DETAILED SOLUTIONS

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ESE 2020 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 22

Full Syllabus Test 6 : Paper-II

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

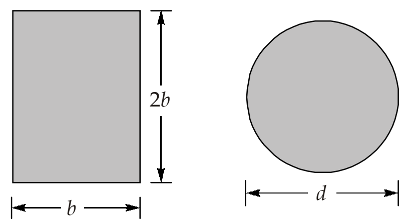
DETAILED EXPLANATIONS

1. (d)

$$d = 100 \text{ mm}$$
$$F = 20 \text{ kN}$$

For circular section, $\tau_{max} = \frac{4}{3}\tau_{avg} = \frac{4}{3} \times \frac{20 \times 10^3 \times 4}{\pi \times 100^2} = \frac{32}{3\pi}$ MPa

2. (d)



For the same maximum bending stress, and same bending moment, section modulus would be the same i.e.

$$Z_R = Z_C$$

$$\Rightarrow \quad \frac{\frac{bd^3}{12}}{\frac{d}{2}} = \frac{\frac{\pi}{64}d^4}{\frac{d}{2}}$$

$$\Rightarrow \quad \frac{bd^2}{6} = \frac{\pi d^3}{32}$$

$$\Rightarrow \quad \frac{b(2b)^2}{6} = \frac{\pi d^3}{32}$$

$$\Rightarrow \quad \frac{4b^3}{6} = \frac{\pi d^3}{32}$$

$$\Rightarrow \quad \left(\frac{b}{d}\right)^3 = \frac{\pi}{32} \times \frac{6}{4} = = \frac{3\pi}{64}$$

$$\therefore \quad \frac{\text{Weight of rectangular bar}}{\text{Weight of circular bar}} = \frac{(LA)_R}{(LA)_C}$$

As $L_R = L_C$

$$\therefore \quad \frac{W_R}{W_C} = \frac{A_R}{A_C}$$

$$= \frac{b \times 2b}{\frac{\pi d^2}{4}} = \frac{8b^2}{\pi d^2} = \frac{8}{\pi}\left(\frac{b}{d}\right)^2$$

$$\therefore \quad \frac{W_R}{W_C} = \frac{8}{\pi}\left(\frac{3\pi}{64}\right)^{2/3} = \frac{(3)^{2/3}}{2(\pi)^{1/3}}$$

3. (b)

Poisson's ratio, $\nu = -\dfrac{\text{lateral strain}}{\text{longitudinal strain}}$

$$= \frac{-(-0.01)}{0.04} = 0.25$$

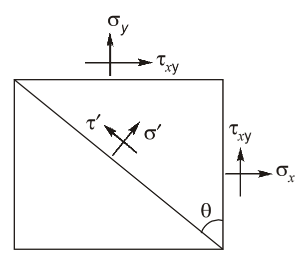
$$E = \frac{\sigma}{\in} = \frac{P}{A\in} = \frac{16\times10^3}{\frac{\pi}{4}\times16^2\times0.04\times10^{-2}\times10^{-6}}$$

$$= 198.944 \times 10^9 = 198.944 \text{ GPa} \simeq 199 \text{ GPa}$$

Also, $E = 2G(1+\mu)$

$\Rightarrow$ $G = \dfrac{198.944}{2\times1.25} = 79.58 \text{ GPa} \simeq 80\,\text{GPa}$

4. (c)



Max shear stress,

$$\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

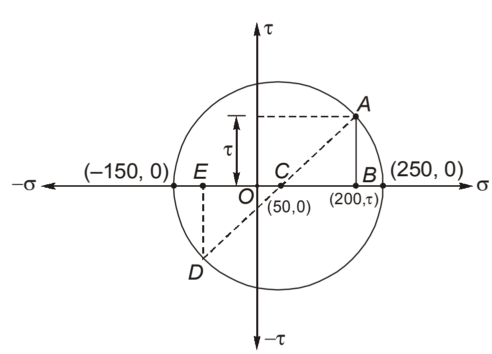
Normal stress on oblique plane

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

$$\tau' = \left(\frac{\sigma_y - \sigma_x}{2}\right)\sin 2\theta + \tau_{xy}\cos 2\theta$$

5. (c)

$\sigma_1 = 250$ MPa; $\sigma_2 = -150$ MPa



In ΔABC

$$AC = \text{radius of Mohr's circle}$$

$$= \frac{\sigma_1 - \sigma_2}{2} = \frac{250-(-150)}{2} = \frac{400}{2} = 200$$

$$BC = 150$$

$$AB = \tau = \sqrt{200^2 - 150^2}$$

$$\Rightarrow \quad \tau = 50\sqrt{7} \text{ MPa}$$

⇒ CD plane is right angle to plane AC

(In Mohr's circle, angle between two planes is represented by double of its actual value)

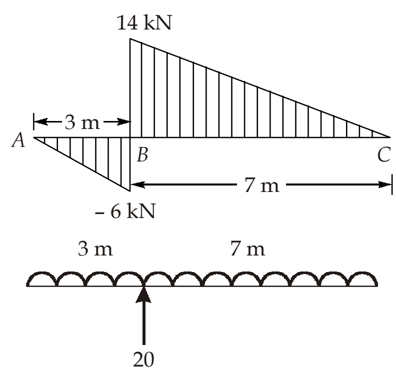
From ΔACB and ΔECD

$$CB = CE = CO + OE$$

$$\Rightarrow \quad 150 = 50 + OE$$

$$\Rightarrow \quad OE = 100 \text{ MPa (compressive)}$$

6. (a)



Area of SFD from A to B = $\frac{1}{2} \times -6 \times 3$ = – 9 kNm

Area of SFD to B to C = $\frac{1}{2} \times 7 \times 14$ = 49 kNm

Bending moments: $M_A = 0$

$M_B = 0 - 9 = -9$ k N.m [Already given]

$M_C = -9 + 49 = 40$ kNm

7. (d)

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

$$\Rightarrow \quad R = \frac{EI}{M}$$

∴ R increases with E and decreases with M.

8. (c)

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

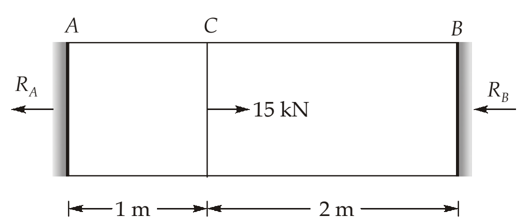
$$= \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \sqrt{\left(\frac{14-(-10)}{2}\right)^2 + 5^2} = \sqrt{12^2 + 5^2}$$

$$= 13 \text{ N/mm}^2$$

9. (b)

Let us consider reaction R_A and R_B at support A and B in direction opposite to that of 15 kN. We are just assuming the direction. If value of reaction comes out negative then just take the direction opposite to that of assumed direction.



By using equilibrium condition, we have

$$R_A + R_B = 15 \text{ kN} \quad \text{...(i)}$$

By using deflection condition

$$\Delta_{AC} + \Delta_{CB} = 0$$

$$\Rightarrow \quad \frac{R_A \times 1}{AE} + \frac{(R_A - 15) \times 2}{AE} = 0$$

$$\Rightarrow \quad R_A \times 1 + 2R_A - 30 = 0$$

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

$$\therefore \quad R_B = 5 \text{ kN}$$

10. (a)

If material of both shafts is same and length is also same then

Weight of shaft $\propto$ Area of shaft

$$\therefore \frac{W_H}{W_S} = \frac{A_H}{A_S} = \frac{\left(\frac{2D}{\sqrt{3}}\right)^2 - \left(\frac{D}{\sqrt{3}}\right)^2}{D^2} = \frac{\frac{4D^2 - D^2}{3}}{D^2} = 1$$

11. (b)

$$\text{Strain energy stored} = \int_0^L \frac{M^2\,dx}{2EI} = \int_0^L \frac{(Px)^2\,dx}{2EI}$$

$$= \frac{P^2}{2EI}\left(\frac{x^3}{3}\right)\Bigg|_0^L = \frac{P^2L^3}{6EI}$$

12. (d)

Given, $l = 4$ m

$\Delta t = 60 - 20 = 40°C$

$\alpha = 10 \times 10^{-6}/°C$

$E = 200 \times 10^3$ MPa

$\Delta = 0.2$ mm

$\sigma = ?$

$$\delta l = l\alpha\Delta t - \Delta$$

Strain, $$\varepsilon = \frac{\delta l}{l} = \left(\alpha \cdot \Delta t - \frac{\Delta}{l}\right)$$

∴ Stress, $$\sigma = \varepsilon \cdot E$$

$$= \left(\alpha \cdot \Delta t - \frac{\Delta}{l}\right) \cdot E$$

$$= \left(10 \times 10^{-6} \times 40 - \frac{0.2 \times 10^{-3}}{4}\right) 200 \times 10^3$$

$= 70$ MPa (compressive)

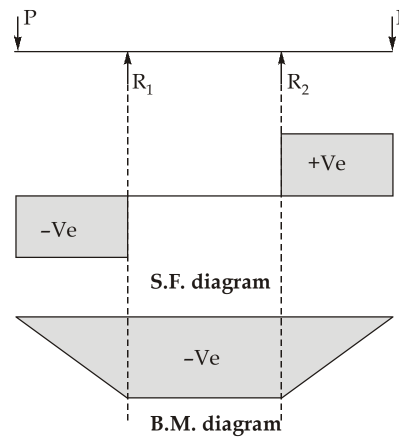
13. (b)

$$\frac{\theta_{Steel}}{\theta_{Brass}} = ?$$

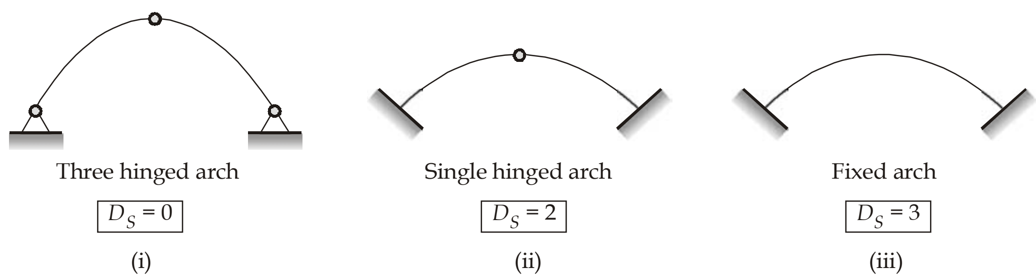
$\because$ $$\frac{T}{J} = \frac{G\theta}{L}$$

$\Rightarrow$ $$\frac{\theta_{Steel}}{\theta_{Brass}} = \frac{\left(\frac{TL}{GJ}\right)_{\text{Steel}}}{\left(\frac{TL}{GJ}\right)_{\text{Brass}}} = \frac{\left(\frac{T \times L}{2G \times J}\right)}{\left(\frac{T \times (L/2)}{G \times J}\right)} = 1$$

14. (b)



15. (b)



16. (a)

Member	M	m	L
BC	$-2x$	$-x$	1 m
BA	–2	–1	2 m

$$\Delta_{VC} = \int \frac{M.m.dx}{EI}$$

$$= \int_0^1 \frac{2x^2}{EI} dx + \int_0^2 \frac{2}{EI} dx$$

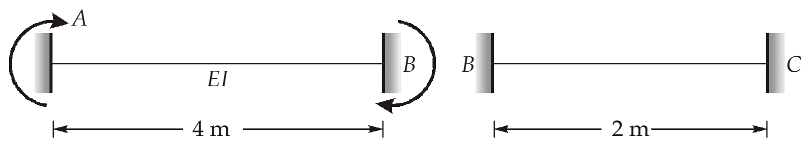
$$= \left[\frac{2x^3}{3EI}\right]_0^1 + \left[\frac{2x}{EI}\right]_0^2$$

$$= \frac{2}{3EI} + \frac{4}{EI} = \frac{14}{3EI}$$

$$= \frac{14 \times 10^3}{3 \times 9.82 \times 10^{11} \times 10^{-6}}$$

$$= 4.75 \times 10^{-3} \text{ m} = 4.75 \text{ mm}$$

17. (a)



$$M_{fAB} = \frac{4EI}{4} \times 0.002$$

$$M_{fBA} = \frac{2EI}{4} \times 0.002 = 0.001(EI)$$

$$M_{fCB} = 0$$

Slope-deflection equations

$$M_{AB} = M_{fAB} + \frac{2EI}{4}(2\theta_A + \theta_B)$$

$$M_{BA} = M_{fBA} + \frac{2EI}{4}(2\theta_B + \theta_A)$$

$\Rightarrow$ $$M_{BA} = 0.001EI + \frac{EI}{2}(2\theta_B)$$ (Because we have already taken the effect of joint rotation at A in the fixed end moment so $\theta_A = 0$)

$$M_{BC} = 0 + \frac{2EI}{2}(2\theta_B + \theta_C) = 2EI\theta_B \qquad \{\because \theta_C = 0\}$$

$\because$ $$M_{BA} + M_{BC} = 0$$

$$0.001EI + 1.5EI\,(2\theta_B) = 0$$

$\Rightarrow$ $$\theta_B = -\frac{0.001}{3}\text{ rad} = -3.33 \times 10^{-4}\text{ rad}$$

18. (b)

$$D_S = D_{si} + D_{se}$$

$$D_{se} = 4 - 3 = 1$$

$$D_{si} = m - (2j - 3)$$

$m = 17, j = 10$

$$D_{si} = 17 - (2 \times 10 - 3) = 0$$

$\therefore$ $$D_s = 1 + 0 = 1$$

19. (c)

$$[k] = [A]^{-1}$$

$$= \frac{6EI}{L^3(54-49)}\begin{bmatrix} 18 & -7 \\ -7 & 3 \end{bmatrix}$$

$$\left[\text{Inverse of matrix A} = \frac{1}{|A|}\text{ adjoint (A)}\right]$$

$$= \frac{6EI}{5L^3}\begin{bmatrix} 18 & -7 \\ -7 & 3 \end{bmatrix}$$

20. (a)

$$|M_{fAB}| = |M_{fBA}|$$

$$= \frac{5wL^2}{96} = \frac{5 \times 8 \times 6 \times 6}{96} \text{ kNm}$$

$$= 15 \text{ kNm}$$

22. (c)

$$\text{KDI} = 3j - r_e - m + r_r$$

$$= 3 \times 6 - 9 - 5 + 3 = 7$$

23. (c)

Using Maxwell-Betti's theorem

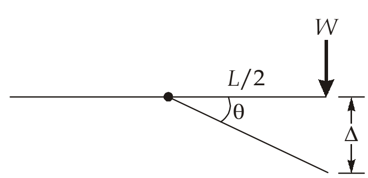
$$50 \times 5 = 15 \times 7 + 30 \times \delta$$

$$\Rightarrow \quad \delta = 4.8 \text{ mm}$$

24. (c)

The beam show in figure is of a non-uniform cross-section. A plastic hinge can form at the point where section changes. Another plastic hinge can also form at the fixed support.

Case I : Plastic hinge at the point, where the cross-section changes



$$\text{External work done} = \text{Load} \times \text{Deflection}$$

$$= W_u \times \Delta$$

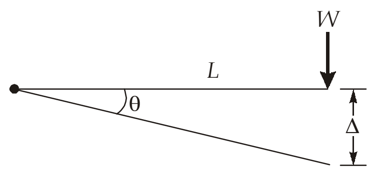
$$= W_u \times \frac{L}{2}\theta$$

$$\text{Internal work done} = M_p\theta$$

So, $$M_p\theta = W_u \times \frac{L}{2}\theta$$

$$\Rightarrow \quad W_u = \frac{2M_P}{L}$$

Case II : Plastic hinge at the fixed support



$$\text{External work done} = W_u \times \Delta = W_u \times L\theta$$

$$\text{Internal work done} = 1.5\, M_p\theta$$

$$\therefore \quad W_u L\theta = 1.5 M_p\theta$$

$$\Rightarrow \quad W_u = \frac{1.5M_P}{L}$$

So, collapse load for beam is $\frac{1.5M_P}{L}$

25. (d)

Static theorem uses the equilibrium and plastic moment condition and kinematic theorem uses the equilibrium and mechanism condition.

26. (d)

All the ways of failure of bolted joints.

27. (a)

Sometimes cost of lug angles, their connection and fabrication will be more which offsets any saving in gusset plates, thereby defeating the purpose.

28. (c)

The buckling load of a steel column pinned at both ends is

$$P_1 = \frac{\pi^2 EI}{l_{eff}^2} = \frac{\pi^2 EI}{l^2} = 200 \text{ kN}$$

When the column is restrained against lateral movement and rotation at its mid-height

$$l_{\text{eff}} = 0.8\left(\frac{l}{2}\right) = 0.4l$$

$$\therefore \quad P_2 = \frac{\pi^2 EI}{(0.4l)^2} = \frac{100}{16}\frac{\pi^2 EI}{l^2}$$

$$= \frac{100}{16} \times 200 = 1250 \text{ kN}$$

29. (a)

A battened column is designed with its effective length 10% in excess of effective length of the column. In laced column, the effective length is increased by 5%.

30. (c)

Maximum deflection should not exceed = $\frac{\text{Span}}{325}$

$$= \frac{7000}{325} = 21.54 \text{ mm}$$

32. (b)

Grillage foundation consists of two tiers of the beams, placed at right angle to each other, to distribute the load progressively to a large area.

33. (a)

Due to transverse component of gravity load (dead load and live load), a purlin is subjected to unsymmetrical bending.

34. (a)

$$\text{Length of weld} = (80 + 50 + 80) = 210 \text{ mm}$$

$$\text{Safe force} = k \cdot s \cdot l_{\text{eff}} \cdot f_{\text{shear}}$$

$$= 0.7 \times 8 \times 210 \times 120 \times 10^{-3} \text{ kN}$$

$$= 141.12 \text{ kN}$$

35. (c)

There is no advantage in using high strength steel as compression reinforcement as the permissible stress is relatively low and unrelated to the grade of steel.

In order to resist a very high moment, a large area of compression steel is called for and hence the A_{sc} required may even exceed A_{st}.

36. (c)

It should be noted that the moment coefficients have been derived assuming unyielding supports. Hence, the use of these coefficients is justified only if the supports are walls or beams that are adequately rigid.

37. (d)

The development length for each bar in a bundle should be taken as $1.1L_d$, $1.2L_d$ and $1.33L_d$ for 2 bars in bundle, 3 bars in bundle and 4 bars in bundle respectively, where L_d is the development length for an individual bar.

Refer **Cl.26.2.3.5** and **26.2.1.2** of IS 456:2000.

41. (c)

$$EI = (20000 \times 10^6) \times (1.2 \times 10^{-4}) = 2.4 \times 10^6 \text{ Nm}^2$$

Also,

$$m = \frac{10000}{10} = 1000 \text{ Ns}^2/\text{m} = 1000 \text{ kg}$$

$$\text{Stiffness of beam, } k_b = \frac{3EI}{L^3} = \frac{3 \times 2.4 \times 10^6}{(3.0)^3}$$

$$= 266.67 \times 10^3 \text{ N/m} = 266.67 \text{ kN/m}$$

$$\text{Stiffness of whole system, } k_{eq} = k_b + 2k$$

$$= 266.67 + 2 \times 40$$

$$= 346.67 \text{ kN/m}$$

$$\text{Natural frequency, } w_n = \sqrt{\frac{k_{eq}}{m}} = \sqrt{\frac{346.67 \times 10^3}{1000}}$$

$$= 18.62 \text{ rad/sec}$$

42. (a)

$$C = T$$

$$\Rightarrow \quad 0.36 \times f_{ck} \times Bx_{\text{ulim}} = 0.87 \times f_y \times A_{st}$$

$$\Rightarrow \quad 0.36 \times 20 \times B \times 0.48d = 0.87 \times 415 \times A_{st}$$

$$\Rightarrow \quad \frac{A_{st}}{Bd} = \frac{0.36 \times 20 \times 0.48}{0.87 \times 415}$$

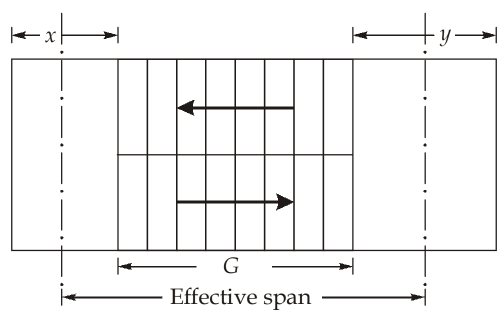
$$\Rightarrow \quad p_t = \% \frac{A_{st}}{Bd} \times 100 = 0.957\%$$

Alternatively,

$$p_{t,\lim} = 41.61\left(\frac{f_{ck}}{f_y}\right)\left(\frac{x_{u,\lim}}{d}\right)$$

$$= 41.61\left(\frac{20}{415}\right)(0.48) = 0.96\%$$

43. (d)



$$\text{Effective span} = G + \min\left[\frac{x}{2} \text{ or } 1\text{ m}\right] + \min\left[\frac{y}{2} \text{ or } 1\text{ m}\right]$$

[Refer Cl.33.1 and Fig. 17 of IS 456:2000]

$$= 5 + 0.75 + 1$$

$$= 6.75 \text{ m}$$

44. (b)

$$\text{Reinforcement in central band width} = A_{st\,short} \times \frac{2}{\beta + 1}$$

[Cl.34.3.1(c) of IS 456:2000]

where $A_{st\,short}$ = Total flexural reinforcement required in the short direction

β = Ratio of longside to the short side of the footing

$\therefore$ Reinforcement in central band width $= 3000 \times \dfrac{2}{\dfrac{4}{3}+1}$

$$= 3000 \times \frac{6}{7} = 2571.43 \text{ mm}^2$$

45. (c)

Freyssinet has split conical wedge and bush to each strand bearing on anchor thrust plate. Lee-McCall has high strength nut and spacing washers bearing on steel plate on end of beam.

46. (b)

When placed in two or more layers, the bars in the upper layers must come directly above those in the bottom layer, with the required clearance.

48. (c)

$$\text{Worker's productivity} = \text{Quantity of workdone per man hour}$$

$$= \frac{\text{Quantity of workdone}}{\text{Man hour consumed}}$$

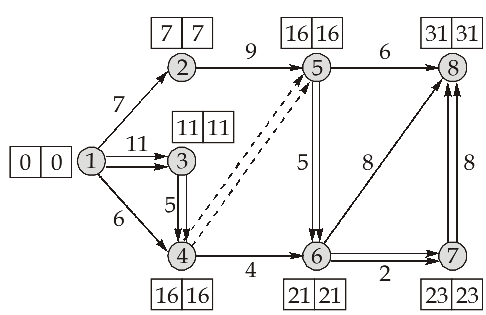
49. (a)

Dumpers can be used for horizontal transportation of materials on and off sites.

51. (a)

Unit price contract is based on estimated quantities of the items involved in the work. The cost per unit of each item is bidded by the contractor and the estimated quantities of these items are given by the owner.

52. (b)



$\therefore$ Independent float of activity 5 - 6 $= \left(t_E^6 - t_L^5\right) - t_{5-6}$

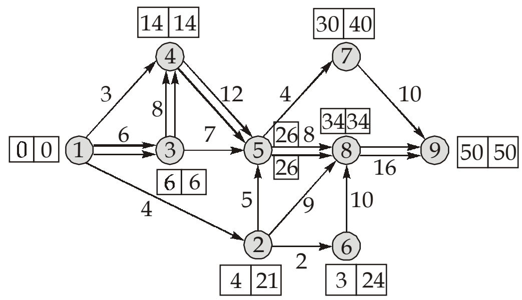
$$= (21 - 16) - 5 = 0$$

53. (c)

$$\text{Injury severity rate} = \frac{\text{Number of days lost} \times 1000}{\text{Number of man hours worked}}$$

$\Rightarrow$ Number of man hours worked $= \dfrac{16 \times 1000}{0.25} = 64000 \text{ hr}$

54. (b)



The critical path is 1 - 3 - 4 - 5 - 8 - 9

Project duration is 50 days.

57. (a)

Lime reduces the shrinkage on drying.

59. (b)

Steel is an alloy of iron and carbon. On mixing with carbon, its strength and toughness gets increased. In order to make it further more temperature and abrasion resistant, chromium is generally mixed with iron which also increases its hardness and load bearing capacity. Stainless steel is a category of steel (74% Fe, 18% Cr and 8% Ni) which is corrosion resistant.

60. (d)

Crookes glass is a type of glass that contains cerium (as cerium oxide, CeO_2) and other rare earths and has a high absorption of ultraviolet radiations and is thus used in sunglasses.

63. (a)

Fly ash brick (FAB) is a building material, specifically masonary units, containing class C fly ash and water. All fly ash includes substantial amounts of silicon dioxide (SiO_2) aluminium oxide (Al_2O_3) and calcium oxide (CaO). Fly ash can be used as a replacement for some of the portland cement contents of concrete.

67. (d)

According to IS code, curing should be done under humidity of 90% at temperature of 27±3°C.

68. (d)

The increase in strength of cement with time depends on the C_2S content of cement.

69. (b)

$$h_f = \frac{8fLQ^2}{\pi^2 g D^5} = \frac{8 \times 0.019 \times 1000 \times 0.5^2}{\pi^2 \times 9.81 \times 0.3^5}$$

$$= 161.51 \text{ m}$$

71. (b)

A forebay in a hydel power system is provided at the junction of the power channel and the penstock.

Draft tube converts kinetic energy at the exit of runner into useful pressure thereby increasing the efficiency.

72. (b)

$$\text{Diameter} = 200 \text{ mm}$$
$$f' = 0.04$$
$$\text{Friction factor, } f = 4f' = 0.04 \times 4 = 0.16$$
$$\because \quad \tau = -\frac{r}{2} \cdot \frac{\partial p}{\partial x}$$
$$\Rightarrow \quad 0.00981 = -\frac{4}{2} \cdot \frac{\partial p}{\partial x}$$
$$\Rightarrow \quad \frac{\partial p}{\partial x} = -\frac{0.00981}{2} \text{ N/cm}^3$$
$$\therefore \quad \text{Shear stress at pipe wall, } \tau_{wall} = +\frac{0.00981}{2} \times \left(\frac{10}{2}\right)$$
$$= 0.0245 \text{ N/cm}^2$$

73. (d)

$$\because \quad \text{Chezy's coefficient, } C = \sqrt{\frac{8g}{f}} = \frac{1}{n} \cdot R^{1/6}$$
$$\therefore \quad \sqrt{\frac{8g}{f}} = \frac{1}{n} \cdot R^{1/6}$$
$$\text{But} \quad R = \frac{A}{P} = \frac{5 \times 2.3}{5 + 2 \times 2.3} = 1.198 \text{ m}$$
$$\therefore \quad \sqrt{\frac{8 \times 9.81}{0.02}} = \frac{1}{n} \cdot (1.198)^{1/6}$$
$$\Rightarrow \quad n = 0.016$$

74. (b)

$$\frac{y_1}{y_2} = \frac{1}{2}\left[-1 + \sqrt{1 + 8F_2^2}\right]$$
$$= \frac{1}{2}\left[-1 + \sqrt{1 + 8 \times 0.15^2}\right] = 0.043$$
$$E_L = \frac{(y_2 - y_1)^3}{4y_1 y_2}$$
$$\therefore \quad \frac{E_L}{y_2} = \frac{\left(1 - \frac{y_1}{y_2}\right)^3}{4\left(\frac{y_1}{y_2}\right)} = \frac{(1 - 0.043)^3}{4 \times 0.043}$$

$$\Rightarrow \quad \frac{E_L}{y_2} = 5.096$$

$$\Rightarrow \quad y_2 = \frac{9}{5.096} = 1.77 \text{ m}$$

$$\therefore \quad y_1 = 0.043y_2 = 0.043 \times 1.77 = 0.076 \text{ m}$$

76. (b)

$$\frac{U}{U_\infty} = \left(\frac{y}{\delta}\right)^{1/6}$$

Displacement thickness, $\delta^* = \int_0^\delta \left(1 - \frac{U}{U_\infty}\right) dy$

$$= \int_0^\delta \left(1 - \left(\frac{y}{\delta}\right)^{1/6}\right) dy$$

$$= \delta - \frac{6}{7}\delta = \frac{\delta}{7}$$

$$\frac{\delta^*}{\delta} = \frac{1}{7}$$

77. (b)

For Reynolds number greater than 1000 for circular cylinders the strouhal number is constant (=0.21).

78. (a)

$$P = \frac{\rho Q g h}{745}$$

$$= \frac{1000 \times 1.5 \times 9.81 \times 140}{745}$$

$$\simeq 2765 \text{ BHP}$$

79. (d)

$$\frac{U_{\max}}{U_{avg}} = 1.43\sqrt{f} + 1$$

For both smooth and rough pipes, the friction factor (f) increases with ageing. So ratio $\frac{U_{\max}}{U_{avg}}$ also increases.

80. (d)

Discharge when approach velocity is neglected,

$$Q = \frac{2}{3} C_D \cdot L\sqrt{2g} \cdot H^{3/2}$$

If velocity of approach, V_a is to be taken into consideration then,

$$Q_a = \frac{2}{3} C_{D'} L\sqrt{2g}\left[(H+h_a)^{3/2} - h_a^{3/2}\right]$$

$$\therefore \quad \text{Excess percentage of flow} = \frac{Q_a - Q}{Q} \times 100$$

$$= \left(\frac{Q_a}{Q} - 1\right) \times 100$$

$$= \left[\frac{(H+h_a)^{3/2} - h_a^{3/2}}{H^{3/2}}\right] \times 100$$

$$= \left[\frac{(0.3+0.02)^{3/2} - 0.02^{3/2}}{(0.3)^{3/2}} - 1\right] \times 100$$

$$= \left[\frac{(0.32)^{3/2} - (0.02)^{3/2}}{(0.3)^{3/2}} - 1\right] \times 100$$

$$= 8.4\%$$

81. (c)

$$\text{Specific speed, } N_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{580 \times \sqrt{12100}}{92^{5/4}}$$

$$= \frac{580 \times 110}{284.9} = 223.9 \simeq 224 \text{ rpm}$$

Specific speed (in SI unit)	Turbine
15 to 30	Pelton with single jet
30 to 51	Pelton with double jet (two or more jet)
51 to 255	Francis
255 to 860	Kaplan

82. (c)

Soils that have been deposited from suspension of sea water is called marine deposit while lacustrine deposit is that have been deposited from suspension in still, fresh water of lakes.

Loess is a deposit of wind blown silt that have been weakly cemented with calcium carbonate and montmorillonite.

Marl is a very fine grained calcium-carbonated soil of marine origin.

83. (c)

$$m_v = \frac{a_v}{1+e_0} = \frac{\Delta e}{\Delta\sigma(1+e_0)}$$

$$= \frac{(1.2-1.1)}{(0.5-0.25)\times(1+1.2)} = 0.18 \text{ cm}^2/\text{kgf}$$

84. (d)

Core cutter method is used to compute in-situ unit weight of soil.

85. (a)

Project	Compaction water content	Reason
Core of an earth dam	Wet of optimum	To reduce permeability and to prevent cracking in core
Homogeneous earth dam	Dry of optimum	To have stronger soil and to prevent build up of high pore water pressure
Subgrade of pavement	Wet of optimum	To limit volume changes

86. (d)

- Constant head test is suitable for pervious, coarse grained soils.
- Sample should be undisturbed for laboratory tests like falling head permeability test.
- Pumping tests are field tests conducted at the site itself.

87. (d)

The cell and the rubber membrane are not required in this test as water is not allowed to drain.

88. (c)

Friction circle method is based on total stress analysis.

Friction circle method assumes a circular slip surface.

89. (b)

$$\text{Load intensity on foundation} = \frac{110}{3\times 3} = 12.22 \text{ t/m}^2$$

$$\therefore \quad S_f = S_p\left[\frac{B_f}{B_p}\frac{(B_p+0.3)}{(B_f+0.3)}\right]^2$$

$$= 5\left[\frac{3}{0.6}\frac{(0.6+0.3)}{(3+0.3)}\right]^2$$

$$= 9.3 \text{ mm}$$

90. (d)

$$\frac{S_g}{S_i} = \left(\frac{4B+2.7}{B+3.6}\right)^2$$

$$B = 2\times 0.9 + 0.3 = 2.1 \text{ m}$$

$$S_g = 2\times\left(\frac{4\times 2.1+2.7}{2.1+3.6}\right)^2 = 2\times\left(\frac{11.1}{5.7}\right)^2 = 7.58 \text{ mm}$$

91. (b)

$$A_r = \frac{51^2 - 35^2}{35^2} \times 100 = 112.33\%$$

92. (b)

Ultimate bearing capacity is not only related to the properties of the soil but also to the characteristics of the foundation such as its size, shape and depth and the type of loading, whether vertical or inclined, axial or eccentric.

94. (c)

Year	Population	Increase in Population	Incremental increase
1930	25000		
1940	28000	3000	
1950	34000	6000	3000
1960	42000	8000	2000
Total		17000	5000
Average increase per decade		$\bar{x} = \frac{17000}{3} = 5666.67$	$\bar{y} = \frac{5000}{2} = 2500$

$$p_n = p_0 + n\bar{x} + \frac{n(n+1)\bar{y}}{2}$$

$\therefore$

$$p_{1980} = 42000 + 2 \times 5666.67 + \frac{2 \times 3}{2} \times 2500$$

$$= 60833.34 \simeq 60834 \quad \text{(say)}$$

95. (a)

Zone of rock fracture is divided into zone of aeration and zone of saturation.

96. (a)

Jackson's turbidimeter cannot measure turbidities lower than 25 JTU.

97. (b)

$$\text{Weir loading per day} = \frac{\text{Discharge per day}}{\text{Length of weir}}$$

Length of the weir along the periphery of tank = πd

$= \pi \times 26$

$= 81.68$ m

$$\text{Discharge in each tank} = \frac{26000}{2} = 13000 \text{ m}^3/\text{d}$$

$$\text{So, weir loading} = \frac{13000}{81.68} = 159.16 \text{ m}^3/\text{m/day} \simeq 159 \text{ m}^3/\text{m/day}$$

98. (c)

Rapid sand filter is used where huge area for its installation is not available.

99. (c)

Ultimate BOD is independent of temperature.

101. (c)

Grit chambers are placed before the primary sedimentation tank.

102. (b)

Disadvantage of disposal of MSW by sanitary land filling method is that low lying depressions or dumping sites may not always be available.

103. (b)

Suspended particulate matter is primary air pollutant.

104. (a)

$$\text{Sound pressure level in dB} = 20\log_{10}\left(\frac{P_{rms}}{P_{rms_0}}\right)$$

$$P_{\text{rms}_0} = 20\ \mu\text{Pa (standard)}$$

$$\therefore \quad \text{Sound pressure level in dB} = 20\log_{10}\left(\frac{40\times10^{-3}\,\text{Pa}}{20\times10^{-6}\,\text{Pa}}\right)$$

$$= 66\ \text{dB}$$

105. (a)

$$V_1 = 75\ \text{m}^3/\text{day}$$

$$V_2 = ?$$

$$V_2\,(100 - p_2) = V_1\,(100 - p_1)$$

$$\Rightarrow \quad V_2\,(100 - 85) = V_1\,(100 - 95)$$

$$\Rightarrow \quad V_2(15) = V_1 \times 5$$

$$\Rightarrow \quad V_2 = \frac{75\times5}{15} = 25\ \text{m}^3/\text{day}$$

$$\text{So,} \quad \text{Capacity of tank} = \left(V_1 - \frac{2}{3}(V_1 - V_2)\right)t_D$$

$$= \left(75 - \frac{2}{3}(75 - 25)\right)\times 30$$

$$= 1250\ \text{m}^3$$

106. (a)

No object should be nearer to the instrument less than 30 m or twice the height of the obstruction.

107. (a)

The data are arranged in descending order and rank number assigned to the recorded events.

Rank (M)	Rainfall (cm)	Probability $\left(\frac{M}{N+1}\right)$
1	130	$\frac{1}{6}$
2	125	$\frac{2}{6}$
3	120	$\frac{3}{6}$
4	110	$\frac{4}{6}$
5	100	$\frac{5}{6}$

$N = 5$

50% dependable annual rainfall at station A = Annual rainfall with probability P = 0.5

So from above table, rainfall with probability P = 0.5 is 120 cm

109. (c)

The discharge in each segment should be less than 10% of the total discharge.

110. (a)

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	
Time (h)	Ordinates of 4-h UH (m^3/s)	Lagged by 4-h (m^3/s)	Legged by 8-h (m^3/s)	DRH of 3 cm in 12-h (m^3/s)	Ordinate of 12-h UH $\left(\text{col.}\frac{5}{3}\right)$ (m^3/s)
0	0			0	0
4	20	0		20	20 / 3
8	80	20	0	100	100 / 3
12	130	80	20	230	230 / 3
16	150	130	80	360	360 / 3
20	130	150	130	410	410 / 3
24	90	130	150	370	370 / 3
		90	130	220	220 / 3
			90	90	90 / 3

So, ordinate of 12-h UH at 16 hr = $\frac{360}{3} = 120\ m^3/s$

112. (c)

Other methods of control of cracking in concrete dams arc:

- By the use of low heat cement.
- By limiting the height of lift.
- By reducing the cement content.

113. (b)

Position of the resultant from the toe is

$$\bar{x} = \frac{\sum M}{\sum V} = \frac{986572}{45272} = 21.8 \text{ m}$$

Position of the resultant from the centre of base of dam, $e = \frac{b}{2} - \bar{x}$

$$= \frac{52}{2} - 21.8 = 4.20 \text{ m}$$

114. (c)

Sugarcane is a perennial crop and wheat is a Rabi crop.

Hence total discharge required = 0.28 + 0.22 = 0.5 cumecs

Time factor = 0.9

$\therefore$ Design capacity of canal = $\frac{0.5}{0.9} = 0.56$ cumecs

117. (b)

For fetch > 32 km,

$$h_w = 0.032\sqrt{VF}$$

$$\Rightarrow \quad h_w = 0.032 \times \sqrt{16 \times 36} = 0.032 \times 4 \times 6$$

$$\Rightarrow \quad h_w = 0.768 \text{ m}$$

118. (c)

$$\text{Width, } L = 4.75\sqrt{Q}$$

$$= 4.75\sqrt{49} = 4.75 \times 7$$

$$= 33.25 \text{ m}$$

119. (c)

$$\sigma_{t(c)} = \frac{E\alpha t}{3(1-\mu)}\sqrt{\frac{a}{l}}$$

$$= \frac{3 \times 10^5 \times 10 \times 10^{-6} \times 10}{3(1-0.15)}\sqrt{\frac{15}{87}} = 4.88 \text{ kg/cm}^2$$

120. (c)

$$f' = \frac{V^2}{2gl} = \frac{40 \times 40}{3.6^2 \times 2 \times 9.81 \times 12} = 0.5244$$

$$\text{Brake efficiency } \eta\% = \frac{f'}{f} = \frac{0.5244}{0.7} \times 100 = 74.91\%$$

121. (b)

$$\text{Grade compensation} = \frac{30 + R}{R}$$

$$= \frac{30+60}{60} = 1.5\%$$

$$\text{Maximum limit of grade compensation} = \frac{75}{R} = \frac{75}{60} = 1.25\%$$

$$\text{Compensated gradient} = 6.2 - 1.25 = 4.95\%$$

122. (d)

$$L = 2\left[\frac{Nv^3}{c}\right]^{1/2}$$

where v (in m/sec) $= \dfrac{100 \times 1000}{3600} = 27.8$ m/sec

$$\therefore \quad L = 2\left[\frac{\left(\frac{1}{25}+\frac{1}{30}\right) \times 27.8^3}{0.6}\right]^{1/2}$$

$$= 102.5 \text{ m}$$

124. (c)

LDF = 0.45 for road with divided carryigeway with four lanes each.

LDF = 0.75 for undivided roads with two lane carriageway.

125. (d)

$$\text{Ruling gradient} = \frac{1}{200} \times 100 = 0.5\%$$

For BG track grade compensation = 0.04% per degree curve

Compensation for 4° curve = 4 × 0.04 = 0.16%

Compensated gradient = 0.5 – 0.16

$$= 0.34\% \text{ or } \frac{1}{294}$$

126. (b)

The direction in which trains will be carrying heavier loads, creep will be developed in that direction.

127. (a)

The intermediate straight distance is

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

$$= (4.5-1)12 - 1\sqrt{1+12^2}$$

$$= 29.96 \text{ m}$$

$$\simeq 30 \text{ m}$$

129. (a)

It is given in terms of number between 0 to 12.

132. (c)

$$\text{Versine, } (O_0) = R - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$$

$$\Rightarrow \quad 4 = R - \sqrt{R^2 - 40^2}$$

$$\Rightarrow \quad R^2 - 40^2 = R^2 + 16 - 8R$$

$$\Rightarrow \quad 8R = 1600 + 16$$

$$\Rightarrow \quad R = \frac{1616}{8} = 202 \text{ m}$$

133. (a)

$$L' = L \pm L\alpha\Delta t$$

$$\Rightarrow \quad 100.0056 = 100 + L\alpha\Delta t$$

$$\Rightarrow \quad 0.0056 = 100 \times 11.2 \times 10^{-6} \times (18 - T)$$

$$\Rightarrow \quad \frac{0.0056}{100 \times 11.2 \times 10^{-6}} = 18 - T$$

$$\Rightarrow \quad T = 13°\text{C}$$

Alternatively,

$$\text{Corrosion} = \text{T.V.} - \text{M.V.}$$

$$= 100 - 100.0056 = -0.0056 \text{ m}$$

$$C_T = \alpha(T_m - T_0)$$

T_m = Temperature at the time of measurement

T_0 = Temperature at the time of standarization of tape

α = Coefficient of thermal extension

Given, $\alpha = 11.2 \times 10^{-6}/°\text{C}$

$T_0 = 18°\text{C}$

$-0.0056 = 100 \times 11.2 \times 10^{-6} (T_m - 18)$

$T_m = 13°\text{C}$

134. (b)

Degree of accuracy in angular measurement,

$$K = \frac{\text{Angular error of closure}}{\sqrt{\text{Number of angles measured}}}$$

$$= \frac{180''}{\sqrt{9}} = 60''$$

136. (a)

$$\Delta h = \left(\frac{p_2 - p_1}{p_1 p_2}\right) \times B.f$$

$$\Rightarrow \quad \Delta h = \left(\frac{50 - 45}{50 \times 45}\right) \times 200 \times 120 = 53.33 \text{ m}$$

137. (b)

Orthographic projection of a survey line on N-S line i.e. reference meridian is called latitude

138. (d)

All the points given in question are the desired relationship of the fundamental lines.

139. (d)

Gradienter can be used to set gradients, horizontal and vertical distances.

140. (d)

Geodetic survey takes into consideration the curvature of earth. It is used for large areas like survey of a country.

141. (c)

The curvature of the cable of an unstiffened bridge changes as the load moves on the deck. To avoid this, the decking is stiffened by provision of either a three hinged stiffening girder or a two hinged stiffening girder.

143. (d)

As per **IS 800:2007**, slenderness ratio of tension members is restricted to 400 to fulfill stiffness requirements associated with self weight.

144. (a)

In order to obtain the runoff hydrograph resulting from a storm of varying intensities, it is preferable to have a unit hydrograph of very short duration, theoretically, the shortest duration is zero. Accordingly if duration of effective rainfall approach, zero, the unit hydrograph is called as an instantaneous unit hydrograph, generally abbreviated as IUH.

The advantage of IUH over unit hydrograph (Sherman, 1932) is that the IUH overcomes the problem of duration of rainfall and the restriction on uniform distribution of rainfall.

145. (a)

Clay backfills should be avoided as far as possible due to swelling and shrinkage. Swelling is likely to cause unpredictable earth pressure and wall movements while shrinkage may lead to tension cracks in soil. The crack may subsequently get filled with water, adding considerably to the lateral earth pressure.

147. (c)

Circulation is increased in the case of rough ball.

148. (d)

If the tunnel alignment contains curves or the changing grades, then the quantity of natural air expected to provide natural ventilation gets considerably reduced.

149. (d)

Relative positions of shear plane changes during the process of folding.