DETAILED SOLUTIONS

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ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 20

Full Syllabus Test 4 : Paper-II

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

Question No. 47. (*) (Mark to all)

Change answer key: [Q. No. 78. (a)]

DETAILED EXPLANATIONS

2. (a)

$$k_{avg} = \frac{\Sigma k_i Z_i}{\Sigma Z_i}$$

$$= \frac{k \times H + 2k \times \frac{H}{2} + 2.5k \times 1.5H}{H + \frac{H}{2} + 1.5H}$$

$$= \frac{5.75H\,k}{3H} = 1.92\text{ k}$$

4. (b)

$$\frac{\Delta H}{H_0} = \frac{\Delta e}{1 + e_0}$$

$$\Rightarrow \quad \Delta H = 20 \times \left(\frac{0.4 - 0.5}{1 + 0.5}\right)$$

$$= \frac{-2}{1.5} = -1.33\text{ cm}$$

5. (a)

For sand, $c' = 0$

Now, $$\sigma_{1f} = \sigma_{3f} \tan^2\left(45° + \frac{\phi}{2}\right)$$

$$\Rightarrow \quad \frac{\sigma_{1f}}{\sigma_{3f}} = \frac{1 + \sin\phi}{1 - \sin\phi} \qquad \left[\because \tan^2\left(45° + \frac{\phi}{2}\right) = \frac{1 + \sin\phi}{1 - \sin\phi}\right]$$

$$\Rightarrow \quad \frac{225 + 125}{125} = \frac{1 + \sin\phi}{1 - \sin\phi}$$

$$\Rightarrow \quad \frac{1 + \sin\phi}{1 - \sin\phi} = \frac{14}{5}$$

$$\therefore \quad \phi = \sin^{-1}\left(\frac{9}{19}\right)$$

6. **(d)**

As per Karman-Cozney relation

$$k = \left(\frac{\gamma}{\mu}\right)_{\text{fluid}} \cdot \frac{e^3}{1+e} CD^2$$

7. **(c)**

As volume of soil solids remains constant,

$$\therefore \quad (V_s)_{\text{fill}} = (V_s)_{\text{Borrow pit}}$$

$$\Rightarrow \quad \left(\frac{V_T}{1+e}\right)_{\text{fill}} = \left(\frac{V_T}{1+e}\right)_{\text{Borrow pit}}$$

$$\Rightarrow \quad \frac{1.5}{1+1} = \frac{(V_T)_{\text{Borrow pit}}}{1+1.25}$$

$$\Rightarrow \quad (V_T)_{\text{Borrowpit}} = \frac{1.5 \times 2.25}{2} = 1.68 \text{ Mm}^3$$

8. **(d)**

Vertical stress at a depth z below line load of infinite length is

$$\sigma_z = \frac{2q}{\pi z}$$

$$= \frac{2 \times 100}{\pi \times 5} = 12.7 \text{ kN/m}^2$$

9. **(c)**

$$\text{Relative density, } I_D = \frac{\dfrac{1}{\gamma_{d\min}} - \dfrac{1}{\gamma_d}}{\dfrac{1}{\gamma_{d\min}} - \dfrac{1}{\gamma_{\max}}}$$

Dry unit weight of sand in the field,

$$\gamma_d = \frac{\gamma}{1+w}$$

$$= \frac{20}{1+0.1} = \frac{20}{1.1}$$

$$= 18.18 \text{ kN/m}^3$$

$$\therefore \quad I_D = \frac{\dfrac{1}{16} - \dfrac{1}{18.18}}{\dfrac{1}{16} - \dfrac{1}{20}}$$

$$= \frac{\dfrac{1}{16} - \dfrac{1}{18.18}}{\dfrac{1}{80}}$$

$$= 5 - \frac{80}{18.18}$$
$$= 5 - 4.4$$
$$= 0.6 \text{ or } 60\%$$

11. (c)

As per Engineering News formula,

$$Q_u = \frac{WH}{S + C}$$

For drop hammer,

$$c = 2.5 \text{ cm}$$

$$\therefore \quad Q_u = \frac{1000 \times 200}{1 + 2.5} \text{kg}$$
$$= \frac{200}{3.5} \text{tonnes} = 57.14 \text{ tonnes}$$

15. (c)

Track modulus is a measure of stiffness of the track and is defined as load per unit length of the rail, required to produce a unit depression in the track.

16. (b)

Methods for tunneling in rock areas:

(i) Full face method

(ii) Heading and beaching method

(iii) Drift method

Compressed air method is done for loose and very soft soil.

18. (c)

In subtense bar method, a bar of fixed length, called a subtence bar is placed in horizontal position. The angle subtended by two target points, corresponding to fixed distance on subtense bar, at the instrument station is measured. The distance between the subtence bar and the instrument is computed from the known distance between the targets and the measured horizontal angle. So there will be no refraction error.

20. (b)

- Combined correction due to curvature and refraction = – $0.0673d^2$.

22. (d)

Using Simpson's rule,

$$\text{Area} = \frac{x}{3}\left[\left(y_0 + y_2\right) + 4y_1\right]$$

where x is the offset interval and y_0, y_1 and y_2 are consecutive ordinates.

$$\therefore \quad \text{Area} = \frac{4}{3}\left[1.36 + 1.94 + 4(2.7)\right]$$

$$= \frac{4}{3}[3.3 + 10.8]$$

$$= \frac{4 \times 14.1}{3} = 18.8 \text{ m}^2$$

23. (b)

The satellites are placed in orbits such that there are six orbits having four satellites each.

24. (b)

$$\text{Longitude} = 60°40'\text{E}$$

$$\therefore \quad 60° = 60 \times 4 \text{ min}$$

$$= 240 \text{ min.} = 4 \text{ hour}$$

$$40' = 40 \times 4 = 160 \text{ sec}$$

$$= 2 \text{ min } 40 \text{ sec}$$

$$\therefore \quad \text{Longitude} = 60°40'\text{E} = 4 \text{ h } 2 \text{ min } 40 \text{ s}$$

$$\text{Greenwich mean time} = \text{Local mean time} - \text{Longitude in time}$$

$$= 8 \text{ h } 20 \text{ m} - 4 \text{ h } 2 \text{ m } 40 \text{ s}$$

$$= 4 \text{ h } 17 \text{ m } 20\text{s}$$

25. (a)

In basins with smaller drainage densities, overland flow is predominant.

26. (a)

For triangular unit hydrograph,

$$\frac{\text{Area of DRH}}{\text{Rainfall excess}} = \text{Area of catchment (A)}$$

$$\Rightarrow \quad A = \frac{\frac{1}{2} \times 56 \times 3600 \times 25}{10^{-2}} \text{m}^2$$

$$= 28 \times 3600 \times 25 \times 10^2 \times 10^{-6} \text{ km}^2 = 252 \text{ km}^2$$

27. (d)

The flow in a river during a flood belongs to the category of gradually varied unsteady flow.

28. (a)

IUH is a single peaked hydrograph with a finite base width.

29. (c)

Slope of the flow duration curve depends on the interval of data selected.

30. (c)

Rainfall during 1^{st} and 4^{th} hour will not produce any runoff as the ϕ-index is more than rainfall intensity.

$$\text{Runoff} = (2.4 - 2.1) \times 1 + (2.5 - 2.1) \times 1$$

$$= 0.3 + 0.4 = 0.7 \text{ cm}$$

31. (b)

In case of cascade aerators, the reduction of CO_2 is usually in the range of 50 – 60%.

32. (b)

During sedimentation with coagulants, very fine suspended particles and some bacteria are removed.

33. (a)

$$\text{For incoming water, } (pH)_1 = 7 = -\log_{10}[H^+]_1$$

$$\text{For outgoing water, } (pH)_2 = 8 = -\log_{10}[H^+]_2$$

$$\therefore \quad [H^+]_1 = 10^{-7} \text{ and } [H^+]_2 = 10^{-8}$$

$$\therefore \quad [H^+]_{Avg} = \frac{[H^+]_1 + [H^+]_2}{2} = \frac{10^{-7} + 10^{-8}}{2}$$

$$= \frac{10^{-8}[10+1]}{2} = 5.5 \times 10^{-8}$$

$$\therefore \quad (pH)_{avg} = -\log_{10}[5.5 \times 10^{-8}]$$

$$= -\log_{10}[10^{-8}] - \log_{10}[5.5]$$

$$= 8 - 0.74 = 7.26$$

34. (a)

An approximate analysis of TDS is after made by determining the electrial conductivity of water. The ability of water to conduct electricity is known as specific conductance is a function of its ionic strength.

35. (c)

The rate at which the dissolved oxygen is used will depend on the quantity of the organics, the ease with which they are bio-degraded, and the dilution capacity of the stream.

36. (b)

- Colloidal suspensions that do not agglomerate naturally are stable.
- The net force becomes attractive after passing the energy barrier.

37. (d)

Effective size of filter sand in slow sand filter varies from 0.2 mm to 0.4 mm.

38. (d)

Relative abundance of the phases depends upon both the pH and temperature of the wastewater.

39. (b)

$$\text{Capacity of the digestion tank} = \left[V_1 - \frac{2}{3}(V_1 - V_2)\right]t$$

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

$$= \left[75 - \frac{100}{3}\right] \times 30 = 1250 \text{ m}^3$$

42. (b)

Tri-calcium silicate produces more calcium hydroxide as compared to di-calcium silicate.

44. (c)

1 m^3 of concrete requires 5.8 bags of cement.

$\therefore$ 0.92 m^3 of concrete will require 0.92 × 5.8

$= 5.336$ bags of cement

To avoid the fractional usage, 5 bags of cement shall be used.

Hence, volume of concrete required,

$$= \frac{5}{5.336} \times 0.92$$

$$= 0.86 \text{ m}^3$$

45. (a)

- The pH value should generally be in between 6 – 8.
- Free vegetable oil is harmful but mineral oil upto 2% is beneficial.

46. (c)

- Crown glass is an improvement over soda-lime glass which is obtained by adding alumina and magnesium oxide with soda lime glass.
- Lead glass, also known as flint glass, is obtained by fusing a mixture of silica, lead and potash.

47. (*)

- Cement with higher lime saturation factor will make more C_3S hence that will be rapid hardening.
- High alumina cement is slow setting rapid hardening cement. Its initial setting time is 3.5 hour not less than 30 minutes. It achieve 30 MPa strength within 24 hour.

49. (c)

Gauged Mortar: To improve the quality of lime mortar and to achieve early strength, the cement is sometimes added in it. It is also known as composite mortar or lime cement mortar.

50. (d)

- Non-refractory timbers can be rapidly seasoned without any trouble.
- Highly refractory timbers are likely to get damaged severely during seasoning.

51. (b)

- Crushing strength of good stone should be atleast 100 N/mm^2.
- Specific gravity of good stone should not be less than 2.7.

54. (a)

$$\text{Power per wheel} = \frac{3000}{2} = 1500 \text{ kW}$$

$$P = \eta_0 \times \gamma \times Q \times H$$

$$\Rightarrow \quad 1500 = 0.9 \times 9.81 \times Q \times 270$$

$$\Rightarrow \quad Q = 0.63 \text{ m}^3/\text{sec.}$$

$$\text{Velocity of jet, } V = C_v\sqrt{2gH}$$
$$= 0.95 \times \sqrt{2 \times 9.81 \times 270}$$
$$= 69.14 \text{ m/s}$$
$$\therefore \quad Q = \frac{\pi}{4} \times d^2 \times V_1$$
$$\Rightarrow \quad 0.63 = \frac{\pi}{4} \times d^2 \times 69.14$$
$$\Rightarrow \quad d = 0.1077 \text{ m}$$
$$= 10.77 \text{ cm}$$

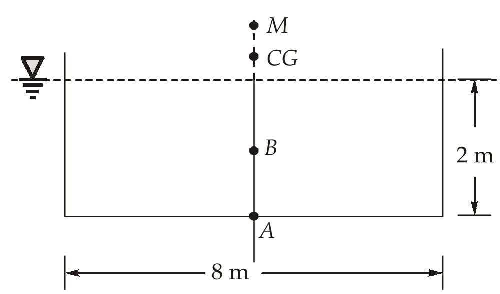
55. (b)

$$\frac{V_w - V_1}{\sqrt{g \cdot y_1}} = \left[\frac{1}{2} \times \frac{y_2}{y_1} \times \left(\frac{y_2}{y_1} + 1\right)\right]^{1/2}$$

Here,
$$y_1 = 1.3 \text{ m}$$
$$y_2 = 2y_1 = 2.6 \text{ m}$$
$$V_1 = 2 \text{ m/s}$$

Now,
$$V_w - 2 = \sqrt{9.81 \times 1.3} \times \left[\frac{1}{2} \times \frac{2.6}{1.3} \times \left(\frac{2.6}{1.3} + 1\right)\right]^{1/2}$$
$$\Rightarrow \quad V_w = 8.185 \text{ m/s}$$

58. (d)



$$\text{Metacentric height, } MA = AB + BM$$

Here, A = A point on the bottom of the barge lying on the vertical axis of symmetry

B = Centre of buoyancy. Since the submerged volume is rectangular prism, B lies on the vertical axis of symmetry and is equal to half the draft.

$$\therefore \quad AB = 1 \text{ m}$$

Now
$$MA = AB + BM$$
$$MB = AB + \frac{I}{\forall} \qquad \left(\because BM + \frac{I}{\forall}\right)$$

$$= 1 + \frac{\frac{15 \times 8^3}{12}}{15 \times 8 \times 2}$$

$$= 3.667 \text{ m} \simeq 3.67 \text{ m}$$

59. (a)

$$V_r = \frac{1}{r}\frac{\partial \psi}{\partial \theta}$$

$$= u_\infty \left[1 - \frac{a^2}{r^2}\right] r \cdot \cos\theta$$

At $r = a$ and $\theta = 90°$, $V_r = 0$

61. (c)

Relative velocity of plane w.r.t. wind = 200 – (– 60)

= 260 km/hr

= 72.2 m/sec.

In pitot tube: $$\frac{\Delta P}{\gamma} = \frac{V^2}{2g}$$

$$\Rightarrow \quad \Delta P = \frac{\rho V^2}{2} = \frac{1.2 \times (72.2)^2}{2}$$

= 3127.7 Pa

= 3.128 kPa $\simeq$ 3.13 kPa

62. (b)

For smooth as well as rough pipes,

$$\frac{U_m - u}{V^*} = 5.75 \log \frac{r_0}{y} + 3.75$$

$$\Rightarrow \quad \frac{4.5 - 4.2}{V^*} = 5.75 \log \frac{0.3}{0.3 - 0.1} + 3.75$$

$$\Rightarrow \quad \frac{0.3}{V^*} = 5.75 \log 1.5 + 3.75$$

$$\Rightarrow \quad V^* = 0.063 \text{ m/s}$$

Now, mean velocity V is related to U_m as,

$$\frac{U_m - V}{V^*} = 3.75$$

$$\Rightarrow \quad \frac{4.5 - V}{0.063} = 3.75$$

$$\Rightarrow \quad V = 4.264 \text{ m/s}$$

$$\therefore \quad Q = \frac{\pi}{4} \times D^2 \times V$$

$$= \frac{\pi}{4} \times 0.6^2 \times 4.264 = 1.2 \text{ m}^3/\text{sec.}$$

63. (a)

For an inclined pipe, $$V_{avg.} = \frac{1}{8\mu}\left[-\frac{\partial(p+\gamma z)}{\partial l}\right] \times R^2$$

$$\Rightarrow \quad \frac{-\partial}{\partial l}(p+\gamma z) = \frac{8V_{avg.}\mu}{R^2}$$

$$\Rightarrow \quad \frac{-\partial}{\partial l}(p+\gamma z) = \frac{8 \times 0.7 \times 0.07}{(0.01)^2}$$

$$\Rightarrow \quad \frac{\partial p}{\partial l} + \gamma\frac{\partial z}{\partial l} = -3920$$

$$\Rightarrow \quad 0 + \gamma\frac{\partial z}{\partial l} = -3920$$

$$\Rightarrow \quad \frac{\partial z}{\partial l} = \frac{-3920}{0.86 \times 1000 \times 9.81} = -0.46$$

[Negative sign indicates that pipe is sloping downwards]

65. (d)

$$F_D = C_D \times \frac{1}{2}\rho \cdot A \times u_\infty^2$$

Here $$C_D = \frac{1.328}{\sqrt{R_e}} = \frac{1.328}{\sqrt{4 \times 10^4}} = 6.64 \times 10^{-3}$$

$$\therefore \quad F_D = 6.64 \times 10^{-3} \times \frac{1}{2} \times 0.925 \times 10^3 \times (0.45 \times 0.15) \times 6^2$$

$$= 7.46 \text{ N}$$

68. (a)

$$\text{L.R.} = \frac{E_{(i)}}{2Ee_{(e)}} = \frac{1.5}{2 \times 10} = 0.075$$

Also, $$LR = \frac{d_i - C_u}{d_i}$$

$$\Rightarrow \quad d_i = \frac{C_u}{1 - LR} = \frac{6}{1 - 0.075} = 6.5 \text{ cm}$$

$$\therefore \quad d_d = d_i - C_u = 6.5 - 6 = 0.5 \text{ cm}$$

70. (c)

Limiting height of the dam, $H_C = \dfrac{f}{\gamma_w (G - C + 1)}$

here, $f = 250 \text{t/m}^2 = 250\,\gamma_w \text{ kN/m}^2$

$G = 2.5$

$C = 0.5$

$\therefore \quad H_C = \dfrac{250 \times \gamma_w}{\gamma_w [2.5 - 0.5 + 1]}$

$= \dfrac{250}{3} = 83.33 \text{ m}$

71. (d)

Pressure intensity, $p_w = 2.4\,\gamma_w.\,h_w$

where $h_w = 0.032\sqrt{V.F}$

$= 0.032\sqrt{70 \times 40}$

$= 1.693 \text{ m}$

$\therefore \quad p_w = 2.4 \times 9.81 \times 1.693$

$= 39.86 \text{ kN/m}^2$

73. (b)

A water logged soil warms up slowly and due to lower temperature, action of soil bacteria is sluggish and plant food available is less.

Therefore fall in soil temperature occurs due to water logging.

74. (a)

Hydraulic mean depth, $R = \dfrac{5}{2}\left[\dfrac{V^2}{f}\right]$

here, $V = 0.85 \text{ m/sec.}$

$f = 1.76\sqrt{d_{mm}} = 1.76\sqrt{0.2} = 0.79$

$\therefore \quad R = \dfrac{5}{2} \times \left[\dfrac{0.85^2}{0.79}\right] = 2.29 \text{ m}$

76. (b)

The minimum grade of concrete shall be M20 for all buildings which are more than three storeys in height.

77. (a)

$$L_d \leq \frac{1.3M_1}{V_u} + L_0$$

$$\Rightarrow \quad L_d \le \frac{1.3 \times 260 \times 10^6}{234 \times 10^3} + 660$$

$$\le 2104.44 \text{ mm} \simeq 2105 \text{ mm}$$

80. (c)

The deflection including the effects of temperature, creep and shrinkage occurring after the erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

81. (c)

As per Rankine Grashoff method,

Short span moment, $M_{ux} = \alpha_x, w_u. l_x^2$

Here moment coefficient $\alpha_x = \frac{1}{8}\left[\frac{r^4}{1+r^4}\right]$

Here $r = \frac{l_y}{l_x}$

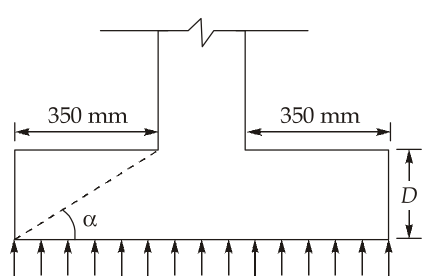
$$l_y = 5000 + (200 - 25) = 5175 \text{ mm} = 5.175 \text{ m}$$

$$l_x = 4000 + (200 - 25) = 4175 \text{ mm} = 4.175 \text{ m}$$

$$\therefore \quad r = \frac{5.175}{4.175} = 1.24$$

$$\therefore \quad \alpha_x = \frac{1}{8}\left[\frac{(1.24)^4}{1+(1.24)^4}\right] = 0.0878$$

82. (d)



$$q_0 = 360 \text{ kN/m}^2$$

$$D = 350 \tan\alpha$$

Also, $\tan\alpha \ge 0.9\sqrt{\frac{100q_0}{f_{ck}} + 1}$

Here, $q_0 = 360 \text{ kN/m}^2 = 0.36 \text{ N/mm}^2$

$$f_{ck} = 20 \text{ N/mm}^2$$

$$\therefore \quad D \ge 350 \times 0.9\sqrt{\frac{100 \times 0.36}{20} + 1}$$

$$\Rightarrow \quad D \ge 527.096 \text{ mm} \simeq 530 \text{ mm (say)}$$

84. (c)

Equivalent upward concentrated load,

$$W_c = 2P\sin\theta$$

$$\text{For small angles, } \sin\theta \simeq \tan\theta = \frac{e}{\left(\frac{L}{2}\right)}$$

$$\therefore \quad W_e = 2P \times \frac{e}{\frac{L}{2}} = \frac{4Pe}{L}$$

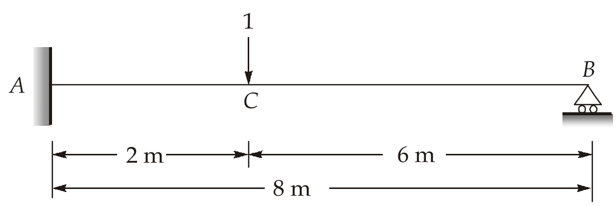
87. (b)

Stiffness matrix can be derived for flexible structures only.

88. (b)

For finding the ordinate of ILD, apply a unit load at 2 m from fixed end as shown in figure below.

Now,



$$M_{FAB} = \frac{-1 \times 2 \times 6^2}{8^2} = \frac{-9}{8}\,\text{m}$$

$$M_{FBA} = \frac{1 \times 6 \times 2^2}{8^2} = \frac{3}{8}\,\text{m}$$

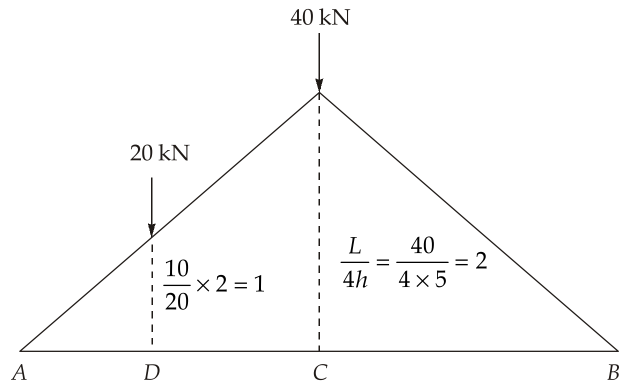
Now, distribution of moments is done as below.

Joint	A	B
F.E.M.	$\frac{-9}{8}$	$\frac{3}{8}$
End correction	$\frac{-3}{16}$ ←	$-\frac{3}{8}$
Final moment (in kNm)	$\frac{-21}{16}$	

89. (a)

ILD for horizontal thrust is shown below.

$$\text{Horizontal thrust at support, } H = 20 \times 1 + 40 \times 2 = 100 \text{ kN}$$



Alternatively:

$$\Sigma M_B = 0$$

$\Rightarrow$ $V_A(40) = 40(20) + 20(30)$

$\Rightarrow$ $V_A = 35$ kN

$\therefore$ $V_A = (20 + 40) - 35 = 25$ kN

$\Sigma M_C = 0$ (from right)

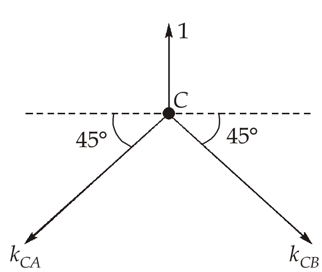
$V_B(20) = H(5)$

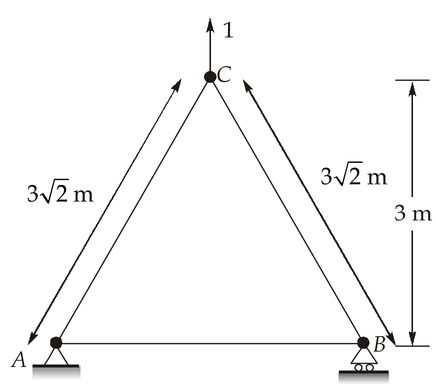
$\Rightarrow$ $H = \dfrac{25 \times 20}{5} = 100\,\text{kN}$

90. (b)

Apply a unit load at joint C as shown in figure below.

Considering joint C,





$$\Sigma F_x = 0$$

$\Rightarrow$ $k_{CA}\cos 45° - k_{CB}\cos 45° = 0$

$\Rightarrow$ $k_{CA} = k_{CB}$

$$\Sigma F_y = 0$$

$$\Rightarrow \quad k_{CA}\sin 45° + k_{CB}\sin 45° - 1 = 0$$

$$\Rightarrow \quad k_{CA} = +\frac{1}{\sqrt{2}}$$

So, $k_{CB} = k_{CA} = +\frac{1}{\sqrt{2}}$

Now, vertical deflection of C, $\Delta_C = \Sigma k_i L\alpha\Delta T$

$$= [k_{AC}L_{AC} + k_{BC}L_{BC}] \times \alpha \times \Delta T$$

$$= \left(\frac{1}{\sqrt{2}} \times 3\sqrt{2} + \frac{1}{\sqrt{2}} \times 3\sqrt{2}\right) \times 1.2 \times 10^{-5} \times 20$$

$$= 1.44 \times 10^{-3} \text{ m}$$

$$= 1.44 \text{ mm}$$

91. (b)

Natural frequency, $w_n = \sqrt{\frac{k}{m}}$

$$= \sqrt{\frac{10^5}{10^3}} = 10 \text{ rad/s}$$

95. (d)

Throat thickness, $t_t = k.S$

where k is constant which depends on angle between the faces of connected plates and 'S' is size of fillet weld.

Angle between fusion faces	k
60° – 90°	0.70
91° – 100°	0.65
101° – 106°	0.60
107° – 113°	0.55
114° – 120°	0.50

$\therefore$ $t_t = k.S$

$$= (0.55) \times 10 = 5.5 \text{ mm}$$

96. (c)

Equivalent stress, $f_{eq.} = \sqrt{(f_2)^2 + 3(f_1)^2}$

where, f_1 is direct vertical shear stress and f_2 is bending stress,

$\therefore$ $f_{eq} = \sqrt{(100)^2 + 3(50)^2}$

$$= 132.2875 \text{ MPa}$$

$$\simeq 132.29 \text{ MPa}$$

98. (a)

The design flexural capacity of the compact section is given by

$$M_d = f_d \cdot Z_p$$
$$= 200 \times 800 \times 10^3 \times 10^{-6} \text{ kN-m}$$
$$= 160 \text{ kN-m}$$

99. (b)

Shape factor, (SF) is given by

$$S.F. = \frac{M_p}{M_y} \quad ...(i)$$

$$\Rightarrow \quad S.F. = \frac{Z_p \cdot f_y}{Z_e \cdot f_y}$$

$$\Rightarrow \quad S.F. = \frac{Z_p}{Z_e} \quad ...(ii)$$

Now from (i),

$$M_y = \frac{M_p}{S.F.} = \frac{165\,\text{kNm}}{1.5} = 110\,\text{kNm}$$

Now from (ii),

$$Z_e = \frac{Z_p}{S.F.} = \frac{7.5\times10^{-4}}{1.5} = 5\times10^{-4}\text{ m}^3$$

Now yield stress (f_y) of material is given by

$$f_y = \frac{M_y}{Z_y} = \frac{110\times10^3}{5\times10^{-4}}\text{N/m}^2$$
$$= 220 \times 10^6 \text{ N/m}^2$$
$$= 220 \text{ N/mm}^2 = 220 \text{ MPa}$$

100. (a)

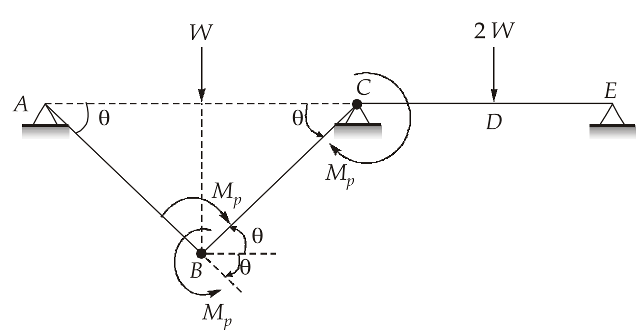
Number of plastic hinges, required for collapse

$$n = D_s + 1$$

Degree of static indeterminacy, $D_s = 3 - 2 = 1$

$$\therefore \quad n = 1 + 1 = 2$$

(i) Mechanism 1

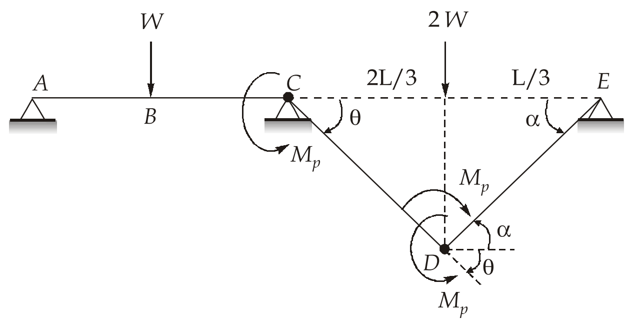


External workdone = Internal workdone

$$\Rightarrow \quad W\left(\frac{L}{2}\theta\right) = M_p(2\theta) + M_p(\theta)$$

$$\Rightarrow \quad W = \frac{6M_p}{L}$$

(ii) Mechanism 2



Now, External workdone = internal workdone

$$\Rightarrow \quad (2W)\left(\frac{2L}{3}\theta\right) = M_p\theta + M_p(\theta + \alpha)$$

$$\Rightarrow \quad \frac{4WL}{3}\theta = M_p\theta + M_p(\theta + 2\theta) \qquad \left[\because \frac{2L}{3}\theta = \frac{L}{3}\alpha\right]$$

$$\Rightarrow \quad \frac{4WL}{3}\theta = 4M_p\theta$$

$$\Rightarrow \quad W = \frac{3M_p}{L}$$

$$\text{Collapse load, } W = \text{Minimum of} \begin{cases} \text{(i) Mechanism 1} \\ \text{(ii) Mechanism 2} \end{cases}$$

$$\Rightarrow \quad W = \frac{3M_p}{L}$$

102. (b)

The non-dimensional slenderness ratio, λ is given by

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

$$= \sqrt{\frac{250}{800}} = 0.5590 \simeq 0.56$$

103. (b)

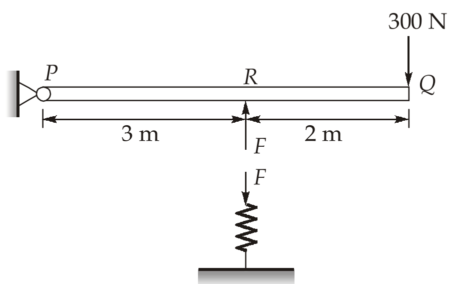
Poisson's ratio, μ is given by

$$\mu = \frac{-\Delta d/d}{\Delta l/l}$$

$$= \frac{-(-0.005/50)}{(0.200/500)} = 0.25$$

104. (a)

FBDs of bar and spring are shown below.



$$\Sigma M_P = 0$$

$$\Rightarrow \quad -(F)(3) + 300(5) = 0$$

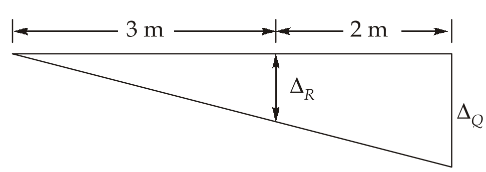
$$\Rightarrow \quad F = 500 \text{ N}$$

Now, $F = k\Delta_R$

$$\Rightarrow \quad 500 \text{ N} = 200\frac{\text{N}}{\text{mm}} \times \Delta_R$$

$$\Rightarrow \quad \Delta_R = 2.5 \text{ mm}$$

Now from similar triangles concept,



$$\frac{\Delta_Q}{5} = \frac{\Delta_R}{3}$$

$$\Rightarrow \quad \Delta_Q = \frac{2.5 \times 5}{3} = 4.167 \text{ mm} \simeq 4.17 \text{ mm}$$

105. (d)

Elongation of tapered bar, Δl is given by

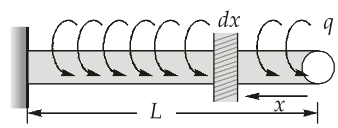
$$\Delta l = \frac{PL}{\frac{\pi}{4} d_1 \cdot d_2 \cdot E} = \frac{500 \times 10^3 \times 2 \times 10^3}{\frac{\pi}{4} \times 40 \times 70 \times 200 \times 10^3}$$

$$= 2.27 \text{ mm}$$

106. (b)

If a body is loaded under plane stress conditions (2D), then number of independent stress components is 3 i.e. two normal stress components and one shear component. However,. in a 3D stress condition, there will be 6 independent stress components i.e. 3 normal components and 3 shear stress components.

107. (c)



Strain energy stored, U is given by

$$U = \int \frac{T_x^2 \cdot dx}{2GJ}, \qquad \text{where,} \quad T_x = q \cdot x$$

$$= \int_0^L \frac{(qx)^2\, dx}{2GJ}$$

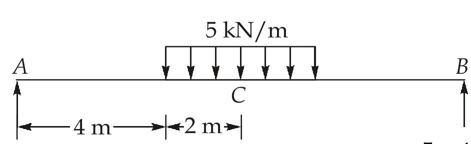
$$= \frac{q^2}{2GJ}\left[\frac{x^3}{3}\right]_0^L$$

$$= \frac{q^2 L^3}{6GJ}$$

$$= \frac{(5 \times 1000)^2 (10)^3}{6 \times 80 \times 10^9 \times 120 \times 10^{-6}} \text{ N-m}$$

$$= 434.03 \text{ N-m} \simeq 434 \text{ Joules}$$

108. (a)



$$R_A = \frac{5 \times 4}{2} = 10\,\text{kN} \qquad R_B = \frac{5 \times 4}{2} = 10\,\text{kN}$$

$$(BM)_c = (10 \times 6) - (5 \times 2)(1)$$
$$= 60 - 10 = 50 \text{ kN-m}$$

110. (a)

$$\sigma_x = 100 \text{ MPa}, \sigma_y = -80 \text{ MPa}$$
$$\tau_{xy} = 50 \text{ MPa}$$

The radius of Mohr's circle, r is given as

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

$$= \sqrt{\left(\frac{100-(-80)}{2}\right)^2 + 50^2}$$

$$= 102.956 \text{ MPa} \simeq 103 \text{ MPa}$$

111. (a)

The centre of Mohr's circle, O is given by

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

$$= \left(\frac{100-80}{2}, 0\right) = (10, 0)$$

112. (d)

Principal stresses $\sigma_{1,}/\sigma_2$ is given by

$$\sigma_{1,}/\sigma_2 = \left(\frac{\sigma_x + \sigma_y}{2}\right) \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2}$$

$$= \left(\frac{100-80}{2}\right) \pm \sqrt{\left(\frac{100-(-80)}{2}\right)^2 + (50)^2}$$

$$= 10 \pm 102.96$$

$\therefore$ Maximum principal stress, $\sigma_1 = 112.96 \text{ MPa} \simeq 113 \text{ MPa}$

113. (b)

$$\sigma_1 = 100 \text{ MPa}, \sigma_2 = 40 \text{ MPa}, \sigma_3 = 0$$

According to maximum principal stress theory

$$\sigma_{max} \le \sigma_y$$

$$\therefore \quad \sigma_{max} = \frac{\sigma_y}{FOS}$$

$$\Rightarrow \quad 100 = \frac{200}{FOS}$$

$$\Rightarrow \quad \text{FOS} = 2$$

According to maximum shear stress theory

$$\tau_{max,\ absolute} \le \frac{\sigma_y}{2}$$

$$\therefore \quad \tau_{max,\ absolute} = \left(\frac{\sigma_y}{2}\right) \times \frac{1}{FOS}$$

$$\Rightarrow \qquad \left(\frac{\sigma_1 - \sigma_3}{2}\right) = \left(\frac{\sigma_y}{2}\right) \times \frac{1}{FOS}$$

$$\Rightarrow \qquad \left(\frac{100 - 0}{2}\right) = \left(\frac{200}{2}\right) \times \left(\frac{1}{FOS}\right)$$

$$\Rightarrow \qquad \text{FOS} = 2$$

115. (b)

$$\text{Moment of inertia, } I = \frac{b.d^3}{12} = \frac{100 \times (200)^3}{12}$$

$$= \frac{800}{12} \times 10^6 \text{ mm}^4$$

Now deflection at free end of cantilever beam due to load (W) at free end is given by

$$\Delta = \frac{WL^3}{3EI}$$

$$\Rightarrow \qquad 10 = \frac{W \times (2000)^3}{3 \times 200 \times 10^3 \times \frac{800 \times 10^6}{12}}$$

$$\Rightarrow \qquad W = 50{,}000 \text{ N} = 50 \text{ kN}$$

116. (a)

The maximum shear stress for triangular cross-section is given by

$$\tau_{\max} = \frac{3}{2}\tau_{avg}$$

$$= \frac{3}{2} \cdot \frac{F}{A}$$

$$\text{Area, } A = \frac{1}{2} \times b \times h = \frac{1}{2} \times 200 \times 250 = 25{,}000 \text{ mm}^2$$

$$\therefore \qquad \tau_{\max} = \frac{3}{2} \times \frac{100 \times 10^3}{25{,}000} = 6 \text{ N/mm}^2 = 6 \text{ MPa}$$

117. (c)

Equivalent bending moment, M_{eq} is given by

$$M_{eq} = \frac{M + \sqrt{M^2 + T^2}}{2}$$

$$= \frac{4 + \sqrt{4^2 + 3^2}}{2} = 4.5 \text{ kN-m}$$

Equivalent twisting moment, $T_{eq.}$ is given as

$$T_{eq} = \sqrt{M^2 + T^2}$$

$$= \sqrt{4^2 + 3^2} = 5 \text{ kN-m}$$

118. (b)

Deflection in closed coil helical spring is given by

$$\Delta = \frac{64PR^3N}{Gd^4}$$

$\Rightarrow$ $$\Delta \propto R^3N$$

Now, $$N_P = 2N_Q$$

and $$R_P = \frac{1}{2}R_Q$$

$\therefore$ $$\frac{\Delta_P}{\Delta_Q} = \left(\frac{R_P}{R_Q}\right)^3 \times \left(\frac{N_P}{N_Q}\right)$$

$$= \left(\frac{R_Q}{2R_Q}\right)^3 \times \left(\frac{2N_Q}{N_Q}\right)$$

$$= \frac{1}{8} \times 2 = \frac{1}{4}$$

120. (a)

Bending stress, σ for leaf spring is given by

$$\sigma = \frac{3Wl}{2n \cdot bt^2}$$

$\Rightarrow$ $$150 = \frac{3 \times 5000 \times l}{2 \times 8 \times 50 \times 6^2}$$

$\Rightarrow$ $$l = 288 \text{ mm}$$

121. (d)

We know that circumferential stress should not be greater than the maximum permissible stress.

Hence, $$\sigma = \frac{Pd}{2t}$$

$\Rightarrow$ $$100 = \frac{P \times 2.5}{2 \times 5 \times 10^{-2}}$$

$\Rightarrow$ $$P = 4 \text{ N/mm}^2$$

122. (c)

Wagon wheel error is a conceptual error.

124. (a)

Gross weight of tractor = 20,000 kg

Hence rolling resistance offered by haul road

= 40 × 20 = 800 kg

Load on driving tyres = 0.6 × 20,000 = 12,000 kg

[Generally in normal vehicle, driving wheel is rear wheel]

Maximum possible rimpull prior to slippage of tyres

$$= \text{Coefficient of traction} \times \text{Load on driving tyres}$$
$$= 0.65 \times 12{,}000 = 7800 \text{ kg}$$

Maximum effective rimpull $= 7800 - 800 = 7000$ kg

125. (b)

From table, for $p = 90\%$, $$Z = 1.2 + \frac{(1.6-1.2)}{(94-88)}(90-88)$$

$$\Rightarrow \quad Z = \frac{4}{3}$$

Now, standard deviation, $\sigma = \sqrt{9} = 3$ days

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

$$\Rightarrow \quad \frac{4}{3} = \frac{T_s - 50}{3}$$

$$\Rightarrow \quad T_s = 54 \text{ days}$$

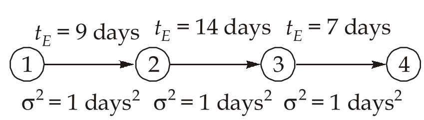
126. (c)

Expected completion time (t_E) of an activity is given by

$$t_E = \frac{(t_0 + 4t_m + t_p)}{6}$$

and variance of an activity (σ^2) is given by

$$\sigma^2 = \left(\frac{t_p - t_0}{6}\right)^2$$



Project completion time, $(T_E) = 9 + 14 + 7 = 30$ days

Variance of project $(\sigma^2) = 1 + 1 + 1 = 3$ days^2

and standard deviation of project, $\sigma = \sqrt{3} = 1.732$ days

Now, range is $T_E - 3\sigma$ to $T_E + 3\sigma$

$= 30 - 3 \times 1.732$ to $30 + 3 \times 1.732$

$= 24.804$ days to 35.196 days

$= 24.8$ days to 35.2 days

129. (a)

$$\text{Annual depreciation} = \frac{C_i - C_s}{n}$$

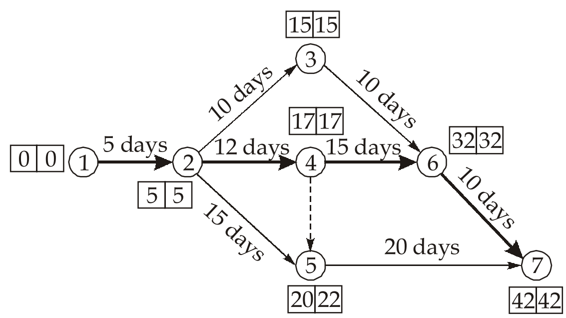
$$= \frac{20,000 - 2000}{6} = \text{Rs. } 3000$$

Book value at the end of 4th year,

$$= 20,000 - 4 \times 3000$$

$$= \text{Rs. } 8000$$

131. (b)



$$\text{Free float}(F_F) = (32) - (15 + 10)$$

$$= 7 \text{ days}$$

132. (c)

In ladder network, the duration will be the sum of the duration of activity having maximum duration and 1/3 of the durations of other two activities.

$$\text{Modified total duration} = 25 + \frac{1}{3}[12 + 15]$$

$$= 34 \text{ days}$$

134. (c)

Stopping sight distance (SSD) is given by

$$\text{SSD} = 0.278Vt_R + \frac{V^2}{254\,f}$$

$$= 0.278(70)(2.5) + \frac{(70)^2}{254 \times 0.35}$$

$$= 103.768 \simeq 104 \text{ m}$$

135. (d)

Optimum cycle time, (C_0) is given by

$$C_0 = \frac{1.5L + 5}{1 - y}$$

$$\Rightarrow \qquad C_0 = \frac{1.5(16)+5}{1-\left[\left(\frac{600}{2000}+\frac{200}{2000}\right)\right]}$$

$$= 48.33 \text{ sec.}$$

136. (b)

The group index value is given by

$$\text{G.I.} = 0.2a + 0.005\,ac + 0.01\,bd$$

where, $a = 60 - 35 = 25 \not> 40$

$b = 60 - 15 = 45 \not> 40$

$\therefore$ $b = 40$

$c = 50 - 40 = 10 \not> 20$

$d = (50 - 42) - 10 = -2 = 0$ (min.)

$\therefore$ $d = 0$

$\therefore$ $\text{G.I.} = 0.2(25) + 0.005(25)(10) + 0.01(40)(0)$

$= 6.25$

137. (b)

The angularity number measures the voids in excess of 33 percent.

138. (b)

Standard diameter of plate is 75 cm

We know that,

$$ka = \text{Constant}$$

where, k is modulus of subgrade reaction a is diameter of plate.

Now, $k_1a_1 = k_2a_2$

$\therefore$ $(8)(75) = k_2(40)$

$\Rightarrow$ $k_2 = 15 \text{ kg/cm}^3$

139. (d)

$$\text{Off tracking} = \frac{l^2}{2R}$$

$$= \frac{(6)^2}{2\times 240} = 0.075 \text{ m} = 7.5 \text{ cm}$$

141. (d)

Rankine's earth pressure theory is a simplified form of coulomb's earth pressure theory.

143. (d)

The rate of biomass production will always be lower than the rate of food utilization in a biological system having mixed culture of microorganisms.

144. (c)

Volute casing in centrifugal pump converts part of velocity head into pressure head.

146. (c)

Shear reinforcement is provided against diagonal tension. As the concrete is strong in compression, generally a beam is safe for diagonal compression. However for any beam, suitably reinforced against diagonal, tension the nominal shear stress will not exceed the maximum shear stress values, given as per IS 456. By this provision, the failure of the beam by diagonal compression is prevented which is a brittle failure.

147. (c)

Strain energy due to axial and shear force are negligible.

150. (c)

IS 1892 : 1979 Cl. 4.1.1 recommends that the inside clearance should be from 1 - 3%. The outside clearance should not be much greater than the inside clearance. Its value usually lies between 0 and 2 percent.

Inside clearance is meant to reduce friction between the soil sample and the sampler when the soil enters the tube, by allowing for elastic expansion. If the inside clearance is too large, there will be too much of lateral expansion. Outside clearance will help reduce friction while the sampler is being driven and when it is being withdrawn after the soil sample has been collected.

■■■■