DETAILED SOLUTIONS

MADE EASY

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ESE 2026 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 18

Full Syllabus Test 2 : Paper-II

1.	(d)	26.	(a)	51.	(b)	76.	(b)	101.	(d)	126.	(c)
2.	(c)	27.	(d)	52.	(c)	77.	(d)	102.	(b)	127.	(d)
3.	(a)	28.	(d)	53.	(a)	78.	(d)	103.	(c)	128.	(c)
4.	(a)	29.	(b)	54.	(d)	79.	(b)	104.	(d)	129.	(c)
5.	(a)	30.	(c)	55.	(c)	80.	(d)	105.	(b)	130.	(b)
6.	(c)	31.	(a)	56.	(d)	81.	(c)	106.	(c)	131.	(b)
7.	(b)	32.	(b)	57.	(b)	82.	(c)	107.	(d)	132.	(a)
8.	(c)	33.	(b)	58.	(b)	83.	(b)	108.	(d)	133.	(b)
9.	(c)	34.	(d)	59.	(c)	84.	(b)	109.	(d)	134.	(c)
10.	(b)	35.	(d)	60.	(a)	85.	(c)	110.	(d)	135.	(d)
11.	(b)	36.	(c)	61.	(d)	86.	(a)	111.	(d)	136.	(b)
12.	(b)	37.	(a)	62.	(d)	87.	(a)	112.	(a)	137.	(b)
13.	(a)	38.	(b)	63.	(a)	88.	(c)	113.	(c)	138.	(c)
14.	(c)	39.	(c)	64.	(a)	89.	(b)	114.	(b)	139.	(b)
15.	(a)	40.	(d)	65.	(b)	90.	(d)	115.	(d)	140.	(d)
16.	(b)	41.	(c)	66.	(b)	91.	(b)	116.	(d)	141.	(d)
17.	(b)	42.	(b)	67.	(b)	92.	(c)	117.	(d)	142.	(d)
18.	(b)	43.	(b)	68.	(a)	93.	(b)	118.	(b)	143.	(c)
19.	(b)	44.	(b)	69.	(d)	94.	(d)	119.	(c)	144.	(d)
20.	(b)	45.	(d)	70.	(c)	95.	(b)	120.	(c)	145.	(d)
21.	(d)	46.	(a)	71.	(c)	96.	(d)	121.	(c)	146.	(d)
22.	(b)	47.	(b)	72.	(c)	97.	(b)	122.	(d)	147.	(a)
23.	(b)	48.	(c)	73.	(c)	98.	(c)	123.	(c)	148.	(d)
24.	(d)	49.	(d)	74.	(b)	99.	(b)	124.	(b)	149.	(a)
25.	(d)	50.	(a)	75.	(b)	100.	(b)	125.	(d)	150.	(c)

DETAILED EXPLANATIONS

1. (d)

Factors affecting creep are as follows:

1. Magnitude of load
2. Temperature
3. Time or age of loading

- At higher temperature creep becomes more important.
- Nature of creep is elastic as well plastic

2. (c)

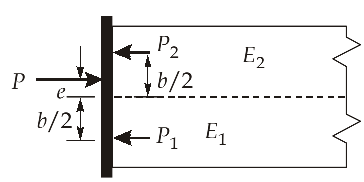
$$\phi_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

$$\Rightarrow \quad \phi_{xy} = \frac{\partial}{\partial y}(-7x + 2y) \times 10^{-3} + \frac{\partial}{\partial x}(-x + 5y) \times 10^{-3}$$

$$\Rightarrow \quad \phi_{xy} = 2 \times 10^{-3} - 1 \times 10^{-3}$$

$$\Rightarrow \quad \phi_{xy} = 1 \times 10^{-3} \text{ unit}$$

3. (a)



- From condition of static equilibrium,

$$P_1 + P_2 = P \quad \text{...(i)}$$

- Deflection in both material is equal

$$\therefore \quad \Delta_1 = \Delta_2$$

$$\Rightarrow \quad \frac{P_1 L}{AE_1} = \frac{P_2 L}{AE_2}$$

$$\Rightarrow \quad P_1 = \frac{E_1}{E_2} P_2 \quad \text{...(ii)}$$

Taking moments of all forces about the line of action P_1.

$$P\left(e + \frac{b}{2}\right) = P_2 b \quad \text{...(iii)}$$

From (i) and (ii)

$$P_2 = \frac{P}{\left(1 + \frac{E_1}{E_2}\right)} = \frac{PE_2}{E_1 + E_2}$$

$\therefore$ Using equation (iii)

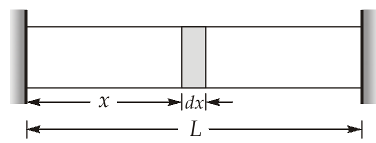
$$P\left(e + \frac{b}{2}\right) = \frac{PE_2 b}{E_1 + E_2}$$

$$\Rightarrow \quad e = \frac{E_2 b}{E_1 + E_2} - \frac{b}{2} = b\left[\frac{2E_2 - E_1 - E_2}{(E_1 + E_2) \times 2}\right]$$

$$\Rightarrow \quad e = \frac{b}{2}\left[\frac{E_2 - E_1}{E_1 + E_2}\right]$$

4. (a)

Consider a strip of length dx at a distance x from left end.



Temperature increase of strip, $\Delta T = \Delta T_B \times \dfrac{x^m}{L^m}$

Free extension of strip $= \alpha \Delta T\, dx$

$$= \alpha \cdot (\Delta T_B) \frac{x^m}{L^m} dx$$

$$\therefore \quad \text{Free extension of bar } AB = \int_0^L \alpha(\Delta T_B) \cdot \frac{x^m}{L^m} dx$$

$$\Rightarrow \quad (\Delta_{AB})_{\text{tree}} = \frac{\alpha(\Delta T_B)}{L^m} \cdot \frac{[x^{m+1}]_o^L}{m+1} = \frac{\alpha(\Delta T_B) L}{m+1}$$

Due to rigidity of supports

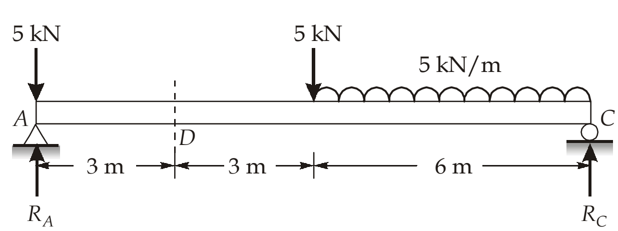
$$\Delta_{AB} = 0$$

$\therefore \quad \Delta_{AB}$ = Free extension of bar due to temperature rise + Contraction of bar due to compressive stress

$$\Rightarrow \quad \Delta_{AB} = \frac{L\alpha(\Delta T_B)}{m+1} + \left(-\frac{\sigma_c \times L}{E}\right) = 0$$

$$\Rightarrow \quad \sigma_c = \frac{E\alpha(\Delta T_B)}{m+1}$$

5. (a)



$$R_A + R_C = 5 + 5 + 5 \times 6 = 40 \text{ kN} \quad \text{...(i)}$$

$$\Sigma M_C = 0$$

$$\Rightarrow \quad R_A \times 12 = 5 \times 12 + 5 \times 6 + 5 \times 6 \times 3$$

$$\Rightarrow \quad R_A = 5 + \frac{5}{2} + \frac{15}{2} = 15 \text{ kN}$$

$$\therefore \quad R_C = 40 - 15 = 25 \text{ kN}$$

$$\text{S.F. at 3 m from support } A = 15 - 5 = 10 \text{ kN}$$

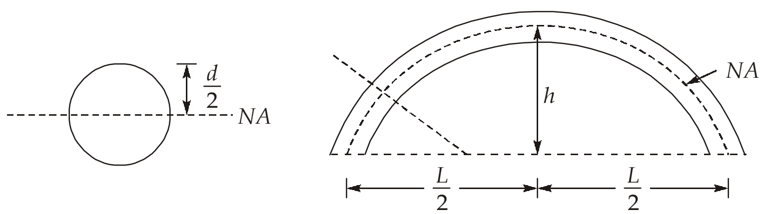
∴ 15 kN, 10 kN and 25 kN respectively.

6. (c)

Initial length of rod is L

$$\therefore \quad \frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

$$\Rightarrow \quad \frac{\sigma}{E} = \frac{y}{R}$$



Using property of circle

$$(2R - h) \times h = \frac{L}{2} \times \frac{L}{2}$$

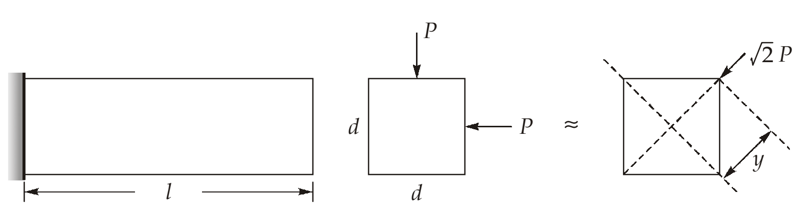
$$\Rightarrow \quad 2Rh - h^2 = \frac{L^4}{4} \qquad \{2Rh >>> h^2\}$$

$$\Rightarrow \quad R = \frac{L^2}{8h}$$

Now,

$$E = \frac{y}{R} = \frac{d}{2 \times \frac{L^2}{8h}} = \frac{4dh}{L^2}$$

7. (b)



$$\text{Resultant of load at free end} = \sqrt{P^2 + P^2} = P\sqrt{2}$$

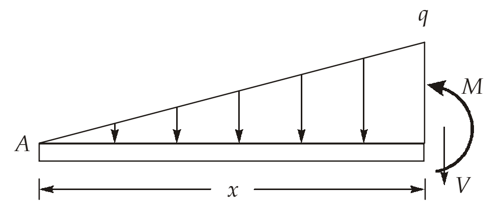
$$\therefore \quad \text{Maximum bending moment} = \left(\sqrt{2}P\right) \times l$$

So,maximum stress is given by, $\dfrac{M}{I} = \dfrac{\sigma}{y}$

$$\Rightarrow \quad \sigma = \frac{M}{I} \cdot y = \frac{\left(\sqrt{2}P\right) \times l}{\frac{d^4}{12}} \times \frac{d}{\sqrt{2}} = \frac{12Pl}{d^3}$$

8. **(c)**

Cut the beam at 'x' distance from left hand end and treating this part of the beam as free body.



The intensity of the distributed load is

$$q = \frac{q_0 x}{L}$$

$$\therefore \quad \text{Total downward load} = \frac{q_0 x^2}{2L}$$

Considering moment equilibrium about an axis through the cut section,

$$\Rightarrow \quad \frac{-q_0 x^2}{2L} \times \frac{x}{3} - M = 0$$

$$\Rightarrow \quad M = \frac{-q_0 x^3}{6L}$$

9. **(c)**

As per strain energy theory,

$$\frac{1}{2E}\left[\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - 2\mu\left(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1\right)\right] = \frac{\sigma_y^2}{2E}$$

Given, $\sigma = \sigma_1 = \sigma_2$ (tensile)

$\sigma_3 = -\sigma$ (compressive)

$$\therefore \quad 2\sigma^2 + \sigma^2 - 2\mu(\sigma^2 - \sigma^2 - \sigma^2) = \sigma_y^{\ 2}$$

$$\Rightarrow \quad 3\sigma^2 - 2\mu(-\sigma^2) = \sigma_y^{\ 2}$$

$$\Rightarrow \quad \sigma = \frac{\sigma_y}{\sqrt{3 + 2\mu}}$$

10. **(b)**

Given: $M = 4$ kN-m, $T = 3$ kN-m

$\sigma_{max} = 360$ MPa, $\tau_{max} = 190$ MPa

$$\sigma_{P1} = \frac{16}{\pi D^3}\left[M + \sqrt{M^2 + T^2}\right]$$

$$\Rightarrow \quad 360 = \frac{16}{\pi D^3}[4 + 5] \times 10^6 = \frac{144 \times 10^6}{\pi D^3}$$

$$\Rightarrow \quad D^3 = \frac{144 \times 10^6}{360\pi} = \left(\frac{2}{5\pi}\right) \times 10^6$$

$$\Rightarrow \quad D = \left(\frac{2}{5\pi}\right)^{1/3} \times \left(10^6\right)^{1/3} = 50 \text{ mm}$$

Also, maximum shear stress due to combine bending and twisting is,

$$\tau_{max} = 190 = \frac{16}{\pi D^3}\sqrt{M^2 + T^2} = \frac{16}{\pi D^3} \times \sqrt{3^2 + 4^2} \times 10^6$$

$$\Rightarrow \quad D^3 = \frac{80 \times 10^6}{\pi \times 190} = \frac{0.42}{\pi} \times 10^6$$

$$\Rightarrow \quad D = 51 \text{ mm}$$

11. (b)

Given: $\in_1 = 200\,\mu, \quad \in_2 = -60\,\mu$

Maximum shear strain ϕ = 2 × Radius of Mohr's circle

$$\Rightarrow \quad \phi_{max} = 2 \times \frac{200 - (-60)}{2} = 260\,\mu$$

$\Rightarrow$ Normal strain on plane of maximum shear strain ε = Centre of Mohr circle

$$\Rightarrow \quad \in = \frac{200 + (-60)}{2} = 70\,\mu$$

12. (b)

In a pure shear, $\sigma_1 = \tau, \; \sigma_2 = -\tau$

and
$$\in_1 = \frac{\sigma_1}{E} - \frac{\mu\sigma_2}{E} = \frac{\tau}{E}(1+\mu)$$

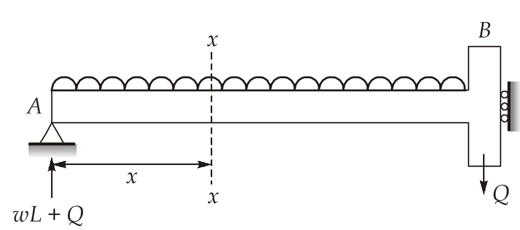
$$\in_2 = \frac{\sigma_2}{E} - \frac{\mu\sigma_1}{E} = \frac{-\tau}{E}(1+\mu)$$

$$\frac{\sigma_1}{\sigma_2} = -1$$

and
$$\frac{\in_1}{\in_2} = -1$$

$$\therefore \quad \frac{\sigma_1}{\sigma_2} = \frac{\in_1}{\in_2}$$

13. (a)



Applying a pseudo force of Q at end B.

$$M_x = wLx - \frac{wx^2}{2} + Qx$$

$$\therefore \quad \frac{\partial M_x}{\partial Q} = x$$

$$\therefore \quad \delta_B = \left.\frac{\partial U}{\partial Q}\right|_{Q=0} = \int_0^L \frac{M_x}{EI}\left(\frac{\partial M_x}{\partial Q}\right) dx$$

$$\therefore \quad \delta_B = \int_0^L \frac{1}{EI}\left(wLx + Qx - \frac{wx^2}{2}\right) xdx$$

$$\therefore \quad \delta_B\big|_{Q=0} = \int_0^L \frac{1}{EI}\left[wLx^2 - \frac{wx^3}{2}\right] dx$$

$$= \frac{1}{EI}\left[\frac{wLx^3}{3} - \frac{wx^4}{8}\right]_0^L$$

$$\Rightarrow \quad \delta_B = \frac{5}{24}\frac{wL^4}{EI}$$

14. (c)

$$\Delta_A = \Delta_B + \theta_B \times L$$

$$\Rightarrow \quad \Delta_A = \frac{wL^4}{8 \times (2EI)} + \frac{wL^3}{6 \times (2EI)} \times L$$

$$= \frac{wL^4}{EI}\left[\frac{1}{16} + \frac{1}{12}\right] = \frac{7}{48}\frac{wL^4}{EI}$$

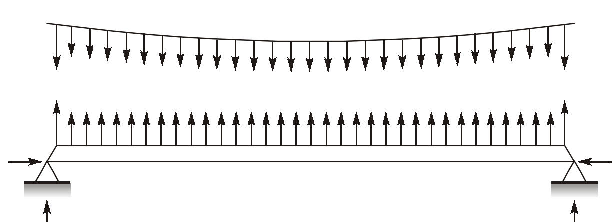
15. (a)

When there is a rise in temperature, the length of the cable increases and dip increases. The relation between change in length of cable and the dip is

$$\Delta y_c = \frac{3}{16}\frac{l}{y_c}\Delta L$$

Increase in temperature leads to increase in length of cable and hence dip.

16. (b)



Two hinged stiffening girder

$$D_s = r_e - 3$$
$$= 4 - 3 = 1$$

Indeterminate to one degree.

17. **(b)**

Horizontal thrust

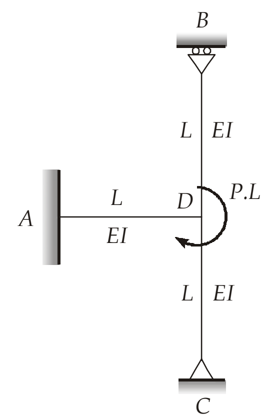
$$H = \Sigma\left(\frac{W}{\pi}\sin^2\alpha\right)$$

$$\Rightarrow \quad H = 2\times\frac{30}{\pi}\sin^2 30 = 2\times\frac{30}{\pi}\times\frac{1}{4}$$

$$\Rightarrow \quad H = \frac{15}{\pi}\text{ kN}$$

18. **(b)**

Distribution factor for *DA*

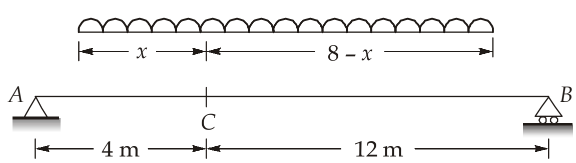


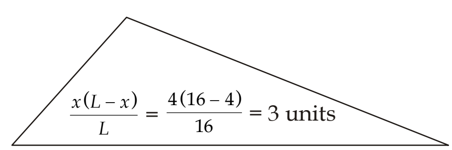
$$(DF)_{DA} = \frac{\frac{4EI}{L}}{\frac{4EI}{L}+\frac{3EI}{L}} = \frac{4}{7}$$

$$M_{DA} = \frac{4}{7}PL$$

$$M_A = \frac{M_{PA}}{2} = \frac{2}{7}PL$$

19. **(b)**





ILD for *BM* at *C*

Load position,

$$\text{Average load on } AC = \text{Average load on } CB$$

$$\frac{wx}{4} = \frac{w(8-x)}{12}$$

$$\Rightarrow \quad 3x = 8 - x$$

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

So, head of UDL from A = $4 + (8 - x)$

= $4 + (8 - 2) = 10$ m

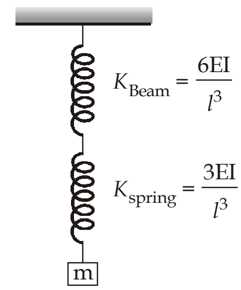
20. (b)

$$\text{Logarithmic decrement} = \frac{2\pi\xi}{\sqrt{1-\xi^2}} = \frac{2\pi \times 0.5}{\sqrt{1-0.5^2}} = 3.63$$

21. (d)

Here beam and spring are in series combination.

Stiffness of beam :



$$K_{Beam} = \frac{48EI}{(2l)^3} = \frac{6EI}{l^3}$$

Stiffness of spring:

$$K_{spring} = \frac{3EI}{l^3}$$

Equivalent stiffness,

$$\frac{1}{K_{eq}} = \frac{1}{K_{Beam}} + \frac{1}{K_{spring}}$$

$$\Rightarrow \quad \frac{1}{K_{eq}} = \frac{l^3}{6EI} + \frac{l^3}{3EI} = \frac{l^3}{2EI}$$

$$\Rightarrow \quad K_{eq} = \frac{2EI}{l^3}$$

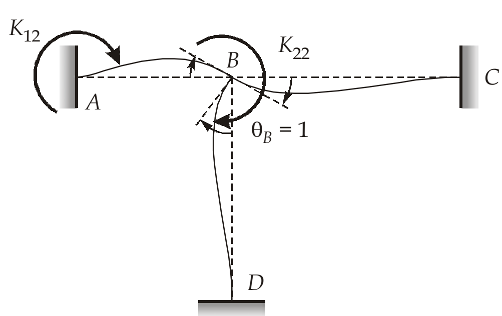
$\therefore$ Natural frequency of system is,

$$\omega_n = \sqrt{\frac{K_{eq}}{m}} = \sqrt{\frac{2EI}{ml^3}}$$

22. (b)

K_{12} = Load in the direction of coordinate 1 due to unit displacement in the direction of coordinate 2.

Apply unit rotation at 2 only,



$$K_{12} = \frac{1}{2}\left(\frac{4EI}{4}\right) = \frac{EI}{2}$$

23. (b)

In HSFG bolt connection, the load transmission primarily occurs through the friction developed between the connected plate due to the high clamping force of the bolt.

This mean a significantly lesser amount of load is transmitted through the net (shear) section of the bolt itself, compared to an ordinary bearing-type bolt connection where the load is primarily resisted by the shear strength of the bolt shank and bearing of the hole.

24. (d)

- **Elastic theory :** Rivets or HSFG bolt do not carry equal force, because end rivets carry more load due to deformation compatibility and similar concept is applicable for HSFG bolt. Also in HSFG bolt slip does not occur in elastic range.
- **Plastic theory:** HSFG bolt and rivet joint both carry equal forces, as in HSFG bolt, at higher load, yielding starts and load redistribution will take place. Also rivets share same concept.

25. (d)

26. (a)

$$\gamma_{shop} = 1.25$$

$$\gamma_{fillet} = 1.5$$

$$\text{Allowable stress in shop fillet weld} = \frac{f_u}{1.25}$$

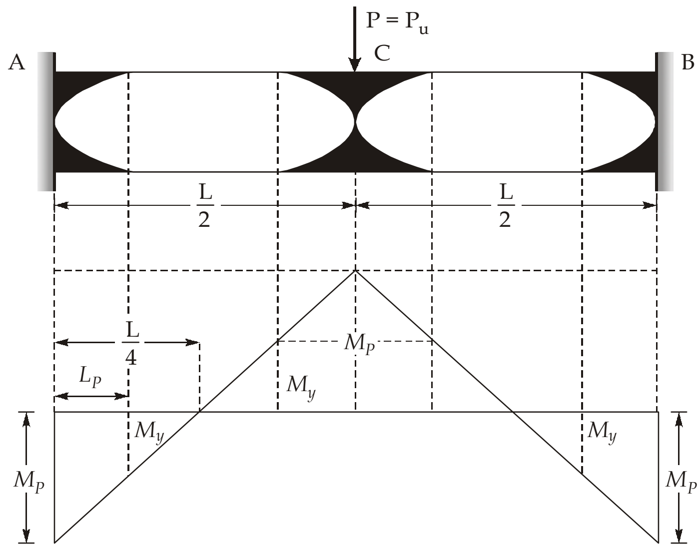
$$\text{Allowable stress in fillet weld} = \frac{f_u}{1.5}$$

$$\therefore \quad \text{Stress is reduced by} \quad \frac{\dfrac{f_u}{1.25} - \dfrac{f_u}{1.5}}{\dfrac{f_u}{1.25}}$$

$$= 1 - \frac{1.25}{1.5} = 0.167 \simeq 16.67\%$$

27. (d)

28. (d)



BMD at the time of collapse ($P = P_u$)

Let plastic hinge length at fixed end at the time of collapse is 'L_P'.
From the collapse BMD.

$$\frac{M_P}{\left(\frac{L}{4}\right)} = \frac{M_y}{\left(\frac{L}{4} - L_P\right)}$$

$$\Rightarrow \quad \frac{M_p}{M_y} = \frac{L/4}{\left(\frac{L}{4} - L_P\right)}$$

$$\Rightarrow \quad \frac{2}{3} = \frac{(L/4 - L_P)}{L/4}$$

$$\Rightarrow \quad L_P = \frac{L}{12}$$

∴ Plastic hinge length at fixed end at the time of collapse is $(L/12)$.

29. (b)

$$A_n = \text{Net area of section 1 - 1}$$

$$\Rightarrow \quad A_n = \left[B - nd_o + \Sigma\frac{P^2}{4g}\right] \times t$$

$$\Rightarrow \quad A_n = (300 - 5 \times 22 + \frac{4 \times 50^2}{4 \times 50}) \times 10 = 2400 \text{ mm}^2$$

$$\therefore \quad T_{dn} = \frac{0.9 f_u A_n}{\gamma_{mb}} = \frac{0.9 \times 500 \times 2400}{1.25} \text{ N} = 864 \text{ kN}$$

30. (c)

31. (a)

32. (b)

$$\delta = 1 + \frac{3P_u}{A_g f_{ck}} \quad \text{(not exceeding 1.5)}$$

Axial load, $P_u = 1000 \times 10^3$ N

Gross area, $A_g = (500 \times 500)\text{mm}^2$

Characteristic compressive strength of concrete,

$$f_{ck} = 30 \text{ N/mm}^2$$

$$\delta = 1 + \frac{3 \times 1000 \times 10^3}{500 \times 500 \times 30} = 1.4 < 1.5$$

33. (b)

Design shear strength, $V_d = \dfrac{f_y}{\sqrt{3}\gamma_{mo}} \times ht_w$

Given: $h = 250$ mm, $f_y = 250$ MPa, $t_{\text{web}} = 6.6$ mm, $\gamma_{\text{mo}} = 1.1$

$$\therefore \quad V_d = \frac{250 \times 250 \times 6.6}{\sqrt{3} \times 1.1} = 125\sqrt{3} \times 10^3 \text{N}$$

$$\Rightarrow \quad V_d = 125\sqrt{3} \text{ kN}$$

34. (d)

Welded steel sections are built up sections.

For built up member buckling about any axis the buckling curve is curve *c*.

Imperfection factor for buckling curve '*c*' is 0.49.

(Table IS 800 : 2007 P.g. 44)

35. (d)

Optimum depth of web, $d = \left(\dfrac{M_z \cdot k}{f_y}\right)^{1/3} = \left(\dfrac{250 \times 10^6 \times 125}{250}\right)^{1/3}$

where $k = \dfrac{d}{t_w} = 125$

$\therefore \quad d = 500$ mm

36. (c)

As per IS 456, Table 5, P.g. 20

Exposure	Minimum grade of plain concrete	Minimum grade of reinforced concrete
(i) Mild	–	M20
(ii) Moderate	M15	M25
(iii) Severe	M20	M30
(iv) Very severe	M20	M35
(v) Extreme	M25	M40

37. (a)

For maximum sagging support moment, loading should be applied on next to adjacent span plus alternate span.

38. (b)

As per IS 800 : 2007

CL 7.6.4 : Lacing bars, whether in double or single systems, shall be inclined at an angle not less than 40° and not more than 70° to the axis of the built-up member.

- *Cl* **7.6.3**: Thickness of flat lacing shall not be less than (1/40) of its effective length for single lacings and (1/60) of the effective length for double lacings.

$$t_{min} \not< \begin{cases} \dfrac{l}{40} \text{ for single lacing} \\ \dfrac{l}{60} \text{ for double lacing} \end{cases}$$

- **CL 7.6.6.1**: Lacing should be designed for transverse shear force in columns due to bending, lateral loading or accidental eccentricity. Transverse shear force is taken as 2.5% of column load.
- **CL 7.6.1.5**: The effective slenderness ratio of laced columns shall be taken as 5% more than the actual maximum slenderness ratio, in order to account for shear deformation effects.

$$\lambda_{\text{Laced column}} = 1.05\ \lambda_{\text{Actual}}$$

39. (c)

Given: $b = 200$ mm, $d = 300$ mm

$$A_{sv} = 2 \times \frac{\pi}{4} \times 10^2 = 157.08 \text{ mm}^2$$

$$\text{Maximum spacing, } s_{max} \leq \min.\begin{cases} \dfrac{A_{sv}}{bS_v} \geq \dfrac{0.4}{0.87\,fy} \\ 0.75d \text{ (For vertical stirrup)} \\ 300 \text{ mm} \end{cases}$$

$$\Rightarrow \quad S_{max} \leq \min.\begin{cases} \dfrac{157.08 \times 0.87 \times 415}{200 \times 0.4} = 708.9 \text{ mm} \\ 0.75 \times 300 = 225 \text{ mm} \\ 300 \text{ mm} \end{cases}$$

$$\Rightarrow \quad S_{max} = 225 \text{ mm c/c}$$

40. (d)

For deep beam.

1. $\frac{L_{eff}}{d} < 2$ for simply supported beam

$\frac{L_{eff}}{d} < 2.5$ for continuous beam

2. $L_{\text{eff}} = \min.\begin{cases} 1.15\, L_{\text{clear}} \\ \text{c/c distance between supports} \end{cases}$

41. (c)

$$\text{For bending tension, } L_P = \max.\begin{cases} L_d \\ 30\phi \end{cases}$$

$$\text{For direct tension, } L_P = \max.\begin{cases} 2L_d \\ 30\phi \end{cases}$$

42. (b)

Given: $T_u = 100$ kN-m

$M_u = 250$ kN-m

$D = 480$ mm, $b = 200$ mm

$\therefore$ $M_t = \frac{T_u}{1.7} \times \left(1 + \frac{D}{b}\right) = \frac{100}{1.7}\left(1 + \frac{480}{200}\right)$

$\Rightarrow$ $M_t = 200$ kNm

Since, $M_t < M_u$

Case-I $M_u = 250$ kNm (Sagging)

$M_t = 200$ kNm (Sagging)

$M_{e1} = M_u + M_t = 450$ kNm (Sagging)

Case-II $M_u = 250$ kNm (Sagging)

$M_t = -\,200$ kNm (Hogging)

$M_{e2} = 250 - 200$ kNm $= 50$ kNm (Sagging)

Therefore, equivalent design BM will be 450 kNm (Sagging)

43. (b)

Given, depth of flange, $D_f = 150$ mm

Width of rib, $b_w = 400$ mm

$l_o = 4.8$ m $= 4.8 \times 10^3$ mm $= 4800$ mm

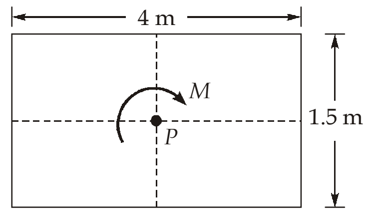
Now, effective flange width of the L-beam is given as below,

$$b_{\text{eff}} = \frac{l_0}{12} + 3d_f + b_w$$

$\Rightarrow$ $b_{\text{eff}} = \frac{4800}{12} + 3 \times 150 + 400$

$\Rightarrow$ $b_{\text{eff}} = 1250$ mm

44. (b)



$$\text{Extreme stress} = \frac{P}{A} \pm \frac{M}{Z}$$

Given: $P = 360 \text{ kN}, M = 60 \text{ kNm}, A = 1.5 \times 4 = 6 \text{ m}^2$

$$Z = \frac{bd^2}{6} = \frac{1.5 \times 4^2}{6} = 4 \text{ m}^3$$

$$\therefore \quad \sigma_{max.} = \frac{360}{6} + \frac{60}{4} = 75 \text{ kN/m}^2$$

$$\sigma_{min.} = \frac{360}{6} - \frac{60}{4} = 45 \text{ kN/m}^2$$

45. (d)

Given: $\Delta = 3 \text{ mm}, L = 30 \text{ m}$

$$\text{Loss due to anchorage} = \frac{\Delta}{L} \times E_s = \frac{3}{30 \times 10^3} \times 2.1 \times 10^5 = 21 \text{ N/mm}^2$$

$$\therefore \quad \text{Percentage loss} = \frac{21}{1200} \times 100 = 1.75\%$$

46. (a)

Time along 1-2-3-6-7-8 = 23 days
Time along 1-2-4-5-7-8 = 27 days
Time along 1-2-3-5-7-8 = 23 days

∴ Critical path is along 1-2-4-5-7-8

47. (b)

The latest start time is the latest possible time by which an activity can start without any delay of project time forecast on the basis of earliest occurrence time to the final event.

48. (c)

From table, for, $p = 90\%$

$$Z = 1.2 + \frac{1.6 - 1.2}{94 - 88} \times (90 - 88) = 1.33 = \frac{4}{3}$$

Now, $$Z = \frac{T_S - T_E}{\sigma}$$

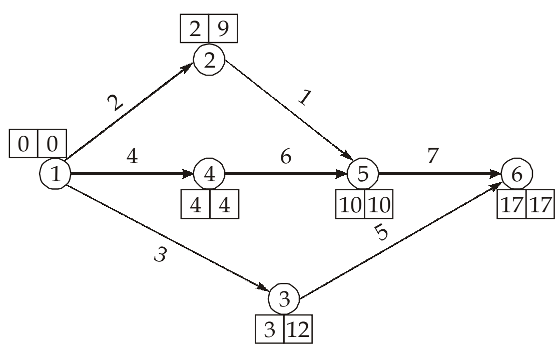
where σ is standard deviation i.e. $\sqrt{9}$ = 3 weeks.

∴ $$Z = \frac{T_S - T_E}{\sigma}$$

⇒ $$\frac{4}{3} = \frac{T_S - 30}{3}$$

⇒ $$T_S = 34 \text{ weeks}$$

49. (d)



Total expected duration = 17 weeks

Critical path is 1 – 4 – 5 – 6

$$V = 9 \text{ week}$$

∴ $$\sigma = \sqrt{V} = \text{ week}$$

∴ $$z = \frac{T_s - T_e}{\sigma}$$

when T_{sL} = 17 + 3 = 20 weeks (i.e. 3 weeks later)

or T_{SE} = 17 – 3 = 14 weeks (i.e. 3 weeks earlier)

$$Z_L = \frac{20 - 17}{3} = 1$$

∴ $$P_L = 84.13\%$$

$$Z_E = \frac{14 - 17}{3} = -1$$

∴ $$P_E = 15.87\%$$

∴ $$P_L - P_E = 84.13 - 15.87 = 68.26\%$$

50. (a)

$$\text{Limit of economical haul distance} = L = \frac{B}{O} + F$$

B = Cost of borrow = Cost of excavation + Cost of hauling

$\therefore \quad B = 3 + 1 = \text{Rs. } 4 \text{ per m}^3$

O = Cost of haulage = Rs. 0.75 /m^3 – Station meter

F = 90 m

$$\therefore \quad L = \left(\frac{4}{0.75}\right) \times 30 + 90 = 250 \text{ m}$$

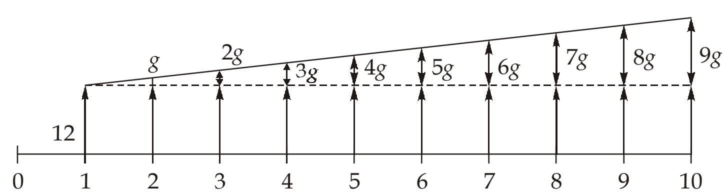
51. (b)

$$A = A_1 + A_2$$

$$= A_1 + g\left[\frac{1}{i} - \frac{n}{i}\left[\frac{i}{(1+i)^n - 1}\right]\right]$$

where, A_1 = Payment at the end of first year

A_2 = Equivalent payment of the gradient series.



g = Rs. 2 lakh, i = 10%, n = 10 year

$$A = 12 \text{ lakh} + 2 \text{ lakh}\left[\frac{1}{0.1} - \frac{10}{0.1} \times \left[\frac{0.1}{1.1^{10} - 1}\right]\right]$$

$$\Rightarrow \quad A = 12 + 2 \times \left[10 - \frac{10}{1.6}\right]$$

$= 12 + 2 \times (10 - 6.25)$

$= 12 + 2 \times 3.75$

$= 19.5$ lakh

52. (c)

No. of installments payment is 3 month

$$\text{i.e. } n = 3$$

$$\text{Interest rate per month} = \frac{9}{12} = \frac{3}{4} = 0.75\%$$

$$\therefore \quad A = \left(\frac{A}{P}, 0.75\%, 3\right) = P\left(\frac{i(1+i)^n}{(1-i)^n - 1}\right)$$

$$A = 10^5\left[\frac{0.0075 \times (1.0075)^3}{1.0075^3 - 1}\right]$$

$$A = 10^5\left[\frac{0.0075 \times 1.02}{1.02 - 1}\right]$$

$$A = \text{Rs. } 38250$$

53. (a)

Volume of excavating material = 2.25 m^3 loose

Swell = 25%

$$\text{Bank measure volume of one cycle} = \frac{2.25}{1.25} = 1.8 \text{ m}^3$$

$$\text{Actual time/hr} = 50 \text{ minute} = \frac{50}{60}\text{hr} = 50 \times 60 \text{ sec.}$$

Output of shovel = Number of cycles per hour × Bank measure volume

$$= \frac{50 \times 60}{30} \times 1.8 = 180 \text{ m}^3/\text{hr}$$

54. (d)

Both the statements are incorrect.

The rate of heat evolution during cement hydration increases with fineness because finer cement particles have a larger surface area, leading to faster hydration and quicker heat release in the early stages. However, the total amount of heat liberated (overall heat of hydration) over the complete hydration period is not significantly affected by fineness; it mainly depends on the chemical composition of the cement.

Le Chatelier's test is used to determine the soundness of cement due to excess presence of free lime.

55. (c)

Standard brick volume = 19 cm × 9 cm × 9 cm

= 1539 cm^3

Volume of mortar needed = 1 – 500 × 1539 cm^3 × 10^{-6} m^3/cm^3

= 1 – 0.7695

= 0.23 m^3

Extra mortar = 20%

∴ Total volume of wet mortar = 0.23 × 1.20 = 0.276 m^3

Now, 1 m^3 of wet mortar = 1.25 m^3 of dry mortar

$$\Rightarrow \qquad 0.276 \text{ m}^3 \text{ of wet mortar} = \frac{1.25 \times 0.276}{1} \text{m}^3 \text{ of dry mortar}$$

$$\therefore \quad \text{Dry mortar as percentage of brick work} = \frac{1.25 \times 0.276}{1} \times 100 = 34.5\% \simeq 35\% \text{ (say)}$$

56. (d)

All the three statements are correct.

Air entraining agents and light weight aggregates sourced from pumice rock are used in the preparation of light weight concrete. Due to its low density, it is suitable in the construction of high-rise buildings. Due to presence of large number of voids, this cement has low thermal conductivity. Hence, it is also suitable for the construction of cold storages.

57. (b)

Statement 1 is incorrect.

Due to reduced micro-cracks, fiber reinforced concrete has a slightly higher density than ordinary concrete.

Due to improved tensile strength, fiber reinforced concrete is more ductile and tough than ordinary concrete.

58. (b)

Statement 3 is incorrect.

With increase in grade, the concrete becomes more and more brittle i.e., ductility of concrete decreases.

59. (c)

Silica:

- It helps brick to retain its shape, imparts durability and prevents shrinkage, cracking and warping.
- Excess of silica destroys cohesion between particles and bricks become brittle and weak on burning.

Alumina:

- It absorbs water and imparts plasticity to clay so that the bricks can be moulded.
- If alumina is present in excess, it causes cracks in bricks on drying and bricks become too hard when burnt.
- Clays having high alumina are found be refractory.

60. (a)

Statements 2 and 3 are incorrect. Natural or air seasoning is the cheapest seasoning method and produces best quality timber, but it is a very slow process as it takes 120 to 180 days. Electrical seasoning is the costliest seasoning method, but it gives least quality timber as rapid reduction in moisture leads to shrinkage effects.

61. (d)

Smith's test is carried out to check whether stones contain earthy impurities such as clay, dust, or fine soil adhering to their surface. In this test, stones are immersed and shaken in water. If the water becomes turbid or muddy, it indicates the presence of earthy matter. This test helps in judging the cleanliness and suitability of stones for construction works.

In the acid test, dilute hydrochloric acid is applied to the stone. If calcium carbonate is present, brisk effervescence occurs due to the release of carbon dioxide gas. This test is mainly used to identify calcareous stones such as limestone and to assess their durability against acidic environments and to check weather resistance of aggregates.

The impact test measures the resistance of stones to sudden shocks or impact loads, which directly represents their toughness.

62. (d)

Given, gel-space ratio $= 0.7 = x$

$\therefore$ S = Strength of concrete $= 240x^3$ MPa

$$\Rightarrow \quad S = 240 \times (0.7)^3 = 240 \times \frac{343}{1000}$$

$$\Rightarrow \quad S = 82.32 \text{ MPa}$$

63. (a)

Given:

$$(FM)_{FA} = 3.68, \quad (FM)_{CA} = 8.72$$

$$(FM)_{MA} = 7.04$$

Percentage % of FA to be combined with coarse aggregate, $x = \dfrac{(FM)_{CA} - (FM)_{MA}}{(FM)_{MA} - (FM)_{FA}} \times 100$

$$\Rightarrow \quad x = \frac{8.72 - 7.04}{7.04 - 3.68} \times 100 = \frac{1.68}{3.36} \times 100$$

$$\Rightarrow \quad x = 50\%$$

64. (a)

$$\lambda_{\text{for wall}} = \min\left\{\frac{h}{t}, \frac{L}{t}\right\}$$

As per IS 1995 (Pg. 14 and 15)

Given, $h = 4 \text{ m} = 4000 \text{ mm}$

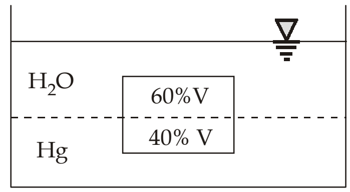
$L = 9000$ mm

$t = 180$ mm

$$\therefore \quad \lambda = \min\left\{\frac{4000}{180}, \frac{9000}{180}\right\} = \min\{22.22, 50\}$$

$$\therefore \quad \lambda = 22.22$$

65. (b)



From Archimede's principle, the weight of fluid displaced must be equal to its weight.

$\therefore$ Weight of metallic body = Weight of mercury displaced + Weight of water displaced

$$\Rightarrow \quad \rho V g = \rho_{Hg} \times 0.4V \times g + \rho_w \times 0.6V \times g$$

$$\rho = 13600 \times 0.4 + 1000 \times 0.6$$

$$= 6040 \text{ kg/m}^3$$

66. (b)

67. (b)

$$\text{Angular velocity, } w = \frac{1}{2}\nabla \times \bar{V}$$

$$\Rightarrow \quad \omega_z = \frac{1}{2}\begin{bmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ u & v & w \end{bmatrix}$$

For 2-dimension flow.

$$w_z = \frac{1}{2}\left[\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right]\hat{k}$$

$$\frac{\partial v}{\partial x} = -3x^2 = -3(1)^2 = -3$$

$$\frac{\partial u}{\partial y} = \frac{3y^2}{3} - x^2 = y^2 - x^2 = 4 - 1 = 3$$

$$\therefore \quad w_z = \frac{1}{2}[-3 - 3]\hat{k}$$

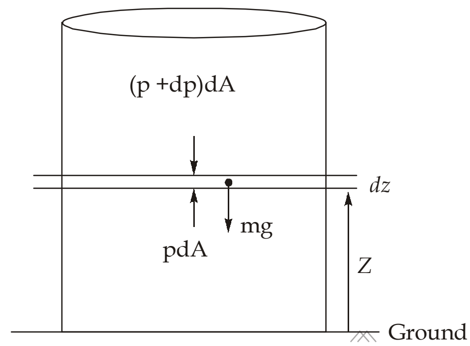
$$\Rightarrow \quad w_z = -3\hat{k}$$

68. (a)

Turbulent flow has steeper velocity gradient at the wall than the laminar boundary layer.

69. (d)

70. (c)



Consider equilibrium of an elementary vertical prism of height dZ and cross sectional area dA.

$$PdA - (P + dP)dA = \text{Weight of prism}$$

$$\Rightarrow \quad -dPdA = \rho g dZ dA$$

$$\therefore \quad -\int_1^2 dP = \int_0^{100} 1000\left[1 + \frac{Z}{500} + \left(\frac{Z}{1000}\right)^2\right] \times 9.81\, dZ$$

$$\Rightarrow \quad P_1 - P_2 = 9810\left[Z + \frac{Z^2}{1000} + \frac{Z^3}{3 \times 10^6}\right]_0^{100}$$

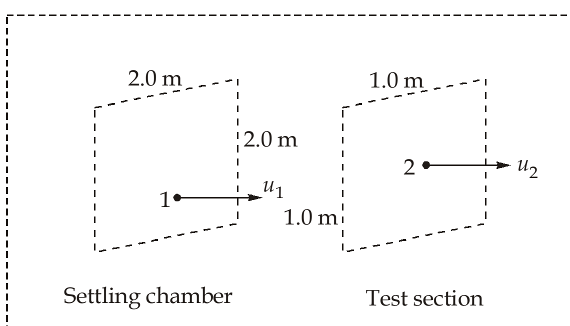
$$\Rightarrow \quad \Delta P = 1.08 \times 10^6 \text{ N/m}^2$$

71. (c)

A streamline is a curve such that the velocity vector at any point is tangential to it, and no fluid crosses a streamline at that instant.

72. (c)

73. (c)



By equation of continuity, $A_1 u_1 = A_2 u_2$

$$\Rightarrow \quad (2 \times 2)u_1 = (1 \times 1)u_2$$

$$\Rightarrow \quad u_2 = 4u_1$$

By using Bernoulli's equation at sections (1) and (2)

$$\frac{P_1}{\gamma} + \frac{u_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{u_2^2}{2g} + Z_2$$

As wind tunnel is horizontal and so, $Z_1 = Z_2$

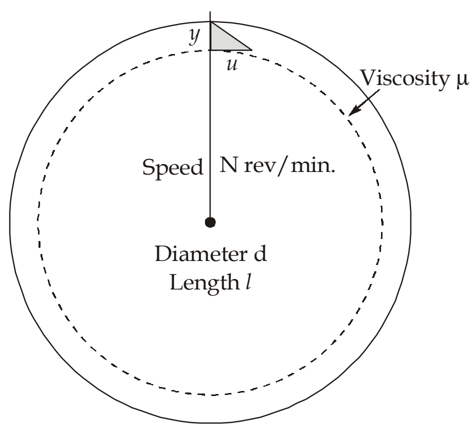
$$\frac{P_1 - P_2}{\gamma} = h_m\left(\frac{\rho_m}{\rho} - 1\right) = \frac{u_2^2 - u_1^2}{2g}$$

$$\Rightarrow \quad 0.2\left(\frac{800}{1.2} - 1\right) = \frac{164_1^2 - u_1^2}{2g}$$

$$u_1 = 13.196 \text{ m/s}, u_2 = 52.78 \text{ m/s}$$

74. (b)

Given the diameter of the shaft is d, rotating at a speed of N revolutions per minute. The clearance between the shaft and the bearing is y, filled with a lubricant of viscosity μ.



$$\text{Peripheral speed of the shaft, } u = \frac{\pi d N}{60}$$

$$\text{Velocity gradient in the gap, } \frac{u}{y} = \frac{\pi d N}{60 y}$$

Shear stress τ is given by

$$\tau = \mu \frac{u}{y} = \frac{\mu \pi d N}{60 y}$$

Shear force over the periphery of the shaft of length l is

$$F = \tau . \pi d . l$$

$$= \frac{\mu \pi^2 d^2 N l}{60 y}$$

$$\text{Torque} = F \times \frac{d}{2} \text{ and power} = T\omega$$

$$\text{Power} = \frac{\mu (\pi d)^2 l N}{60 y} \frac{d}{2} \times \frac{2\pi N}{60}$$

$$= \frac{\mu l N^2}{3600 y} (\pi d)^3$$

75. (b)

$$\text{Recirculation ratio, } R = \frac{\text{Recirculated flow}}{\text{Inflow}} = \frac{300}{600} = 0.5$$

$$\text{Recirculation factor, } F = \frac{1+R}{\left[1+(1-f)R\right]^2}$$

$$= \frac{1+0.5}{(1+0.1\times 0.5)^2} = \frac{1.5}{1.05^2} = 1.36$$

76. (b)

The minimum velocity (or self cleansing velocity) is given by,

$$V_s = \sqrt{\frac{8\beta}{f}(G_s-1)\,gd}$$

$$\Rightarrow \quad V_s = \sqrt{\frac{8\times 0.06(2.6-1)\times 9.81\times 0.005}{0.02}}$$

$$\Rightarrow \quad V_s = 1.3724 \text{ m/s}$$

77. (d)

Year	Population	Increase in population	Incremental increase
1990	25000		
		3000	
2000	28000		3000
		6000	
2010	34000		3000
		9000	
2020	43000		
Total		18000	6000
Average per decade		$\bar{x} = \frac{18000}{3} = 6000$	$\bar{y} = \frac{6000}{3} = 3000$

Future population in 2030 is,

$$P_n = P_o + n\bar{x} + \frac{n(n+1)\bar{y}}{2}$$

$$\Rightarrow \quad P_{2030} = 43000 + 1\times 6000 + 1\times\frac{(1+1)}{2}\times 3000$$

$$\Rightarrow \quad P_{2030} = 52{,}000$$

78. (d)

Fire demand, Q as per National Board of Fire Underwriters formula

$$Q = 4637\sqrt{P}\left[1-0.01\sqrt{P}\right]$$

where Q = Fire demand in litre/mintue

$$P = \text{Population in thousands} = \frac{144000}{1000} = 144$$

$$\therefore \quad Q = 4637\sqrt{144}\left[1 - 0.01\sqrt{144}\right]$$
$$= 48966.72 \text{ litre/minute}$$
$$= \frac{48966.72 \times 10^{-3}\ \text{m}^3}{60\ \text{sec}}$$
$$= 0.816\ \text{m}^3/\text{s}$$

79. (b)

Minimum height of chimney emitting SO_2 is

$$h = 14(Q_s)^{1/3}$$
$$Q_S = SO_2 \text{ emission (kg/hour)}$$
$$\therefore \quad Q_S = \frac{0.216 \times 10^3\ \text{kg}}{24\ \text{hr}} = 9\ \text{kg/hr}$$
$$\therefore \quad h = 14 \times 9^{1/3}$$
$$\Rightarrow \quad h = 29.12\ \text{m}$$

80. (d)

$$\text{Return sludge ratio, } \frac{Q_r}{Q} = \frac{Q_r}{Q} = \frac{X_t}{\frac{10^6}{SVI} - X_t}$$
$$X_t = \text{Mixed liquour suspended solids, (mg/}l)$$
$$SVI = \text{Sludge volume index (m}l\text{/g)}$$
$$\therefore \quad \frac{Q_r}{Q} = \frac{3000}{\frac{10^6}{100} - 3000} = 0.43$$

81. (c)

- Ultimate BOD represents the total amount of oxygen required by micro-organisms to completely decompose the biodegradable organic matter in waste water under aerobic conditions.
- It does not depend on temperature and it is a function of the organic matter content in the waste water

Note: Temperature affects the rate of BOD exertion, but not the ultimate BOD.

82. (c)

Aerobic digestion is generally restricted to biological sludges. It stabilizes waste activated sludge in the absence of primary sludge.

Process mainly involves thickening of sludge in the secondary clarifier and sludge thickener.

Aerobic digestion involves stabilizing sludge without supplying any external food source.

Aerobic process is not as sensitive to environmental factors an anaerobic digestion.

Digested sludge is relatively inert but settles poorly.

83. (b)

84. (b)

Primary pollutants are the pollutants which are emitted directly from source.

Examples - SO_2, NO_x, CO, VOCs, Particulate matter, Hazardous air pollutants (HAPs)

Secondary pollutants are those pollutants which are formed in atmosphere by chemical or photochemical reactions. Example - Ozone (O_3), PAN, Aldehydes , HNO_3

85. (c)

Clarigester is a modern, mechanical imhoff tank with two-storeys.

Sludge-stirring mechanism pushes sludge to hopper. Clarigester requires lesser depth because bottom hopper is eliminated.

Sludge gas can be collected in a dome and used.

86. (a)

As per standard empirical values (Marriot's recommendations), the approximate specific yield values (in $m^3/hr/m^2$ under unit drawdown) are: Clay: 0.25, Fine sand: 0.50, Coarse sand: 1.00

87. (a)

Alum forms $AI(OH)_3$ floc, which enmeshes colloidal impurities.

Calcium sulphate formation causes permanent hardness

Optimum pH range for alum coagulation is 6.5 – 8 3.

1 mg/L of alum consumes about 0.5 mg/L of alkalinity, not 1.0 mg/L.

88. (c)

Given:

$$\text{Normal flow on road, } A = q_u = 400 \text{ pcu/hr}$$

$$\text{Saturation flow on road } A = S_a = 1200 \text{ pcu/hr}$$

$$\text{Normal flow on road } B = q_b = 300 \text{ pcu/hr}$$

$$\text{Saturation flow on road } B = S_b = 900 \text{ pcu/hr}$$

$$\text{No. of phases, } n = 2$$

$$\text{All red time, } R = 12 \text{ seconds}$$

$$\text{Total loss time, } L = 2n + R$$

$$\Rightarrow L = 2 \times 2 + 12$$

$$\Rightarrow L = 16 \text{ seconds}$$

$$\text{Optimum cycle length, } C_o = \frac{1.5L + 5}{1 - y}$$

$$y = y_a + y_b$$

$$\Rightarrow y = \frac{400}{1200} + \frac{300}{900}$$

$$\Rightarrow y = \frac{2}{3}$$

$$C_o = \frac{1.5 \times 16 + 5}{1 - \frac{2}{3}}$$

$$\Rightarrow C_o = 87 \text{ sec}$$

89. **(b)**

90. **(d)**

Angularity number, A_N = % voids – 33 = 67 – 100 W/CG_d

where, W = weight of aggregate filled in cylinder = 1500 g

C = weight of water filled in same cylinder = 1000 g

G_a = Specific gravity of aggregate = 2.5

$$\text{Percent voids} = 67 - 100 \times \frac{1500}{1000 \times 2.5} + 33$$

$\Rightarrow$ Percent voids = 100 – 60

$\Rightarrow$ Percent voids = 40%

91. **(b)**

Transition curves do not reduce the required radius of the circular curve; they only ensure smooth transition between tangent and circular curve.

92. **(c)**

Graphical methods of proportioning:

- Triangular chart method is specifically meant for three aggregates.
- Rothfuch's method is flexible and can handle any number of aggregates.
- Graphical methods are widely used in bituminous mix design to achieve target gradation

93. **(b)**

$$CSA = 365\, N_1 F_1 \frac{D\left[(1+r)^n - 1\right]}{r}$$

$$= 365 \times 800 \times 2.5 \times 0.5 \frac{\left[(1+0.05)^{15} - 1\right]}{0.05} \times 10^{-6}$$

$$= 7.88 \text{ msa}$$

94. (d)

- Conical surface : Extends outward and upward from the horizontal surface
- Approach surface : Centered on the extended runway
- Primary surface : Centered on the runway itself
- Transitional surface : Extends upward and outward perpendicular to runway center line

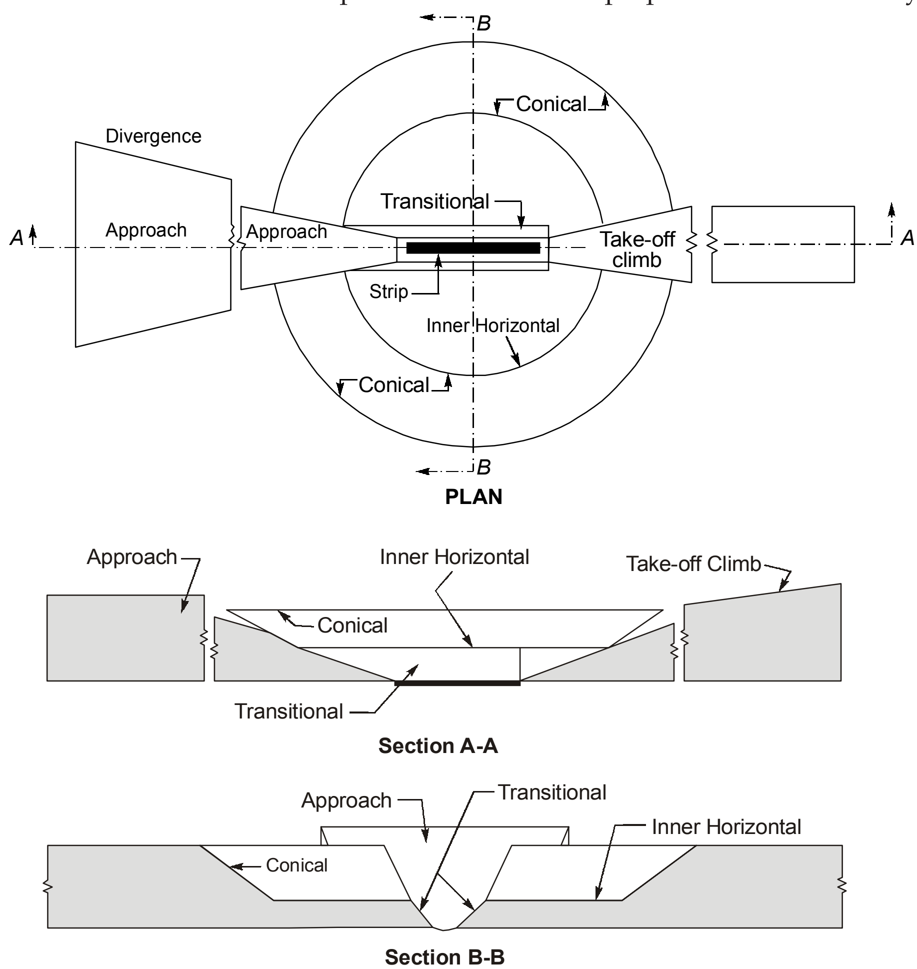


Fig. Schematic View of Imaginary Surfaces

95. (b)

Frontage roads provide controlled access, not unrestricted access, to properties along highways.

96. (d)

Speed and delay study methods:

- Floating car (riding check) method
- License plate method
- Elevated observation method
- Photographic method
- Interview technique

Purpose: To determine journey speed, running speed, delays, and causes of delay.

97. **(b)**

Obligatory points are control points that govern highway alignment.

98. **(c)**

Airport refrence temperature, $T_R = T_a + \left(\frac{T_m - T_a}{3}\right)$

$\Rightarrow \quad T_R = 24 + \frac{42-24}{3}$

$\Rightarrow \quad T_R = 30°\text{C}$

99. **(b)**

$$\text{RQD} = \frac{\text{Sum of lengths of core pieces (> 10 cm)}}{\text{Total core length}} \times 100$$

$$= \frac{15+25+13+35+40}{150} \times 100 = 85.33\% \simeq 85\% \text{ (say)}$$

100. **(b)**

Given: $N = 13, G = 1.676 \text{ m}, D = 4.5 \text{ m}$

Intermediate straight distance, $S = (D-G)N - G\sqrt{1+N^2}$

$\Rightarrow \quad S = (4.5-1.676)\times 13 - 1.676\sqrt{1+13^2}$

$\Rightarrow \quad S = 14.86 \text{ m}$

Overall length of the crossover, $l = 4GN + S$

$= 4 \times 1.676 \times 13 + 14.86$

$= 102.012 \text{ m}$

101. **(d)**

Required depth of harbour channel, D is:

$$D = D_1 + \frac{H}{3} + D_2$$

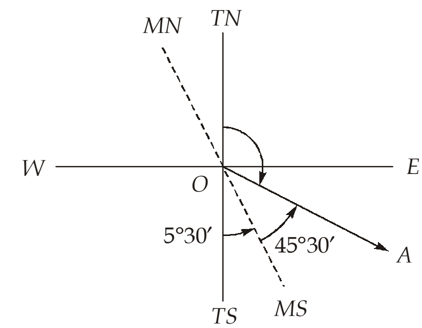
where D_1 = Draft of the largest ship to be accommodated = 9 m

H = Height of storm waves = 3 m

D_2 = Allowance for squat of the moving ship = 0.6 m

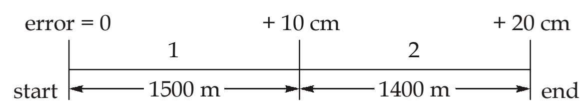
$\therefore \quad D = 9 + \frac{3}{3} + 0.6 = 10.6 \text{ m}$

102. (b)



$$\text{TB of line} = 180° - [5°30' + 45°30']$$
$$= 129° \text{ (WCB)}$$

103. (c)



1^{st} chaining, average error $= \dfrac{0+10}{2} = 5\,\text{cm}$

True length $= \dfrac{1500 \times 20.05}{20} = 1503.75\,\text{m}$

2^{nd} chaining, average error $= \dfrac{10+20}{2} = 15\,\text{cm}$

True length $= \dfrac{1400 \times 20.15}{20} = 1410.50\,\text{m}$

$\therefore$ True distance $= 1503.75 + 1410.50 = 2914.25$ m

104. (d)

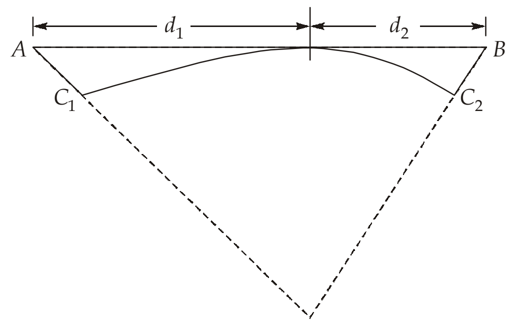
Area, by average ordinate rule, $A = \dfrac{L}{n+1}\sum O$

where,
L = Length of one interval = 15 m
n = Number of intervals = 7
ΣO = Ordinate sum

$\Rightarrow \Sigma O = 0 + 2.6 + 3.85 + 3.75 + 4.65 + 4.95 + 5.25 + 5.40$
$= 30.45$ m

Area $= \dfrac{15}{8} \times 30.45 = 57.09\ \text{m}^2$

105. (b)



The distances d_1 and d_2 are given as

$$d_1 = 3.855\sqrt{C_1} = 3.855\sqrt{49} = 26.985 \text{ m}$$

$$d_2 = 3.855\sqrt{C_2} = 3.855\sqrt{9} = 11.565 \text{ m}$$

Distance between observer and lighthouse = $d_1 + d_2$ = 38.550 m

106. (c)

In axis method:

- Angles remain unchanged
- Only lengths are adjusted
- Overall shape of traverse is preserved

Method	Best Condition	Basis of Correction
Bowditch	Linear & angular equally precise	Length of sides
Transit	Angular more precise	Latitudes & departure
Graphical	Rough surveys	Geometrical closure
Axis	Angles very accurate	Lengths only

107. (d)

Angle and distance methods include:

- Protractor method
- Tangent method
- Chord method

The co-ordinate method is a separate principal method of plotting a traverse and does not fall under angle and distance methods.

108. (d)

Striding level tests trunnion axis, not vertical axis.

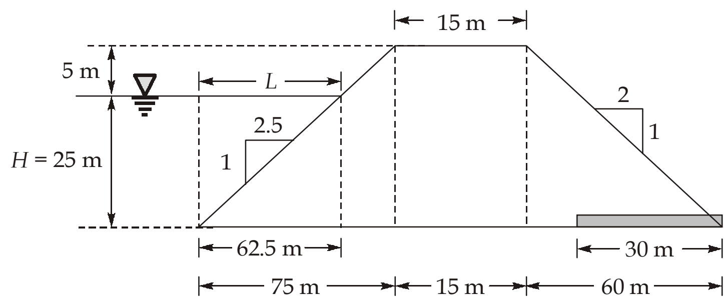
109. (d)

In a prismatic compass, graduations are engraved inverted so that they appear erect when viewed through the prism. In a surveyor's compass, graduations are engraved erect and read directly.

110. (d)

111. **(d)**

112. **(a)**



$$\Rightarrow \quad d = \text{Base width} - 0.7L - \text{Filter length}$$

$$\Rightarrow \quad d = 150 - 30 - 0.7 \times 62.5$$

$$\Rightarrow \quad d = 76.25 \text{ m}$$

$$\text{Focal length, } (S) = \sqrt{d^2 + H^2} - d$$

$$= \sqrt{(76.25)^2 + (25)^2} - 76.25 = 3.99 \text{ m} \simeq 4 \text{ m}$$

113. **(c)**

$$\sigma_z = \frac{2q}{\pi z}\left[\frac{1}{1+\left(\frac{x}{z}\right)^2}\right]^2$$

Given: $q = 120$ kN/m, $z = 4$ m, $x = 2$ m

$$\therefore \quad \sigma_z = \frac{2 \times 120}{\pi \times 4} \times \left[\frac{1}{1+\left(\frac{2}{4}\right)^2}\right]^2 = \frac{60}{\pi} \times \frac{16}{25}$$

$$\Rightarrow \quad \sigma_z = 12.22 \text{ kN/m}^2 \simeq 12.2 \text{ kN/m}^2$$

114. **(b)**

As per spring analysis, the initial load is completely taken by water which is present in voids of soil.

Initial pore water pressure, $U_i = 500$ kN/m^2

Time, $t = 12$ hours

Final pore water pressure, $U = 200$ kN/m^2

$$\therefore \quad \text{Percent consolidation} = \%U = \frac{U_i - U}{U_i} \times 100$$

$$\Rightarrow \quad \%U = \frac{500 - 200}{500} \times 100 = 60\%$$

$$\therefore \quad T_v = \frac{\pi}{4} \times (0.6)^2 = \frac{C_v \times 12}{d^2} \quad \text{...(i)}$$

For $\%U = 50\%$

$$T_v = \frac{\pi}{4} \times (0.5)^2 = \frac{C_v \times t}{d^2} \qquad \text{...(ii)}$$

Comparing (i) and (ii),

$$\frac{(0.6)^2}{(0.5)^2} = \frac{12}{t}$$

$$\Rightarrow \qquad t = \frac{12 \times 0.25}{0.36} = \frac{25}{3}\text{hr} = 8.33 \text{ hr}$$

115. (d)

When consolidation of a saturated soil sample occurs, the degree of saturation remains constant.

116. (d)

The pore pressure change and the volumetric change can be measured directly.

117. (d)

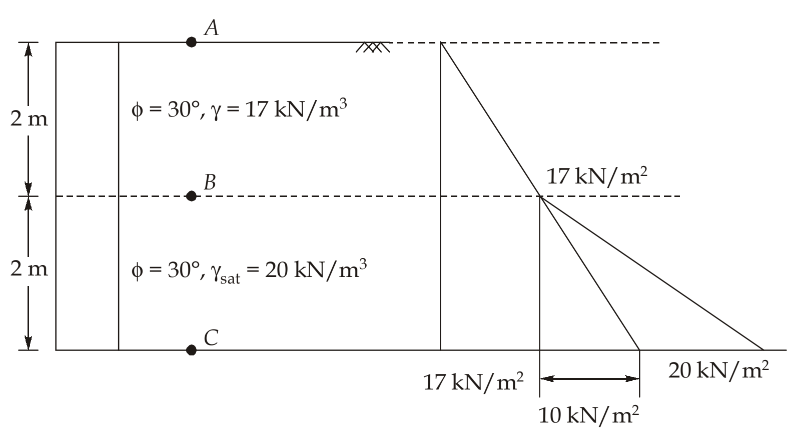
$$F = kx = 100 \times 3 = 300 \text{ N}$$

$$\in = \frac{\text{Deformation of sample}}{\text{Length of sample}} = \frac{12 \times 10^{-1}}{12} = 0.1$$

$$A = \frac{A_o}{1 - \in_0} = \frac{12}{0.9}\text{cm}^2$$

$$\therefore \qquad q = \frac{F}{A} = \frac{300}{12} \times 0.9 = 22.5 \text{ N/cm}^2$$

118. (b)



At 2m depth from top of retaining wall

$$p_{a_1} = k_o \gamma_1 h_1 = \frac{1}{2} \times 17 \times 2 = 17 \text{ kN/m}^2$$

At base of retaining wall

$$\begin{aligned} p_{a_2} &= 17 + \frac{1}{2}(20 - 10)(2) + 10(2) \\ &= 17 + 10 + 20 \\ &= 47 \text{ kN/m}^2 \end{aligned}$$

∴ Total lateral earth pressure at rest is,

$$F = \frac{1}{2}p_{a_1}h_1 + p_{a_1}h_2 + \frac{1}{2}\left(p_{a_2} - p_{a_1}\right)h_2$$

$$F = \frac{1}{2}(17)(2) + 17(2) + \frac{1}{2}(47-17)(2)$$

$$F = 17 + 34 + 30$$

$$F = 81 \text{ kN/m length of wall}$$

119. (c)

Refer IS : 1904 – 1978

	Sand and hard clay			Plastic clay		
	Max. settlement	**Diff. settlement**	**Angular Distortion**	**Max. settlement**	**Diff. settlement**	**Angular Distortion**
Isolated Foundations						
(i) Steel Structures	50 mm	0.0033 *L*	1/300	50 mm	0.0033 *L*	1/300
(ii) R.C.C structures	50 mm	0.0015 *L*	1/666	75 mm	0.0015 *L*	1/666
Raft Foundations						
(i) Steel Structures	75 mm	0.0033 *L*	1/300	100 mm	0.0033 *L*	1/300
(ii) R.C.C structures	75 mm	0.002 *L*	1/500	100 mm	0.002 *L*	1/500

120. (c)

For square footing, ultimate bearing capacity is,

$$q_u = 1.2CN_C + qN_q + 0.4B\gamma N\gamma$$

As local shear failure, $C_m' = \frac{2}{3}C' = \frac{2}{3} \times 15 = 10 \text{ kN/m}^2$

$$q_u = 1.2 \times 10 \times 14 + 1 \times 18 \times 6 + 0.4 \times 2 \times 18 \times 3$$

$$= 319.2 \text{ kN/m}^2$$

Net ultimate bearing capacity, $(q_{nu}) = q_u - \gamma D_f$

$$= 319.2 - 18 \times 1$$

$$= 301.2 \text{ kN/m}^2$$

Net safe bearing capacity, $q_{ns} = \frac{q_{nu}}{FOS} = \frac{301.2}{3} = 100.4 \text{ kN/m}^2$

121. **(c)**

Ultimate load carrying capacity pile, $Q_u = CN_cA_p + \alpha\bar{C}A_s$

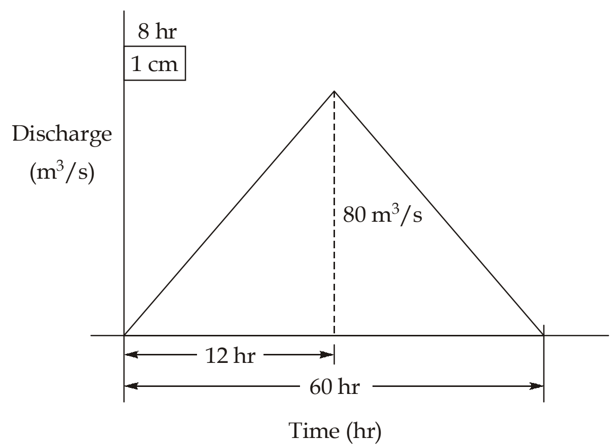
$$= 40 \times 9 \times \frac{\pi}{4} \times 0.3^2 + 0.7 \times 40 \times \pi \times 0.3 \times 10$$

$$= 289.34 \text{ kN}$$

$$\text{Safe load, } Q_s = \frac{Q_u}{FOS} = \frac{289.34}{2.5}$$

$\Rightarrow$ $$Q_s = 115.736 \text{ kN} \simeq 115.74 \text{ kN}$$

122. **(d)**



Volume of runoff due to 1 cm of rainfall excess = Area of UH

$\Rightarrow$ $$(A \times 10^6) \times \frac{1}{100} = \frac{1}{2} \times 80 \times 60 \times 3600$$

$\Rightarrow$ $$A = 864 \text{ km}^2$$

123. **(c)**

$$Q_{peak} = CiA$$

Q_{peak} $$Q_{peak} = 0.3 \times \left(\frac{100 \times 10^{-3}}{3600}\right)(100 \times 10^4)\text{ m}^3/\text{s}$$

$\Rightarrow$ $$Q_{peak} = 8.33 \text{ m}^3/\text{s}$$

124. **(b)**

Depth of rainfall during 8 hr of rainfall = 1.5 cm/hr × 8 hr = 12 cm

$$\text{Volume of rainfall during 8 hr} = \text{Area} \times \text{Depth of rainfall}$$

$$= 800 \times 10^4 \times 12 \times 10^{-2} \text{ m}^3 = 0.96 \text{ Mm}^3$$

$$\text{Infiltration capacity, } \phi = \frac{\text{Rainfall} - \text{Runoff}}{\text{Time}}$$

$\Rightarrow$ $$\phi = \frac{\dfrac{(0.96 - 0.8) \times 10^6 \text{ m}^3}{800 \times 10^4 \text{ m}^2}}{8} = 2.5 \times 10^{-3} \text{ m/hr}$$

$\Rightarrow$ $$\phi = 2.5 \text{ mm/hr}$$

125. (d)

$$\text{Mean precipitation } \overline{P} = \frac{\sum_{i=1}^{n} \text{Average depth} \times \text{Area}}{\sum_{i=1}^{n} \text{Area}}$$

$$\Rightarrow \quad \overline{P} = \frac{10 \times 25 + \left(\frac{10+8}{2}\right) \times 100 + \left(\frac{8+6}{2}\right) \times 90 + \left(\frac{6+4}{2}\right) \times 200 + \left(\frac{4+2}{2}\right) \times 10}{25 + 100 + 90 + 200 + 10}$$

$$\Rightarrow \quad \overline{P} = 6.61 \text{ cm}$$

126. (c)

For uniform rainfall, the values of ϕ-index and W-index are equal.

127. (d)

Analytical methods of evaporation estimation include:

- Water-budget method
- Energy-balance method
- Mass-transfer method

The pan evaporimeter method is an empirical/observational method, not an analytical one.

128. (c)

$$\text{Setting} = \frac{\text{Outlet index (m)}}{\text{Channel index (n)}}$$

$$\text{For weir type outlet, } q \propto H^{3/2}, \text{ m} = \frac{3}{2}$$

$$\text{For orifice type outlet, } q \propto H^{1/2}, \text{ m} = \frac{1}{2}$$

$$\text{Channel index, } n = \frac{5}{3}$$

$$\therefore \quad S = \frac{3/2}{5/3} = 0.9$$

129. (c)

$$\text{Discharge} = \text{Area} \times \text{Velocity}$$

$$\Rightarrow \quad \frac{1500 \times 10^{-3}}{60} = [(\pi \times 0.20) \times l] \times 0.20 \times 0.02$$

$$\Rightarrow \quad l = 9.947 \text{ m} \simeq 10 \text{ m}$$

130. (b)

$$\text{SAR} = \frac{Na^+}{\sqrt{\frac{\text{Ca}^{+2} + \text{Mg}^{+2}}{2}}} = \frac{25}{\sqrt{\frac{5+3}{2}}} = 12.5$$

- As SAR is between 10 – 18 so S_2 i.e. medium sodium water.
- As electrical conductivity is 200 μ mho/cm at 25°c which is between 100 – 250 μ mho/cm at 25°C so low conductivity $\{C_1\}$ water.
- Classification is $C_1 - S_2$.

131. (b)

Thiem's non-equilibrium equation is,

$$\text{Drawdown, } S = \frac{Q}{4\pi T}\left[\ln\frac{4Tt}{r^2 A} - 0.5772\right]$$

As $S_1 = S_2$

$$\therefore \quad \ln\frac{4Tt_1}{r_1^2 A} = \ln\frac{4Tt_2}{r_2^2 A}$$

$$\Rightarrow \quad \frac{t_1}{r_1^2} = \frac{t_2}{r_2^2}$$

$$\Rightarrow \quad \frac{2}{10^2} = \frac{t_2}{20^2}$$

$$\Rightarrow \quad t_2 = 8 \text{ hr}$$

132. (a)

Statement 4 is incorrect because the site elevation should be higher than the cultivable command area to ensure gravity irrigation.

133. (b)

Factors affecting duty of irrigation water:

1. More losses leads to lower the duty.
2. Rainfall supplements irrigation and hence higher duty.
3. Longer base period leads to lower duty.
4. Uneven slope leads to water wastage so less duty.
5. Deep ploughing retains moisture so higher duty.
6. Perennial systems are better regulated so higher duty.

134. (c)

135. (d)

Discharge, as per Manning's equation,

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

For wide rectangular channel, $R \simeq y$

$$A = By$$

$$\therefore \quad Q = \frac{1}{n}(By)(y)^{2/3} S^{1/2}$$

$$\therefore \quad Q \propto y^{5/3}$$

$$\therefore \quad \frac{Q_1}{Q_2} = \left(\frac{y_1}{y_2}\right)^{5/3} = \left(\frac{y_1}{1.2y_1}\right)^{5/3}$$

$$\Rightarrow \quad Q_2 = (1.2)^{5/3}Q_1$$

$$\Rightarrow \quad Q_2 = (1 + 0.2)^{5/3}Q_1$$

$$\Rightarrow \quad Q_2 = (1 + 0.2 \times 5/3)Q_1$$

$$\Rightarrow \quad Q_2 = 1.333Q_1$$

$\therefore$ Percentage increase in discharge $= 33.3\% \simeq 35\%$

136. (b)

For most efficient trapezoidal channel section, bed width,

$$B = \frac{y}{\sin 60} = \frac{2}{\sqrt{3}}y$$

$$\therefore \quad \text{Ratio of flow depth and width} = \frac{y}{\frac{2}{\sqrt{3}}y} = \frac{1.732}{2} = 0.866 \simeq 0.87$$

137. (b)

Discharge over a broad crested weir,

$$Q = 1.705\ C_d\ LH^{3/2}$$

$$L = \text{Length of weir} = 4 \text{ m}$$

$$H = \text{Energy head} = 0.81 \text{ m}$$

$$C_d = 0.98$$

$$\therefore \quad Q = 1.705 \times 0.98 \times 4 \times 0.81^{3/2} = 1.705 \times 0.98 \times 4 \times (0.9^2)^{3/2}$$

$$= 4.87 \text{ m}^3/\text{s}$$

138. (c)

Given, $H = 500$ m, $N = 400$ rpm, Jet diameter $= 0.20$ m

Power developed $= \eta_0 \gamma QH$

$$Q = \left(\frac{\pi}{4}d^2\right)V_1$$

$$V_1 = C_v \times \sqrt{2gH}$$

$$= 0.98 \times \sqrt{2 \times 10 \times 500} = 98 \text{ m/s}$$

$$\therefore \quad Q = \frac{\pi}{4} \times 0.2^2 \times 98 = 3.079 \text{ m}^3/\text{s}$$

$$\therefore \quad P = 0.85 \times 10 \times 3.079 \times 500$$

$$= 13085.75 \text{ kW}$$

$$\simeq 13085 \text{ kW}$$

139. (b)

$$\text{Critical cavitation number, } \sigma_c = \frac{NPSH_{\min}}{\text{Head}}$$

$$\Rightarrow \quad 0.15 \times 30 = \text{NPSH}_{\min}$$

$$\text{But} \quad \text{NPSH} = H_{atm} - H_{vap.} - h_L - Z_{S,\max}$$

$$\Rightarrow \quad 4.5 = 10 - 0.50 - 0.30 - Z_{s,\max}$$

$$\Rightarrow \quad Z_{s,\max} = 4.7 \text{ m}$$

140. (d)

$$\text{Stopping sight distance, } S = \text{Braking distance + Lag distance}$$

$$= 80 \text{ m} + 60 \text{ m} = 140 \text{ m}$$

$$\text{As length of curve, } L > S$$

$$L = \frac{NS^2}{4.4}$$

$$\Rightarrow \quad L = \frac{0.08 \times 140 \times 140}{4.4} = 356.36 \text{ m}$$

$$\Rightarrow \quad L \simeq 357 \text{ m}$$

141. (d)

Statement (I) is incorrect. Statement (II) is correct. The difference between mean strength and minimum strength is controlled by quality control measures such as proper batching, mixing, curing, workmanship and testing. Better quality control reduces variability (standard deviation), which helps in controlling the strength margin. Whereas cement content is primarily governed by strength requirement, durability requirement, and water-cement ratio, not directly by the numerical difference between mean and minimum strength. Therefore, saying that a lower difference automatically results in lower cement content is incorrect.

142. (d)

In Coulomb's theory, the failure surface is assumed to be plane but actual failure surface is slightly curved.

143. (c)

Basic capacity represents an ideal upper limit, while possible capacity represents extreme operating conditions but neither is suitable for design.

144. (d)

145. (d)

Negative skin friction develops a drag force on the surface of pile in downward direction resulting in decrease in load carrying capacity of the pile.

146. (d)

Eutrophic lakes are not necessarily polluted; eutrophication can occur naturally without human interference.

Natural eutrohication is a slow, long-term ecological process driven by natural nutrient inputs.

147. (a)

Time-grid is a graphical representation of network diagram on time scale. It facilitates to readout the float of activity between its end node events. Floats are shown by horizontal broken lines whereas activity duration is shown by continuous lines.

148. (d)

Crack width in RCC members increase when high grade steel is used.

149. (a)

150. (c)

For isotropic material, two elastic constants Young's Modulus (E) and Poisson's ratio (μ).
i.e. for isotropic material, G and K are found out from E and μ.
All metals at micro-level are anisotropic.

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