 mg/l

$$\therefore \quad \frac{2 \times BOD_{u_W} + 100 \times 2}{102} = 4$$

$$\Rightarrow \quad BOD_{u_W} = \frac{4 \times 102 - 200}{2} = 104\ mg/l$$

So, BOD_{u_W} of waste water must be reduced to 104 mg/l.

$$\text{Degree of treatment required} = \frac{155 - 104}{155} \times 100 = \frac{51}{155} \times 100 = 32.9 \approx 33\%$$

63. (c)

Initial weight of sludge = 100 kg

Weight of solids = 2% = 2 kg

Weight of water = 100 – 2 = 98 kg

$$\text{Initial volume } V_i = \frac{W_s}{G_s \rho_s} + \frac{W_w}{\rho_w} = \frac{2}{2 \times 1000} + \frac{98}{1000} = \frac{99}{1000}\ m^3$$

$$\text{Volume after thickening } V_f = \frac{V_i}{2} = \frac{99}{2000}\ m^3$$

Weight of solids = 2 kg (No digestion is carried out)

Let, Weight of water = x kg

$$\therefore \quad V_f = \frac{W_s}{G_s \rho_s} + \frac{W_w}{\rho_w}$$

$$\frac{99}{2000} = \frac{2}{2000} + \frac{x}{1000}$$

$$\Rightarrow \quad x = \frac{97}{2000} \times 1000 = 48.5\ kg$$

Weight of sludge = Weight of solids + Weight of water

= 2 + 48.5 kg = 50.5 kg

Note: Do not use $V_1(100 - P_1) = V_2(100 - P_2)$ because in deriving this relation, density of sludge is assumed to remain the same before and after thickening.

64. (b)

For a completely mixed reactor, concentration at any time t,

$$L_t = \frac{L_o}{1+kt}$$

where, L_o is initial concentration, k is the rate constant, t is the detention time

$$\Rightarrow \quad 15 = \frac{60}{1+6k}$$

$$\Rightarrow \quad k = \frac{1}{6}\left(\frac{60}{15}-1\right) = 0.5$$

Now,

$$L_t = \frac{60}{1+10(0.5)} = \frac{60}{6} = 10 \text{ mg}/l$$

66. (b)

For satisfactory performance of a machine foundation, the foundation should satisfy the following criteria:

Under static loads:

- The foundation should be safe against shear failure of soil.
- The foundation should not settle more than a certain permissible value.

Under dynamic loads:

- There should be no resonance, i.e., the natural frequency of the foundation-soil system should either be larger than or smaller than the operating frequency of the machine.
- The amplitudes of vibration under the operating frequency of the machine should be within permissible limits.
- The vibrations should not be annoying to the persons or detrimental to other machines and structures.

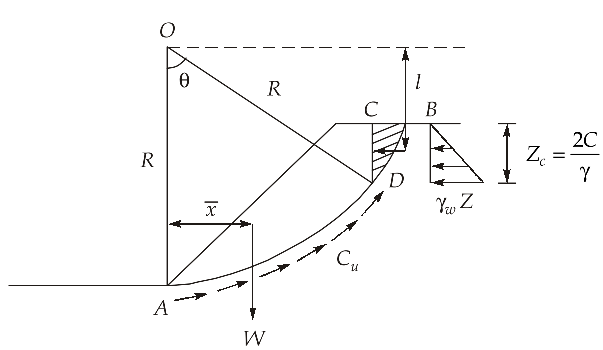
67. (c)

The number of blows required to effect the first 150 mm of penetration is called the seating drive. Seating drive is disregarded.

Overburden pressure correction : Granular soils

Dilatancy correction : Saturated fine sands and silts

69. (b)



$$\text{FOS} = \frac{C_u R^2 \theta_1}{W\bar{x} + P_w l} \le \frac{C_u R^2 \theta_2}{W\bar{x}}; \ (\theta_2 > \theta_1)$$

In cohesive soils, tension cracks tend to open up near the top of the slip surface.
The maximum depth of tension crack is given by the equation

$$Z_c = \frac{2C}{\gamma}$$

The length of arc is *AD* which is less than *AC*. (*AC* is length when tension crack does not develop)

70. (b)

$$S_n = \frac{C}{\gamma H F_c}$$

But $\frac{C}{F_c} = 5\text{ kN/m}^2 = C_m$

$\therefore$ $S_n = \frac{C_m}{\gamma H} = \frac{5}{20 \times 5} = 0.05$

71. (c)

$$S_i = \frac{qB}{E}(1-\mu^2)I_f$$

Here, E = Elasticity of soil

72. (d)

In clays, large displacement piles remould the soil to a distance of about twice the diameter of the pile. Also, during driving, very high pore water pressures are set up around the pile and the soil regains its initial strength only after a period of time. Therefore large displacement piles are not preferred for clay.

73. (d)

Ultimate BOD (L_o) is always constant irrespective of any temperature change. BOD at any time 't' increases on increasing temperature because the rate constant increases on increasing temperature.

74. (a)

Blanket rising occurs due to high sludge age.

$$\text{Sludge age '}\theta_c\text{'} = \frac{VX\downarrow}{Q_w X_u} \text{ and } \frac{F}{M} = \frac{Q_o S_o}{VX\downarrow}$$

An increase in F/M ratio decreases 'θ_c' which prevents blanket rising.

75. (c)

When a consolidating clay stratum is placed after the piles are installed, there is a relative motion, where the clay stratum moves downward with respect to installed piles. An upward skin friction resistance acts on the clay stratum and reaction on the pile in the downward direction. This reaction is known as negative skin friction.

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