DETAILED SOLUTIONS

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ESE 2026 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

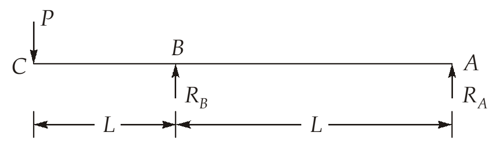
Test 20

Full Syllabus Test 4 : Paper-II

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

DETAILED EXPLANATIONS

1. (d)



$$\Sigma F_y = 0$$

$$\Rightarrow \quad R_A + R_B = P$$

$$\Sigma M_B = 0$$

$$\Rightarrow \quad P \times L + R_A \times L = 0$$

$$\Rightarrow \quad R_A = -P$$

$$\therefore \quad R_B = 2P$$

Strain energy stored in a beam is,

$$U = U_{CB} + U_{AB}$$

$$\Rightarrow \quad U = \int_0^L \frac{(-Px)^2\,dx}{2EI} + \int_0^L \frac{(-Px)^2\,dx}{2EI}$$

$$\Rightarrow \quad U = \int_0^L \frac{P^2x^2dx}{2EI} + \int_0^L \frac{P^2x^2dx}{2EI}$$

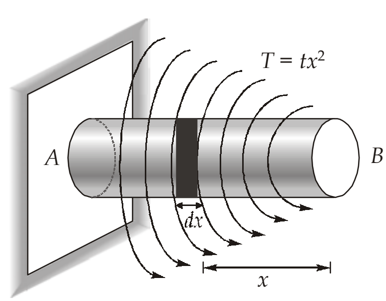
$$\Rightarrow \quad U = \frac{P^2}{2EI} \times \frac{L^3}{3} \times 2 = \frac{P^2L^3}{3EI}$$

$$\therefore \quad \Delta_C = \frac{\partial U}{\partial P} = \frac{2PL^3}{3EI}$$

2. (c)

3. (c)

Consider an elementary disc of thickness dx at a distance x from free end.



$$d\theta = \frac{T_x \cdot dx}{GI_p} = \frac{t \cdot x^2 dx}{GI_p}$$

$$\int_0^\theta d\theta = \int_0^L \frac{t}{G} \times \frac{x^2 dx}{\frac{\pi d^4}{32}}$$

$$\theta = \frac{32t}{G\pi d^4} \times \left[\frac{x^3}{3}\right]_0^L = \frac{32tL^3}{3G\pi d^4}$$

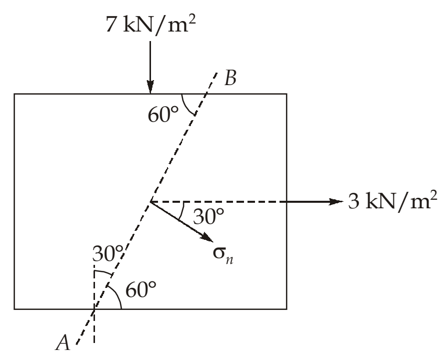
4. (b)

$$\text{Torsional rigidity} = GJ$$

$$\text{Torsional flexibility} = \frac{GJ}{L}$$

$$\text{Torsional stiffness} = \frac{L}{GJ}$$

5. (b)



Now, $\sigma_n = \frac{\sigma_1 + \sigma_2}{2} + \frac{\sigma_1 - \sigma_2}{2}\cos 2\theta$

Here θ is the angle in between the plane *AB* and vertical plane

∴ $\theta = 30°$

∴ $\sigma_n = \frac{3-7}{2} + \frac{3-(-7)}{2}\cos(2 \times 30)$

⇒ $\sigma_n = -2 + 5 \times \frac{1}{2} = 0.5 \text{ kN/m}^2$

6. (b)

Given: $\sigma_2 = 6 \text{ kN/m}^2$, $\tau_{max} = 2 \text{ kN/m}^2$

Resultant stress on the plane of maximum shear stress is given by

$$\sigma_R = \sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}}$$

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

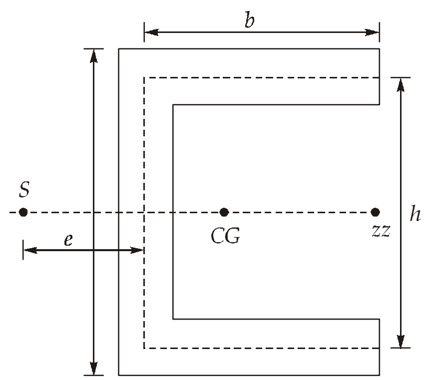
$$\Rightarrow \quad 2 = \frac{\sigma_1 - 6}{2}$$

$$\therefore \quad \sigma_1 = 10 \text{ kN/m}^2$$

So $$\sigma_R = \sqrt{\frac{10^2 + 6^2}{2}} = 8.246 \text{ kN/m}^2$$

$$\simeq 8.25 \text{ kN/m}^2$$

7. (d)



$$b = B - \frac{t_F}{2} = 165 - \frac{10}{2} = 160 \text{ mm}$$

$$h = D - t_f = 510 - 10 = 500 \text{ mm}$$

$$\therefore \quad e = \frac{b^2 h^2 t_f}{4 I_z} = \frac{(500)^2 \times (160)^2 \times 10}{4 \times 3 \times 10^8}$$

$$\Rightarrow \quad e = \frac{25 \times 16 \times 16}{4 \times 3 \times 10} = \frac{160}{3} = 53.33 \simeq 53 \text{ mm}$$

8. (b)

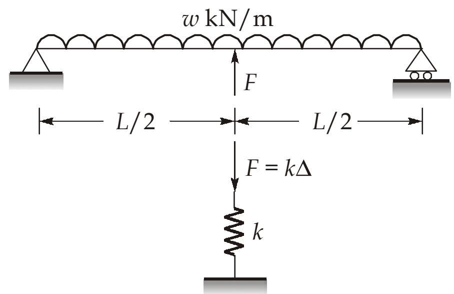
- BMD is one degree higher than SFD, and SFD is one degree higher than loading.

$$M = \int S\,dx$$

$$S = \int w\,dx$$

- At point of contraflexure, BM and curvature changes their sign.
- The BM at a section shall be maximum or minimum when $\frac{dM}{dx} = 0$ i.e., $S = 0$.

9. **(b)**



Let 'Δ' be the deflection in beam

$\therefore \quad F = k\Delta$

Now, using compatibility condition,

$$\frac{5}{384}\frac{wl^4}{EI} - \frac{Fl^3}{48EI} = \Delta$$

$$\Rightarrow \quad \frac{5}{384}\frac{wl^4}{EI} - \frac{k\Delta l^3}{48EI} = \Delta$$

$$\Rightarrow \quad \frac{5wl^4}{384EI} = \Delta\left[1 + \frac{kl^3}{48EI}\right]$$

$$\Rightarrow \quad \frac{5wl^4}{8} = \Delta\left[48EI + kl^3\right]$$

$$\Rightarrow \quad \Delta = \frac{5wl^4}{8\left[48EI + kl^3\right]}$$

10. **(b)**

In case of hydrostatic loading, equal and alike normal stress acts on two mutually perpendicular planes without any shear, i.e.,

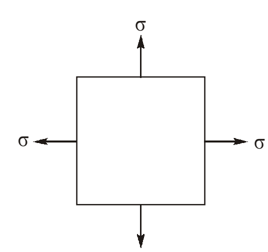
$$\sigma_x = \sigma_y = \sigma$$

and $\quad \tau_{xy} = 0$

For Mohr's circle

$$\text{Centre} = \left(\frac{\sigma_x + \sigma_y}{2}\right)$$

and $\quad \text{Radius} = \tau_{max}$



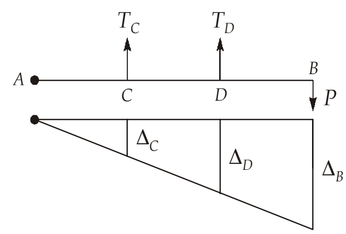
$\therefore$ Centre is at (σ, 0) and radius = 0

This represents a point on σ-axis.

11. (a)

1. If *SF* changes sign, then *BM* at that sections either maximum or minimum
2. If load is symmetrical about centre of beam the *BMD* will be symmetric but *SFD* will be skew symmetric about centre.

12. (c)



Deformation diagram

$$\Rightarrow \quad \Sigma \text{ Moments about } A = 0$$

$$P \times L = T_C \times a + T_D \times b$$

$$\Rightarrow \quad aT_C + bT_D = PL \quad \text{...(i)}$$

Using deformation diagram

$$\frac{\Delta_C}{\Delta_D} = \frac{a}{b}$$

$$\Rightarrow \quad b \cdot \Delta_C = a \cdot \Delta_D \quad \text{...(ii)}$$

$$\Rightarrow \quad b \cdot \frac{T_C L}{AE} = a. \frac{T_D \cdot 2L}{AE}$$

$$\Rightarrow \quad T_C = \frac{2aT_D}{b} \quad \text{...(iii)}$$

From equation (i) and (iii)

$$a \cdot \frac{2aT_D}{b} + b\,T_D = PL$$

$$\Rightarrow \quad T_D\left(\frac{2a^2 + b^2}{b}\right) = PL$$

$$\Rightarrow \quad T_D = \frac{PLb}{2a^2 + b^2}, \qquad T_C = \frac{2aPL}{2a^2 + b^2}$$

$$\therefore \quad T_C - T_D = \frac{(2a - b)PL}{(2a^2 + b^2)}$$

13. (a)

Given: $L = 2$ m, $\Delta_S = 0.25$ mm

Δ = Free expansion of bar + Contraction by stress developed in bar

$$0.25 = L\alpha\Delta T + (-\sigma_c) \times \frac{L}{E}$$

$$\Rightarrow \quad 0.25 = 2 \times 10^3 \times 18 \times 10^{-6} \times 100 - \frac{\sigma_c \times 2 \times 10^3}{10^5}$$

$$\Rightarrow \quad \frac{\sigma_c \times 2}{100} = 3.6 - 0.25$$

$$\Rightarrow \quad \sigma_c = \frac{360 - 25}{2}$$

$$\sigma_c = 167.5 \text{ N/mm}^2$$

14. (c)

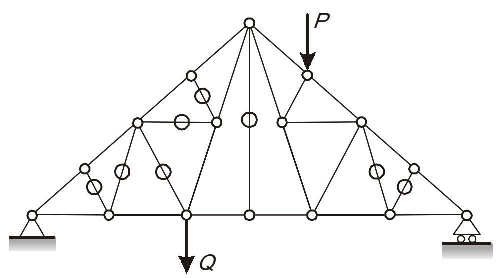
As per IS 210 : 2009 [Grey Iron casting specifications]

Annexure C: Typical properties of Gray Cast Iron, minimum modulus of elasticity in tension and compression (FG 150) is 100 GPa and it goes upto 145 GPA for FG 400.

- Modulus of elasticity of aluminium is one-third of that of the steel.

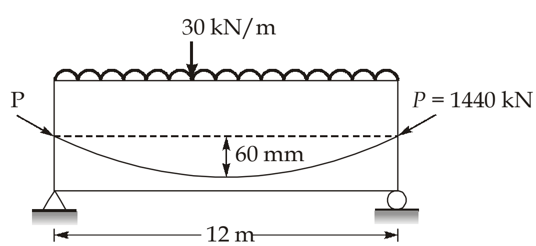
15. (b)

If three members meet at a joint and two of them are collinear, then the third member will carry zero force, provided there is no load on that joint. Thus, using above condition we identify 8 members which carry zero forces.



Hence option (b) is correct.

16. (d)



Intensity of equivalent load due to parabolic cable is,

$$w_p = \frac{8Ph}{l^2}$$

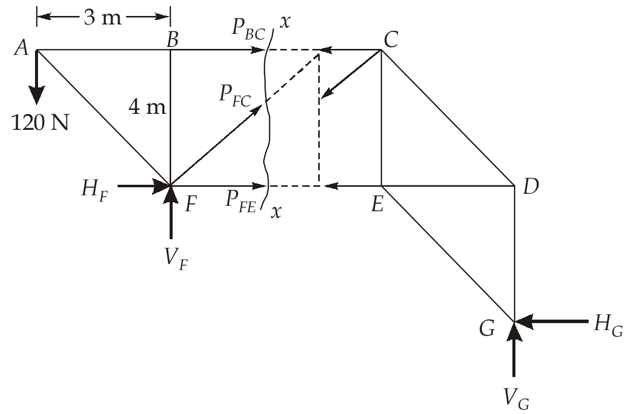
$$\Rightarrow \quad w_p = \frac{8 \times 1440 \times 0.06}{12^2} = 4.8 \text{ kN/m}$$

So, net downward UDL, $w_{net} = 30 - 4.8 = 25.2$ kN/m

Maximum shear force at support $= \dfrac{25.2 \times 12}{2} = 151.2$ kN

17. (b)

Pass a section *x-x* through *BC*, *FC* and *FE*.



Taking moments about *F*,

$\Sigma M_F = 0 \Rightarrow \quad P_{BC} \times 4 - 120 \times 3 = 0$

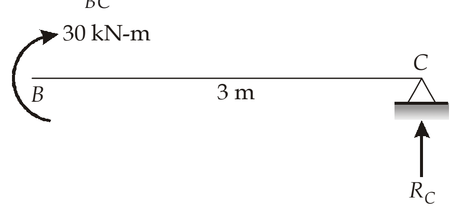
$$\Rightarrow \quad P_{BC} = \frac{120 \times 3}{4}$$

$$\Rightarrow \quad P_{BC} = 90 \text{ N (Tensile)}$$

18. (b)

Joint	Member	k	D.F
B	BC	$\frac{3EI}{3} = EI$	0.5
	BA	$\frac{4EI}{4} = EI$	0.5

So, $M_{BC} = 0.5 \times 60 = 30$ kN-m

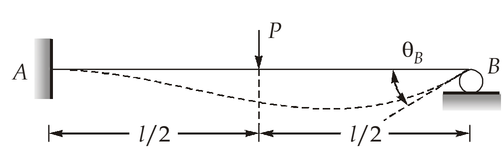


$$\Sigma M_B = 0$$

$$\Rightarrow \quad R_C \times 3 = 30$$

$$\Rightarrow \quad R_C = 10 \text{ kN}$$

19. (c)



From slope deflection equation

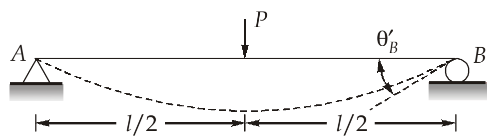
$$M_{BA} = \bar{M}_{BA} + \frac{2EI}{l}(2\theta_B + \theta_A)$$

$$\Rightarrow \quad 0 = \frac{Pl}{8} + \frac{2EI}{l}(2\theta_B + 0)$$

$$\Rightarrow \quad \theta_B = \frac{-Pl^2}{32EI}$$

$$\therefore \quad \theta_B = \frac{Pl^2}{32EI} \text{ (Anticlockwise)}$$

Now fixed support gets converted into hinged support.



$$\theta'_B = \frac{Pl^2}{16EI} \text{ (Anticlockwise)}$$

Now,
$$\frac{\theta'_B}{\theta_B} = \frac{\left(\frac{Pl^2}{16EI}\right)}{\left(\frac{Pl^2}{32EI}\right)} = 2$$

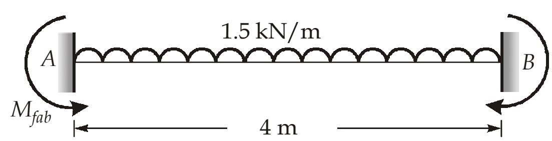
$$\Rightarrow \quad \theta'_B = 2\,\theta_B$$

$\therefore$ θ_B gets increased by 100%

20. **(c)**

- The flexibility matrix will always be a square matrix in which diagonal elements will be non-negative and non zero.
- Order of flexibility matrix will be equal to degree of static indeterminacy.

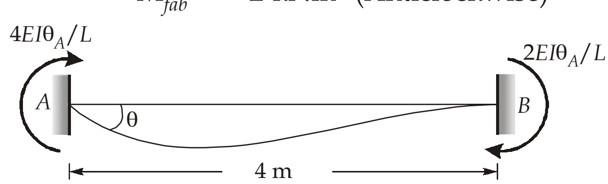
21. **(a)**



Fixed end moment at left support due to loading

$$M_{fab} = \frac{-wl^2}{12} = \frac{-1.5 \times 4^2}{12}$$

$$\Rightarrow \quad M_{fab} = -2 \text{ kNm (Anticlockwise)}$$



Moment due to rotation at A

$$M'_{fab} = \frac{4EI\theta_A}{l}$$

$$= \frac{4 \times 10^6 \times 0.001}{4} \qquad (10^{10} \text{ N-cm}^2 = 10^6 \text{ Nm}^2)$$

$= 1000$ Nm

$= 1$ kNm (Clockwise)

So, fixed end moment developed at A

$= -2 + 1 = -1$ kNm i.e. anticlockwise

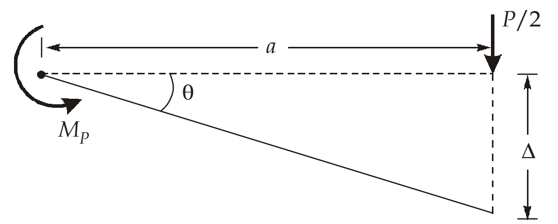
22. (b)

23. (a)

24. (c)

For simultaneous collapse of overhang and span, plastic moment of overhang and span should be the same.

For overhang portion (QR):

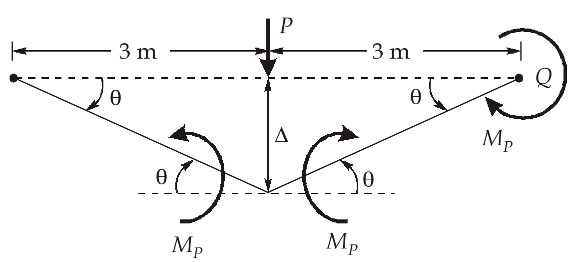


$$\frac{P}{2} \times \Delta = M_p \times \theta$$

$$\Rightarrow \quad \frac{P}{2} \times a\theta = M_p \times \theta$$

$$\Rightarrow \quad M_p = \frac{Pa}{2} \qquad \ldots(i)$$

For span PQ:



$$P \times \Delta = 3M_p\theta$$

$$\Rightarrow \quad P \times 3\theta = 3M_p\theta$$

$$\Rightarrow \quad M_p = P \qquad \ldots(ii)$$

From equation (i) and (ii)

$$P = \frac{Pa}{2}$$

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

25. (c)

26. (a)

As per IS 800 : 2007 (Cl 6.3.3)

The rupture strength of an angle connected through one leg is affected by shear lag. The design strength, T_{dn}, as governed by rupture at net section is given by:

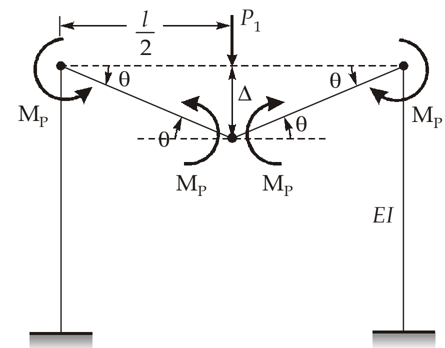
$$T_{dn} = 0.9\, A_{nc} f_u/\gamma_{m1} + \beta A_{go} f_y/\gamma_{m0}$$

where

$$\beta = 1.4 - 0.076\,(w/t)\,(f/f_u)\,(b_s/L_c) \leq (f_u\gamma_{m0}/f_y\gamma_{m1})$$
$$\geq 0.7$$

27. **(c)**

Beam mechanism

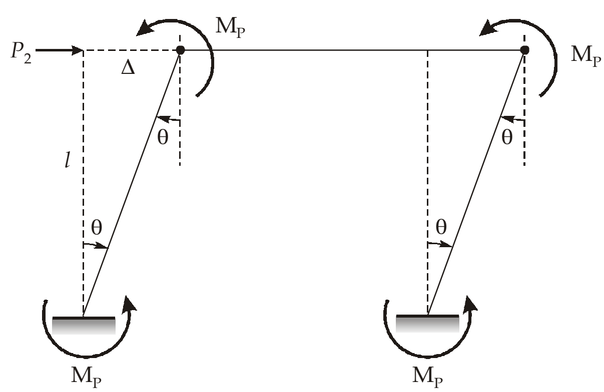


Applying principle of virtual work.

$$M_p\theta + M_p\,(2\theta) + M_p\theta = P_1\Delta = P_1 \times \frac{l}{2}\theta$$

$$\therefore \qquad P_1 = \frac{8M_P}{l}$$

Sway mechanism



Applying principle of virtual work.

$$M_p\theta + M_p\theta + M_p\theta + M_p\theta = P_2 \times \Delta = P_2 \times l\theta$$

$$\Rightarrow \qquad P_2 = \frac{4M_P}{l}$$

$$\therefore \qquad \frac{P_1}{P_2} = \frac{8}{4} = 2.$$

28. (b)

Number of plastic hinges required for collapse = $D_S + 1$

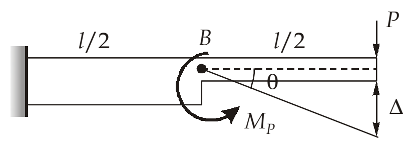
$$D_S = r - 3 = 3 - 3 = 0$$

$\therefore$ Number of plastic hinges = 0 + 1 = 1

Hinge will form at *A* or at *B*.

Case-1

Hinge forms at *B*.



$\therefore$ Using principle of virtual work

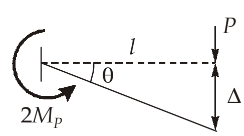
$$M_p\theta = P \times \Delta$$

$$\Rightarrow \quad M_p\theta = P \times \frac{l}{2}\theta$$

$$\Rightarrow \quad P = \frac{2M_P}{l}$$

Case-2

Hinge forms at *A*.

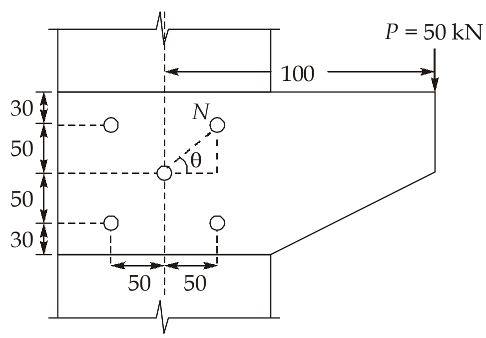


$$\therefore \quad 2\,M_p(\theta) = P \times \Delta = P \times l\,\theta$$

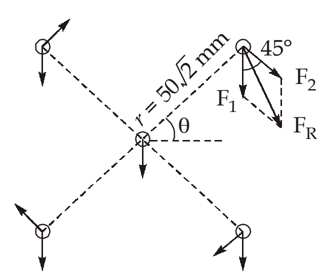
$$\Rightarrow \quad P = \frac{2M_P}{l}$$

$$\text{Collapse load} = \frac{2MP}{l}$$

29. (a)



(All dimensions in mm)



Here, $\theta = 45°,\ r = 50\sqrt{2}$ mm

$$\text{Direct shear force, } F_1 = \frac{50}{5} = 10 \text{ kN}$$

Force in extreme bolt (1) due to moment (P.e) is,

$$F_2 = \frac{(Pe)r}{\Sigma r_i^2} = \frac{(Pe)r}{4r^2} = \frac{Pe}{4r}$$

$$\Rightarrow \quad F_2 = \frac{50 \times 100}{4 \times 50\sqrt{2}} = \frac{25}{\sqrt{2}} \text{ kN}$$

Maximum resultant force,

$$(F_R)_{max} = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$

$$= \sqrt{10^2 + \left(\frac{25}{\sqrt{2}}\right)^2 + 2 \times 10 \times \frac{25}{\sqrt{2}} \times \frac{1}{\sqrt{2}}} = 25.74 \text{ kN}$$

30. (a)

$$k_b = \text{minimum} \begin{cases} \dfrac{e}{3d_o} \\ \dfrac{P}{3d_o} - 0.25 \\ \dfrac{f_{ub}}{f_u} \end{cases}$$

where, e = edge distance

P = pitch

d_o = diameter of bolt hole

$\therefore$ k_b does not directly depend upon bolt diameter.

31. (c)

Given: $l_j = 750$ mm

$t_t = k \times s$,

For $\theta = 116°$

$\Rightarrow$ $k = 0.5$

$\therefore$ $t_t = 0.5 \times 6 = 3$ mm

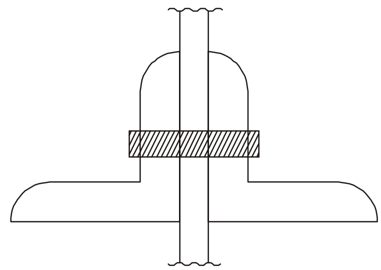
$$\beta_{lj} \text{ (Reduction factor)} = 1.2 - \frac{0.2\, l_j}{150\, t_t} \le 1.0$$

$$\Rightarrow \quad \beta_{lj} = 1.2 - \frac{0.2 \times 750}{150 \times 3} = 1.2 - 0.333$$

$$= 0.867$$

32. (c)

33. (a)



$$A_{net} = A_1 + k_{A2}$$

where $k = 1$ (if tack rivet))

$$k = \frac{3A_1}{3A_1 + A_2}$$ if not tack riveted then both will be considered separately.

34. (b)

Maximum strain for steel, $\in_s = \frac{f_y}{(FOS)E_s} + 0.002$

$$= \frac{f_x}{1.5E_s} + 0.002$$

$$= \frac{0.67 f_y}{E_s} + 0.002$$

35. (b)

$T_{a_{RC}} = 0.075\ h^{0.75}$ for RC frame building

$T_{a_{st}} = 0.085\ h^{0.75}$ for steel frame building

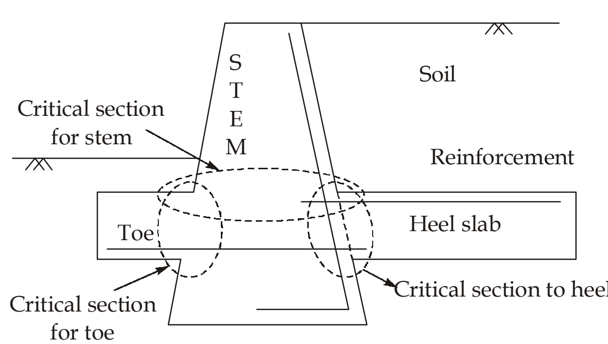
$\therefore$ $T_a = T_{a_{st}} - T_{a_{RC}} = (0.085 - 0.075) \times (16)^{3/4}$

$\Rightarrow$ $T_a = 0.01 \times (2)^3$

$\Rightarrow$ $T_a = 0.08$ sec

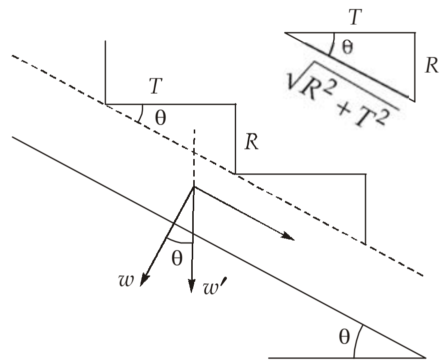
36. (c)

Cantilever retaining wall



37. **(b)**

Given:



w = Weight of slab per m^2 at right angle to the direction of flight

Corresponding load per unit horizontal area is obtained by increasing w by the ratio of $\left(\dfrac{\sqrt{R^2+T^2}}{T}\right)$

Hence dead weight w' per unit horizontal area is given by

$$w = w' \cos\theta$$

$$\Rightarrow \quad w' = \frac{w}{\cos\theta} = \frac{w\sqrt{R^2+T^2}}{T}$$

$$\Rightarrow \quad w' = w\sqrt{1+\left(\frac{R}{T}\right)^2}$$

38. **(c)**

Spacing in case of *PSC* member for side face reinforcement should not be more than 200 mm.

39. **(c)**

Given: $L = 6$ m, $B = 3$ m

$\eta_c = 12, \eta_T = ?$

For shorter side reinforcement detailing.

$$\eta_c = \eta_T \times \left(\frac{2}{1+\frac{L}{B}}\right)$$

$$\Rightarrow \quad \eta_T = \frac{\eta_c}{2}\times\left(1+\frac{L}{B}\right) = \frac{12}{2}\times\left(1+\frac{6}{3}\right)$$

$$\Rightarrow \quad \eta_T = 18$$

40. **(a)**

41. **(b)**

If $\lambda \le 3$ = Pedestal

$3 \le L \le 12$ = Short column

$\lambda > 12$ = Long column

$\therefore \quad \lambda = \dfrac{l_{\text{eff}}}{\text{least lateral dimension}} = \dfrac{0.65 \times 3000}{650}$

$\Rightarrow \quad \lambda = 3$

42. (b)

As per Clause 26.2.3.2 (pg.44) IS 456: 2000 condition for flexure reinforcement curtailment in tension zone.

If shear force in a beam is more than 2/3rd of shear capacity at actual cutoff point. Stirrup area in excess of that required for shear and torsion is provided along each terminated bar over a distance from the cut-off point equal to ¾th of the effective depth of member.

43. (d)

Refer **Clause D-1.4 to D-1.6** of **IS 456:2000**.

44. (b)

C*l*.40.4 1S456 : 2000

(a) For vertical stirrup

$$V_{ur} = \frac{0.87\, f_y A_{sv} d}{S_v}$$

(b) For inclined stirrup are a series of bars

$$V_{ur} = \frac{0.87\, f_y A_{sv} d}{S_v}(\sin\alpha + \cos\alpha)$$

(c) For single bar or single group of parallel bars, all bent up at the same cross-section:

$$V_{ur} = 0.87\, f_y\, A_{sv}\, \sin\alpha.$$

45. (b)

Advantages of ADT over RDT are:

(i) Higher maneuverability

(ii) Lower turning radius

(iii) Higher tractive effort

(iv) Better operator comfort

(v) Faster cycle times and therefore lower fleet costs.

46. (a)

47. (d)

48. (d)

49. (c)

Given: C_i = 50 lakh, C_s = 5 lakh, n = 9 year

Component of depreciation at the end of each year = D

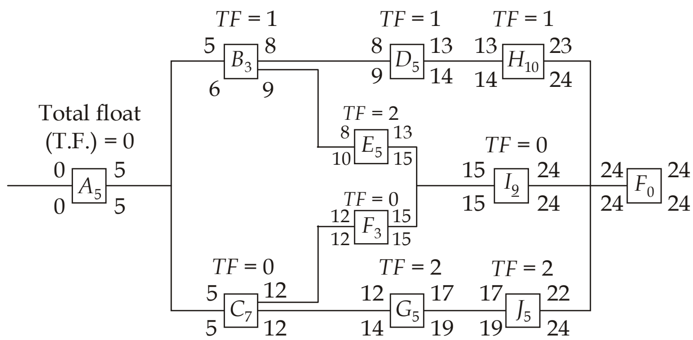
Depreciation for month year = $D_m = D(1+i)^{m-1}$

$$\therefore \quad D_3 = (C_i - C_s)\left[\frac{i}{(1+i)^n - 1}\right] \times (1+i)^{3-1}$$

$$\Rightarrow \quad D_3 = (50-5) \times \left[\frac{0.08}{(1.08)^9 - 1}\right] \times (1.08)^2 = 45 \times \frac{0.08}{1} \times 1.2$$

$$\Rightarrow \quad D_3 = 4.32 \text{ lakh}$$

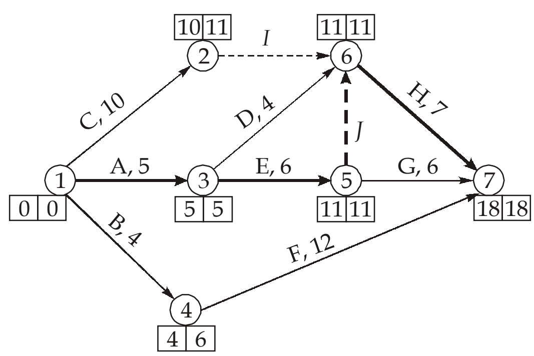
50. (b)



T.F is equal to zero for activities on critical path.

$$\text{T.F.} = LFT - EFT = LST - EST$$

51. (d)



$$\text{Critical path} = A - E - J - H \text{ or } 1-3-5-6-7$$

$$\text{Critical Time} = 18 \text{ days}$$

52. (b)

Given:

$$\text{Average speed } (v) = 1.5 \text{ kmph} = 1500 \text{ m/hr}$$

$$b_{eff} = 1.5 \text{ m}$$

$$\therefore \quad \text{Output} = \frac{v \times b_{eff}}{\text{No.of passes}} = \frac{1500 \times 1.5}{6}$$

$$= 375 \text{ m}^2/\text{hr} = \frac{375}{60} \text{ m}^2/\text{min}$$

$$= 6.25 \text{ m}^2/\text{min}$$

53. (c)

White cement has < 1% of Fe_2O_3 therefore it does not have greyish colour like *OPC*.

54. (b)

Statement 1 - TRUE: Lime improves plasticity and workability.
Statement 2 - FALSE: Lime does not increase strength; it slightly reduces it.
Statement 3 - TRUE : Lime provides smooth finish and ease of application in top coat.

55. (d)

According to IS 1200 minimum height of stacks for sand is 61 cm and allowance to be deducted for sinkage and for shrinkage is 1/8th of the height of stack or 12.5%.

56. (a)

Calcium chloride addition in slow hardening cement is more effective than in rapid hardening cement as calcium chloride acts as an accelerator and increases the rate of hydration in slow hardening cement whereas the rate of hydration is already high in rapid hardening cement.

57. (b)

$$\text{Tensile strength} = \frac{2P}{\pi dL}$$

Given: $P = 200$ kN, d = diameter = 300 mm, L = 300 mm

$$\therefore \quad F_t = \frac{2\times 200\times 10^3}{3.14\times 300\times 300} = 1.42 \text{ MPa}$$

58. (b)

Maturity of concrete at the age of 7 days.

$$= \Sigma(\text{Time} \times \text{Temperature})$$
$$= 7 \times 12\,[20 - (-11)] + 7 \times 12\,[10 - (-11)]$$
$$= 7 \times 12 \times 31 + 7 \times 12 \times 21$$
$$= 4368\text{°C-hr}$$

Percentage strength of concrete at maturity of 4368°C-hr

$$= A + B \times \log_{10}(4368/1000)$$
$$= 32 + 54 \times (3.65 - 3)$$
$$= 32 + 54 \times 0.65$$
$$= 67.1\%$$

$$\text{Strength at 7 days} = 40 \times 67.1/100 = 26.84 \simeq 26.8 \text{ MPa}$$

59. (a)

1. Bituminous paint: Underwater structures
   It is highly water-resistant, therefore used for surfaces exposed to water.
2. Cement paint: Masonry surfaces
   It gives good adhesion on brickwork, concrete, and plastered surfaces.
3. Distemper: Decorative interior finish
   It provides a smooth and economical finish for interior walls.
4. Aluminium paint: Roofing sheets
   It reflects heat and protects metal surfaces from corrosion.

60. (d)

The fibre saturation point (FSP) of wood is the condition, when all free water has been removed from the cell cavities, but the cell walls are still completely saturated with bound water. Below this point, further loss of moisture causes shrinkage and change in strength of wood.

61. (d)

Statement 1: Kiln seasoning reduces moisture content rapidly and uniformly, thereby increasing the strength of timber.
Statement 2: Timber is cut to required size before treatment so that preservatives can penetrate properly.
Statement 3: Water seasoning removes sap gradually, which helps in reducing internal stresses and prevents warping.
Statement 4: *AsCu* treatment provides resistance against insect attack, especially white ants (termites).

62. (d)

63. (d)

Statement 1: English bond provides better load distribution through alternate header courses, making it stronger for thick walls.
Statement 2: Flemish bond has alternate headers and stretchers in the same course, giving a more decorative appearance.
Statement 3: Flemish bond allows use of bats, but it increases mortar consumption.
Statement 4: English bond has a simpler pattern and therefore requires less workmanship skill.

64. (c)

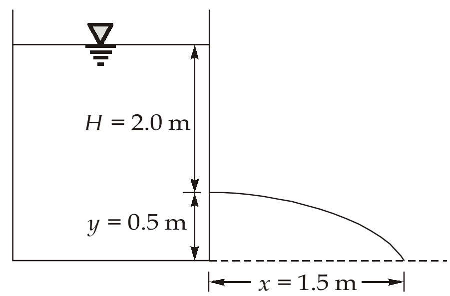
65. (c)

66. (c)

$$\text{Hydraulic mean diameter } (D_h) = \frac{4 \times \text{Area}}{\text{Wetted perimeter}}$$

$$\Rightarrow \quad D_h = \frac{4 \times 0.5 \times 0.2}{2(0.5 + 0.2)} = 0.2857 \text{ m} \simeq 0.29 \text{ m}$$

67. (b)



Coefficient of velocity, $C_v = \frac{x}{2\sqrt{yH}} = \frac{1.5}{2\sqrt{0.5\times 2.0}} = 0.75$

68. (b)

Turbulent boundary layers have higher momentum near the wall, hence separation is delayed, not earlier

69. (b)

$$\text{Shear velocity } (V^*) = \bar{U}\sqrt{\frac{f}{8}}$$

$$f = \frac{64}{R_e} \text{ (for smooth circular pipe)}$$

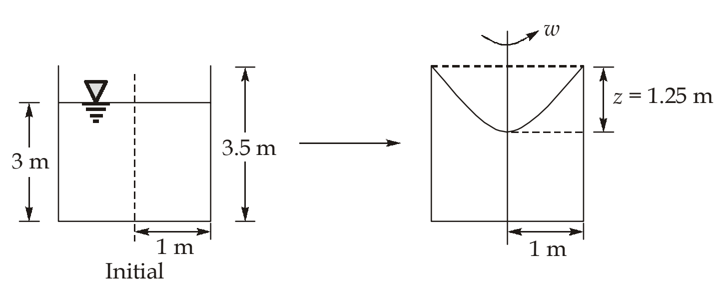
$$f = \frac{64}{10^4}$$

$$V^* = 4\times\sqrt{\frac{64}{10^4\times 8}} = \frac{4}{100}\times\sqrt{8}$$

$$\Rightarrow \quad V^* = \frac{8\sqrt{2}}{100} = 0.11314 \text{ m/s}$$

$$\Rightarrow \quad V^* = 11.31 \text{ cm/s}$$

70. (d)



$$z = \frac{w^2r^2}{2g} = \frac{5^2\times 1^2}{2\times 10} = 1.25 \text{ m}$$

Initial volume of water $= \pi r^2 h = \pi \times 1^2 \times 3 = 3\pi \text{ m}^3$

$$\text{Final volume of water} = \pi \times 1^2 \times 3.5 - \frac{\pi \times 1^2 \times 1.25}{2}$$

$$= 2.875\pi$$

$$\text{Volume of water spilled} = 3\pi - 2.875\,\pi = 0.125\,\pi$$

71. **(a)**

Velocity potential exists only when vorticity is zero i.e. irrotational flow.

72. **(b)**

In a horizontal pipe of uniform diameter, HGL cannot rise unless energy is added or diameter changes.

Even if pressure is atmospheric, velocity head exists, so TEL does not coincide with the pipe centreline.

73. **(d)**

For gases, dynamic viscosity is almost independent of pressure, and since density increases with increase in pressure and thus kinematic viscosity decreases.

74. **(c)**

$$SO_2 \text{ in } \mu g/m^3 = \frac{SO_2 \text{ in ppm} \times \text{Molecular weight} \times 10^3}{\text{Volume } (l/\text{mole})}$$

$$= \frac{0.5 \times 64 \times 10^3}{22.4} = 1428.57 \text{ mg/m}^3$$

75. **(b)**

Chemical reaction which is involved in treating water with alum is given by:

$$Al_2(SO_4)_3 \cdot 18\,H_2O + 3\,Ca(HCO_3)_2 \longrightarrow 2\,Al\,(OH)_3\downarrow + 3\,CaSO_4 + 6\,CO_2 + 18\,H_2O$$

666 g $\qquad$ 6 × 44 g

$$\text{Amount of alum required daily} = \frac{10\,mg}{l} \times 10 \times 10^6\,\frac{l}{d} \times 10^{-6}\,\frac{kg}{mg}$$

$$= 100 \text{ kg/day}$$

$\because$ 666 g Alum produces 6 × 44 g CO_2

$$\text{100 kg Alum will produce } CO_2 = \frac{6 \times 44 \times 100}{666}$$

$$= 39.64 \text{ kg}$$

76. **(c)**

Discharge $\quad Q = \dfrac{KL[H^2 - h^2]}{2R}$

where $\quad K$ = Permeability coefficient of aquifer = 150 m/day

L = Length of gallery

H = Static water level above the bottom of the gallery = 9 m

H' = Depth of water in gallery on pumping at equilibrium = 5 m

$\therefore \quad h = 9 - 5 = 4$ m

$$\therefore \quad 750 \text{ m}^3/\text{day} = 150 \times L\left(\frac{9^2 - 4^2}{2 \times 150}\right)$$

$\Rightarrow \quad L = 23.08$ m

73. (b)

As per Lea's formula, economical diameter is given by,

$$D = 0.97 \text{ to } 1.22\sqrt{Q}$$

where Q = Discharge (in m^3/s)

$$Q = 10^5 \cdot l/\text{hr} = \frac{10^2 \text{ m}^3}{3600\, s} = \frac{1}{36}\frac{\text{m}^3}{s}$$

$$\therefore \quad D = 1.22\sqrt{\frac{1}{36}} = \frac{1.22}{6}$$

$\Rightarrow \quad D = 0.203$ m

78. (b)

Discharge, $Q = \left(\frac{C'}{A}\right) A.S$

$$= \left(\frac{2.30}{T}\log\frac{S_1}{S_2}\right) AS$$

where, S_1 = Initial drawdown = 4.0 m

S_2 = Final drawdown = 2.0 m

T = Time = 60 min = 3600 second = 1 hr

S = Depression head = 3.0 m

$$A = \text{Area of well} = \frac{\pi \times 4^2}{4} = 4\,\pi \text{ m}^2$$

$$\therefore \quad Q = \left(\frac{2.3}{1}\log\frac{4}{2}\right) \times 4\pi \times 3$$

$\Rightarrow \quad Q = 26.10 \text{ m}^3/\text{hr}$

79. (d)

Capacity of tank = Supply of water to be treated during the detention period of 4 hr.

$$= \frac{1.8 \times 10^6 \times 10^{-3} \times 4}{24} = 300 \text{ m}^3$$

Length of tank, L = Flow velocity × Detention period

$$= \frac{0.09}{60} \times 4 \times 60 \times 60$$

$= 21.6$ m

Water depth in tank, H = Total depth of tank – Sedimentation zone depth

$$= 4.2 - 1.2 = 3 \text{ m}$$

$$\text{Width of tank} = \frac{\text{Capacity}}{L \times H} = \frac{300}{21.6 \times 3}$$

$$\Rightarrow \quad B = 4.63 \text{ m}$$

80. **(c)**

81. **(a)**

Acid fermentation stage produces of volatile acids and gases which leads to decrease in *pH*. Acid regression stage is still acidic; *pH* is low due to volatile acids and gases like H_2S and CO_2. In alkaline fermentation stage *pH* rises above 7, odour reduces, granular and stable sludge forms. In acid regression stage, BOD decreases, not increases.

82. **(c)**

Drop manholes are required when branch sewer invert level is 0.5-0.6 m higher than main sewer. For small drop heights, a sloping/inclined ramp can be used instead of a vertical pipe. Vertical drop pipe takes flow directly to the bottom to prevent disturbance. The purpose is to avoid noise, splashing, turbulence, and structural damage.

83. **(d)**

Silence zone limits:
Day: 55 dB, Night: 45 dB as per Environment (Protection) Act, 1986.

84. **(a)**

Venturi scrubbers are the most efficient for fine particles

85. **(a)**

86. **(c)**

Electrostatic precipitator features:
- High efficiency (95-99% or more).
- Particles may be collected wet or dry.
- Effective mainly for particles of size greater than 1 μm.
- ESPs are sensitive to dust loading and flow variations.
- High initial cost and high-voltage operation.

87. **(b)**

A circular tunnel section is the most efficient shape under high ground pressure because:
- Ground pressure acts radially and uniformly around the tunnel.
- A circular shape develops pure compressive stresses in the lining.
- No stress concentration occurs at corners (unlike rectangular sections).
- Bending moments in the lining are minimum.
- Structural efficiency is highest, requiring less lining thickness.

88. (a)

Jayakar Committee = 1927
Central Road Fund = 1929
CRRI = 1950
National Highways Act = 1956

89. (c)

The Earth rotates once in about 24 hours, but since the Moon also moves in its orbit, the Earth must rotate an additional 50 minutes to realign with the Moon, causing the tidal cycle to repeat after 24 h 50 min.

90. (d)

Shoulders are not meant for regular traffic and their surface is usually rougher/distinct from the carriageway.

91. (c)

The New Austrian Tunnelling Method (NATM) is based on the fact that:

- The surrounding ground itself acts as the main load-bearing structure.
- Controlled deformation is allowed and monitored to mobilize the inherent strength of rock/soil.
- Immediate but flexible supports (shotcrete, rock bolts, wire mesh) are provided.
- Instrumentation and observational method guide the support design.
- Final lining is placed after ground stabilization, not immediately

92. (c)

Origin and Destination (O and D) Study Methods:

- Road-side interview method
- Home interview method
- License plate method
- Return post-card method
- Tag-on-car method

Purpose: To find trip origin, destination, purpose, route, and time.

93. (b)

Spacing between successive lamp is,

$$S = \frac{\text{Lamp lumen} \times \text{Coefficient of utilization} \times \text{Maintenance factor}}{\text{Average lux} \times \text{Width of road}}$$

$$= \frac{5000 \times 0.4 \times 0.8}{5 \times 15} = 21.33 \text{ m}$$

94. (c)

$$\frac{\alpha}{2} = \frac{180\, L_c}{2\pi(R-d)} = \frac{180 \times 250}{2 \times 3.14(450 - 1.9)}$$

$$\frac{\alpha}{2} = 15.97°$$

$\Rightarrow$ Set back distance, $m = R - (R - d)\cos\frac{\alpha}{2} + \left(\frac{S - L_c}{2}\right)\sin\frac{\alpha}{2}$

$$= 450 - (450 - 1.9) \times 0.96 + \left(\frac{350 - 250}{2}\right) \times 0.27$$

$$= 33.324 \simeq 33.32 \text{ m}$$

95. (d)

As per Green Shields model $\frac{u}{V_f} + \frac{K}{K_J} = 1$ ...(i)

$$u = 55 - 0.44\,K$$

$$\frac{u}{55} + \frac{0.44K}{55} = 1$$

$\Rightarrow$ $\frac{u}{55} + \frac{K}{125} = 1$ ...(ii)

Comparing (i) and (ii)

$$V_f = 55 \text{ kmph}$$

$$K_J = 125 \text{ vehicle/km}$$

Maximum flow, $q = \frac{V_f}{2} \times \frac{K_J}{2} = \frac{55 \times 125}{4} = 1718.75$ veh/hr

$$\simeq 1719 \text{ veh/hr}$$

96. (b)

Extra widening of pavement at curve is,

$$W_e = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}} = \frac{2 \times 6^2}{2 \times 400} + \frac{80}{9.5\sqrt{400}} = 0.511 \text{ m} \simeq 0.51 \text{ m}$$

97. (b)

Time to stop vehicle = 2 sec.

Length of skid marks = 10 m

As per Newton's equation

$V = u + at$ ...(i)

$V^2 = u^2 - 2as$ (due to declaration) ...(ii)

where V = Final velocity = 0

$\therefore$ $u = -at$

and $S = \frac{u^2}{2a} = \frac{a^2t^2}{2a}$

$\Rightarrow$ $10 = \frac{a \times 2^2}{2}$

$\Rightarrow$ $a = 5$

and $\mu g = a$

$\Rightarrow$ $\mu = \frac{a}{g} = \frac{5}{10} = 0.5$

98. (d)

- Pulling back of rails directly corrects accumulated creep.
- Creep anchors restrain longitudinal rail movement.
- Steel sleepers provide higher resistance to creep than wooden sleepers.
- Increased sleeper density improves rail-sleeper grip thereby reducing creep.

99. (d)

$$\text{Minimum space headway, } S = \text{Minimum gap + Length of vehicle}$$
$$= 0.278\, Vt + l$$
$$= 0.278 \times 60 \times 0.7 + 6 = 16.676$$
$$\simeq 17.68 \text{ m}$$

$$\text{Theoretical capacity, } C = 1000\frac{V}{S} = 1000 \times \frac{60}{17.68}$$
$$= 3393.67\frac{\text{veh}}{\text{hr}} \simeq 3394\frac{\text{veh}}{\text{hr}}$$

100. (b)

1. Marking
   White → Runway
   Yellow → Taxiway and Apron
2. Lighting
   Blue → Taxiway lights
   Green → Threshold lights

101. (d)

$$R_{LA} - R_{LB} = \frac{(h_b - h_a) + (h'_b - h'_a)}{2}$$
$$= \frac{(2.860 - 1.285) + (2.220 - 0.860)}{2}$$
$$= 1.4675 \text{ m} \simeq 1.468 \text{ m}$$

102. (b)

$$\text{Angular value, } \alpha = \frac{S}{nD} \times 206265 \text{ seconds}$$

n = Number of division throughs which bubble is out = 1.5

D = Distance of the staff = 100 m

S = Error in staff reading due to deviation of the bubble

$\therefore$ $35 = \frac{S \times 206265}{1.5 \times 100}$

$\Rightarrow$ $S = 0.025$ m

103. (c)

Given the constant S are K and C

$$\text{Distance} = KS + C$$

From the 1st observation

$$20 = KS_1 + C = 0.196K + C \quad ...(i)$$

From the 2nd observation

$$100 = KS_2 + C \quad ...(ii)$$

Solving equation (i) and (ii)

$$(S_1 - S_2)K = -80$$

$$\Rightarrow \quad (0.196 - 0.996)K = -80$$

$$\Rightarrow \quad K = 100$$

Put $K = 100$ in equation (i) or (ii)

$$20 = 100 \times 0.196 + C$$

$$\Rightarrow \quad C = 0.4$$

104. (b)

$$\text{Most probable value} = \frac{\Sigma w \times s}{\Sigma w}$$

$$= \frac{30°28'40'' \times 2 + 30°29'30'' \times 3}{2+3} = 30°29'10''$$

105. (d)

A magnetic compass consists of a magnetic needle, line of sight, graduated circle and compass box. The compass is supported on a tripod or suitable stand, not by a theodolite or sextant.

106. (c)

Sensitivity increases by:

(i) Larger radius of curvature

(ii) Larger tube diameter

(iii)Longer bubble

(iv) Lower viscosity of liquid

Increasing roughness of the tube walls causes resistance to bubble movement, which reduces sensitivity.

107. (b)

Lines of magnetic force of the earth generally run from the north magnetic pole to the south magnetic pole inside the earth.

108. (a)

Given:

$$A_1 = 15 \text{ m}^2$$

$$A_2 = 18 \text{ m}^2$$

$$A_3 = 24 \text{ m}^2$$

$$A_4 = 30 \text{ m}^2$$

and $$A_5 = 12 \text{ m}^2$$

Using prismoidal formula, volume of embankment is given by

$$V = \frac{d}{3}\left[(A_1 + A_5) + 4(A_2 + A_4) + 2(A_3)\right]$$

$$\Rightarrow \quad V = \frac{15}{3}\left[(15+12) + 4(18+30) + 2(24)\right]$$

$$\Rightarrow \quad V = 1335 \text{ m}^3$$

109. (c)

Given: $e_1 = 2 \quad \Delta V = 0.5V$

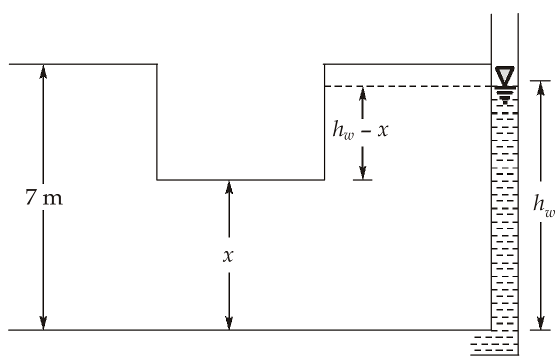
$e_2 = ? \quad V_1 = V$

$$\therefore \quad \frac{\Delta V}{V} = \frac{\Delta e}{1+e}$$

$$\Rightarrow \quad 0.5 = \frac{e_1 - e_2}{1+e_1} = \frac{2 - e_2}{1+2}$$

$$\Rightarrow \quad e_2 = 0.5$$

110. (b)



$$\gamma_{sub} = 12 \text{ kN/m}^3$$

At $x_1 = 3$ m, quick sand condition, $h_{w1} = ?$

Submerged weight = (Seepage head) γ_w.

$$\Rightarrow \quad \gamma_{sub} \times x = (h_{w1} - x)\gamma_w$$

$$\Rightarrow \quad 12 \times 3 = (h_{w1} - 3) \times 10$$

$$\Rightarrow \quad h_{w1} = 6.6 \text{ m}$$

At $x_2 = 4$ m, $h_{w2} = ?$

$$\therefore \quad 12 \times 4 = (h_{w2} - 4) \times 10$$

$$\Rightarrow \quad h_{w2} = 8.8 \text{ m}$$

$$\therefore \quad \text{Difference} = h_{w2} - h_{w1} = 8.8 - 6.6 = 2.2 \text{ m}$$

111. (c)

Given: Fineness = 50%, $w_L = 50\%$, $w_p = 30\%$

a = (75 μ passing – 35) $(0 \le a < 40)$

$$\Rightarrow \quad a = 50 - 35 = 15$$

$$b = (75\ \mu \text{ passing} - 15)\ (0 \le b \le 40)$$
$$\Rightarrow \quad b = 50 - 15 = 35$$
$$c = w_L - 40\ (0 \le c \le 20)$$
$$\Rightarrow \quad c = 50 - 40 = 10$$
$$d = I_P - 10\ (0 \le b \le 40)$$
$$\Rightarrow \quad d = 20 - 10 = 10$$
So,
$$G.I. = 0.2\,a + 0.01\,bd + 0.005\,ca$$
$$= 0.2(15) + 0.01\,(35)(10) + 0.005(10)(15) = 7.25$$

112. (c)

Graphical properties of flow net can be used for many seepage problems such as seepage losses from reservoirs, determination of seepage pressure, uplift pressure below dam to check against the possibility of piping and many others.

To obtain coefficient of permeability, constant head and falling head laboratory test are done.

113. (a)

Given,
$$w = 15\%,\ \gamma_d = 1.6\ \text{gm/cm}^3,\ G = 2.65$$
$$\gamma_d = \frac{G\gamma_w}{1+e}$$
$$\Rightarrow \quad 1.6 = \frac{2.65 \times 1}{1+e}$$
$$\Rightarrow \quad e = \frac{2.65}{1.6} - 1 \quad \Rightarrow \quad e = 0.65$$
$$\therefore \quad n = \frac{e}{1+e} = \frac{0.65}{1.65} = 0.39 \simeq 0.4$$

114. (a)

Given:
$$\bar{\sigma}_o = 200\ \text{kPa}, \qquad \bar{\sigma}_1 = 400\ \text{kPa}$$
$$\Delta H_1 = 4\ \text{cm}, \quad \Delta\bar{\sigma} = \Delta\bar{\sigma}_1 - \bar{\sigma}_o = 200\ \text{kPa}$$
As,
$$\Delta H_1 = \frac{H_o C_c}{1+e_o} \log\left(\frac{\Delta\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}\right)$$
$$\Rightarrow \quad 4 = \frac{H_o C_c}{1+e_o} \log\left(\frac{200+200}{200}\right) = \frac{H_o C_c}{1+e_o} \log(2) \quad \text{...(i)}$$
Similarly
$$\Delta H = \frac{H_o C_c}{1+e_o} \log\left(\frac{200+1400}{200}\right) = \frac{H_o C_c}{1+e_o} \log(8) \quad \text{...(ii)}$$
From (i) and (ii)
$$\frac{4}{\Delta H} = \frac{\log(2)}{\log(8)}$$
$$\Rightarrow \quad \Delta H = 12\ \text{cm}$$
$$\therefore \quad \text{Additional settlement} = 12 - 4 = 8\ \text{cm}$$

115. (d)

Rupture plane passes through heel of wall.

116. (a)

Given: $B = 2S + d = 2 \times 1 + 0.4 = 2.4$ m

∴ Group settlement ratio for sand (G.S.R) is,

$$\text{G.S.R} = \frac{S_g}{S_i} = \left[\frac{4B+2.7}{B+3.6}\right]^2$$

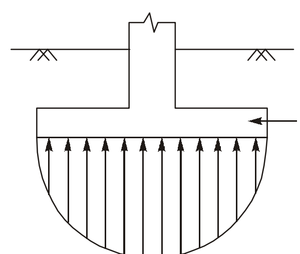
∴ S_i = Settlement of individual pile = 5 mm

S_g = Group settlement

$$\therefore \quad S_g = 5 \times \left[\frac{4 \times 2.4 + 2.7}{2.4 + 3.6}\right]^2$$

$$S_g = 5 \times \left[\frac{12.3}{6}\right]^2 = 5 \times (2.05)^2 = 21 \text{ mm}$$

117. (b)



118. (b)

Given: $UCS = 100 \text{ kN/m}^2$

$$\therefore \quad USC = \frac{UCS}{2} = 50 \text{ kN/m}^2 = C$$

$Q_S = 400$ kN

∴ $Q_u = Q_s \times \text{FOS}$

⇒ $Q_u = 400 \times 2.5 = 1000$ kN

⇒ $\alpha = 0.8$, $B = 0.3$ m

∴ $Q_u = \alpha \bar{c} A_b + \alpha \bar{c} A_s$

⇒ $1000 = 0.8 \times 50 \times 4 \times 0.3 \times L$

(Neglecting $\alpha \bar{c} A_b$ as given in question)

$$L = \frac{1000}{50 \times 4 \times 0.8 \times 0.3} = \frac{500}{24} = 20.83 \text{ m}$$

∴ $L \approx 21$ m

119. (b)

Hand operated augers may be used for boring holes to a depth of 6 m is soft soil which can withstand unsupported.

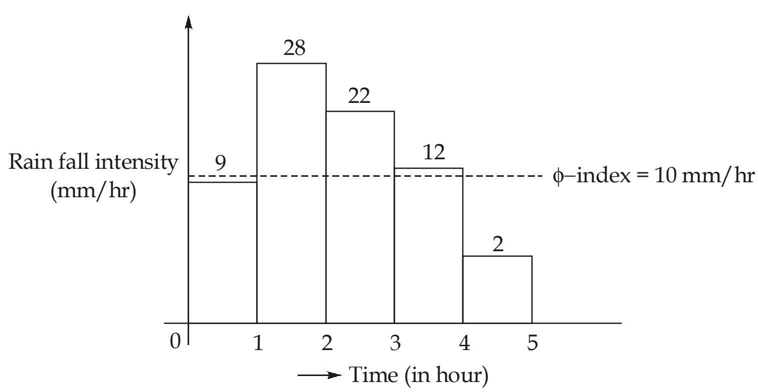
By auger boring, we get severely disturbed samples

120. (a)

The geotextile serve both as reinforcement and also as facing unit. The procedure is described below:

1. Start with adequate working surface and staging area.
2. Lay a geotextile sheet of proper width on the ground surface with 4 to 7 feet at the wall face draped over temporary wooden form.
3. Backfill over the sheet with soil, granular soil or soils containing maximum 30 percentage silt and for 5% clay are customary.
4. Construction equipment must work from the soil backfill and be kept of the unprotected geotextile. The spreading equipment should be a wide-tracked bulldozer that exerts little pressure on the ground on which it rests. Rolling equipment likewise should be of relatively light weight.

121. (c)



$$\text{Runoff depth} = (28 - 10) \times 1 + (22 - 10) \times 1 + (12 - 10) \times 1$$
$$= 18 + 12 + 2$$
$$= 32 \text{ mm}$$

122. (b)

As per Penman's, $$\text{PET} = \frac{AH_n + E_a\gamma}{A + \gamma}$$

A = Slope of saturation vapour pressure curve = 0.20

H_n = Net radiation in mm of evaporable water per day = 6 mm/d

E_a = Parameter include wind velocity and saturation deficit (aerodynamic term) mm/day = 4 mm /d.

γ = Psychrometric constant = 0.10

PET = Potential evapotranspiration in mm/day

$\therefore$ $\text{PET} = \dfrac{0.20 \times 6 + 0.10 \times 4}{0.20 + 0.10}$

$\Rightarrow$ $\text{PET} = 5.33 \text{ mm/d}$

123. (c)

As per Horton's equation, $f_t = f_c + (f_o - f_c)e^{-Kht}$

Total infiltration, $F_p = \int_0^t f_t dt = f_c t + (f_o - f_c)\int_0^t e^{-k_h t} dt$

As time $t \to \infty$, $\int_0^\infty e^{-k_h t} dt \longrightarrow \dfrac{1}{k_h}$

$$F_p = f_c t + \frac{(f_o - f_c)}{K_h}$$

$\Rightarrow$ $16 = 2 \times 6 + \dfrac{8-2}{K_h}$

$\Rightarrow$ $K_h = 1.5\ h^{-1}$

124. (b)

$$C_o = \frac{-Kx + 0.5\,\Delta t}{K - Kx + 0.5\,\Delta t}$$

$$= \frac{-12 \times 0.2 + 0.5 \times 6}{12 - 12 \times 0.2 + 0.5 \times 6} = 0.0476 \simeq 0.048$$

125. (d)

The base period of direct runoff hydrograph corresponding to effective rainfall of different intensities is constant, provided rainfall duration is same.

126. (c)

Factors that decrease infiltration capacity of soil are as follows:

- Vegetative cover improves soil structure and so less infiltration.
- Wet soil leads to lower infiltration.
- Pore sealing reduces infiltration.
- Lower temperature of soil makes it impermeable and so lower infiltration

127. (d)

IDF analysis requires time distribution so recording type rain gauge is required.

128. (d)

Storativity, $S = \gamma_w H(\alpha + n\beta)$

$\Rightarrow$ $S = 10 \times 30\,(1.5 \times 10^{-6} + 0.4 \times 4.5 \times 10^{-7})$

$\Rightarrow$ $S = 5.04 \times 10^{-4}$

129. (c)

For wide rectangular channel, scour depth, $R' = 0.473\left(\frac{Q}{f}\right)^{1/3}$

$$R' = 0.473\left(\frac{125}{1}\right)^{1/3}$$

$$\Rightarrow \quad R' = 2.365 \text{ m} \simeq 2.37 \text{ m}$$

130. (c)

Water distribution efficiency, $\eta_d = \left(1 - \frac{d}{D}\right)$

$$\text{Mean depth, } D = \frac{2.0 + 1.8 + 1.6 + 1.4 + 1.2}{5} = 1.6 \text{ m}$$

Deviations from the mean are, (2 – 1.6), (1.8 – 1.6), (1.6 – 1.6), (1.4 – 1.6), (1.2 – 1.6)

$$= 0.4 \text{ m}, 0.2 \text{ m}, 0, -0.2 \text{ m}, -0.4 \text{ m}$$

Average of these absolute values of deviation are,

$$= \frac{0.4 + 0.2 + 0 + 0.2 + 0.4}{5} = 0.24 \text{ m}$$

$$\Rightarrow \quad \eta_d = \left(1 - \frac{0.24}{1.6}\right) \times 100 = 85\%$$

131. (a)

Duty of various crops is as below:

Rice	:	900 ha/cumec
Wheat	:	1800 ha/cumec
Cotton	:	1400 ha/cumec
Sugarcane	:	800 ha/cumec

132. (a)

- In Non-modular outlet discharge depends on water levels of both distributary and watercourse
- In semi-modular (flexible) module discharge depends only on distributary water level
- In Rigid module, discharge constant, independent of both distributary and watercourse.
- Open sluice/drawn pipe outlet, discharge depends on working head

133. (c)

134. (b)

$$\because \quad \frac{y_2}{y_1} = 4$$

$$\therefore \quad \frac{y_1}{y_2} = \frac{1}{4}$$

But $\frac{y_1}{y_2} = \frac{1}{4} = \frac{1}{2}\left[-1+\sqrt{1+8F_{r_2}^2}\right]$

$F_{r_2} = 0.395 \simeq 0.4$

135. (c)

For subcritical approach flow, any hump higher than the critical height causes choking, leading to critical flow at the crest and a rise in upstream water level.

136. (d)

Critical depth for rectangular channel is,

$$y_C = \left(\frac{q^2}{g}\right)^{1/3} = \left(\frac{\left(\frac{6.28}{2}\right)^2}{9.81}\right)^{1/3}$$

$\Rightarrow$ $y_C = 1.0$ m

Specific energy for rectangular channel, $E_c = \frac{3}{2}y_c = \frac{3}{2}\times 1$

$\Rightarrow$ $E_C = 1.5$ m

137. (c)

For a rectangular channel,

$$\frac{2q^2}{g} = y_1 y_2 (y_1 + y_2)$$

$\Rightarrow$ $2q^2 = 9.81 \times 1 \times 0.2 \times (1 + 0.2)$

$\Rightarrow$ $q = 1.085\ \text{m}^3/\text{s/m}$

$\therefore$ Discharge, $Q = q \times B = 1.085 \times 4$

$= 4.34\ \text{m}^3/\text{s}$

138. (a)

Given; $D_2 = 0.30$ m, $N = 1400$ rpm, $\eta_0 = 0.80$

From velocity triangle, $V_2 \cos\alpha_2 = V_{u2} = u_2$

where, $u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.3 \times 1400}{60} = 21.99$ m/sec

$\simeq 22$ m/s

Manometric efficiency, $\eta_0 = \frac{gH_m}{u_2 V_{u2}} = \frac{gH_m}{u_2^2}$ $(\because V_{u2} = u_2)$

$\Rightarrow$ $0.8 = \frac{10 \times H_m}{(22)^2}$ $\Rightarrow$ $H_m = 38.72$ m

139. (c)

$$\text{For a turbine, } \frac{H}{D^2N^2} = \text{constant}$$

As head, H is same for both model and prototype

$$\therefore \quad D^2N^2 = \text{constant}$$

$$\Rightarrow \quad D_p^2 N_p^2 = D_m^2 N_m^2$$

$$\Rightarrow \quad 600^2 = \left(\frac{1}{3}\right)^2 \times N_m^2$$

$$\Rightarrow \quad N_m = 1800 \text{ rpm}$$

140. (a)

Pelton = Highest head (Over 250 m)
Francis = Medium head (45 m to 250 m)
Kaplan = Low head (Under 45 m)
Bulb = Very low head (0.5 m to 45 m)

141. (c)

142. (a)

Steep grain size distribution curve means that most soil particles are of nearly the same size. This indicates a uniformly graded soil.

A uniformly graded soil has a low coefficient of uniformity (C_u), generally close to 1 to 2. A value around 1.2 clearly represents uniform grading.

Because a low C_u indicates a narrow range of particle sizes, the grain size distribution curve becomes steep.

143. (a)

- **Statement (I) TRUE:** In the three-point problem, correct orientation is achieved only when the three resectors meet at a single point, giving the true position of the instrument station.
- **Statement (II) TRUE:** Proper orientation means ground rays and plotted rays are parallel, which is the fundamental requirement in plane table surveying
- **Statement (II)** correctly explains the Statement-(I)

Parallelism of rays ensures that all three resectors intersect at one point.

144. (c)

On a curve, the outer wheel must travel a longer distance than the inner wheel.

Because of coning, lateral shift of the axle causes:

Outer wheel = larger rolling diameter
Inner wheel = smaller rolling diameter

Thus, both wheels cover different distances without slipping, enabling smooth curve negotiation.

145. (a)

Standard BOD_5 test conditions require incubation for 5 days at 20°C in darkness.

Light promotes algal photosynthesis, which adds dissolved oxygen and falsely lowers the measured BOD value.

146. (c)

The process of removing moisture in the form of sap is known as seasoning.

147. (b)

148. (a)

CI. 43.2 IS 456 : 2000.

Crack caused by bending in compression member generally do not need explicit checking or control measure, as the high compressive force keeps the section compressed.

149. (d)

150. (b)

■■■■