DETAILED SOLUTIONS

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ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 10

Section A : Structural Analysis [All Topics]

Section B : CPM PERT-I + Hydrology and Water Resource Engineering-I [Part Syllabus]

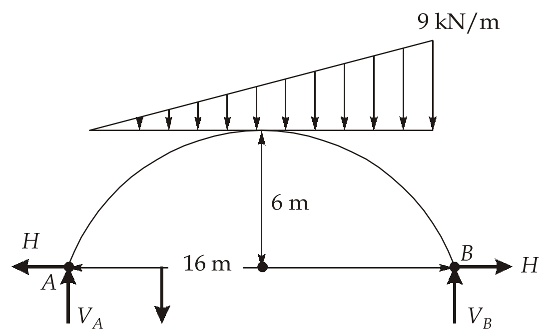
Section C : Design of Steel Structure-II + Surveying and Geology-II [Part Syllabus]

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

DETAILED EXPLANATIONS

1. (c)

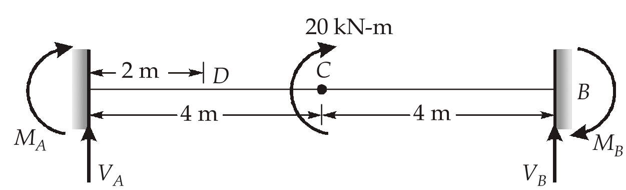
In this case,



$$\text{Horizontal thrust, } H = \frac{wl^2}{16h}$$

$$= \frac{9\times 16^2}{16\times 6} = 24 \text{ kN}$$

2. (b)



Due to moment of 20 kN-m at mid span

$$M_A = \frac{M_c}{4} = \frac{20}{4} = 5\,\text{kN-m}$$

$$M_B = \frac{M_c}{4} = \frac{20}{4} = 5\,\text{kN-m}$$

Now, $\Sigma M_B = 0$

$\Rightarrow$ $V_A \times 8 + 20 + 5 + 5 = 0$

$\Rightarrow$ $V_A = \frac{-30}{8} = -3.75$ kNm

Now, bending moment at D, $(BM)_D = M_A + V_A \times 2$

$= 5 - 3.75 \times 2$

$= -2.5$ kN-m

3. (a)

$$\text{Increase in dip, } dh = \frac{3}{16}\alpha\Delta t\frac{l^2}{h}$$

where $\alpha = 12 \times 10^{-6}/°C$

$\Delta t = 16°C$

$$l = 50 \text{ m}$$
$$h = 6 \text{ m}$$

So,
$$dh = \frac{3}{16} \times 12 \times 10^{-6} \times 16 \times \frac{50^2}{6}$$
$$= 15 \times 10^{-3} \text{ m} = 15 \text{ mm}$$

4. (a)

$$\text{Logarithmic decrement, } \delta = \ln \frac{y_1}{y_2}$$
$$= \ln \frac{1.5}{1.4} = \ln 1.07$$

5. (c)

Let, the left support A sinks by 'Δ' in downward direction.

Now, fixed end moment at A, $M_{FAB} = \frac{-wl^2}{12}$

$$= \frac{-4 \times 6^2}{12}$$
$$= -12 \text{ kN-m}$$

Using slope deflection equation,

$$M_{AB} = M_{FAB} + \frac{2EI}{L}\left(2\theta_A + \theta_B + \frac{3\Delta}{L}\right)$$

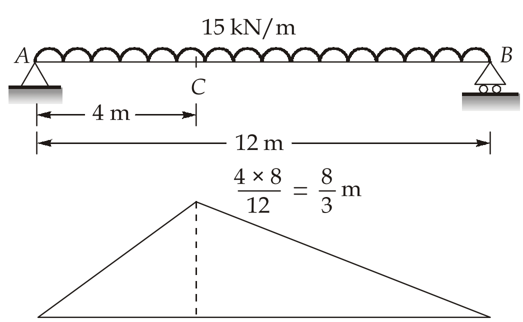
$$\Rightarrow \quad 0 = -12 + \frac{2EI}{6} \times \frac{3\Delta}{6} \qquad [\because \theta_A = \theta_B = 0]$$

$$\Rightarrow \quad 12 = \frac{6EI\Delta}{36}$$

$$\Rightarrow \quad \Delta = \frac{72}{EI}$$

8. (c)

As the load is longer than span, so it should cover the whole span for maximum moment at C.

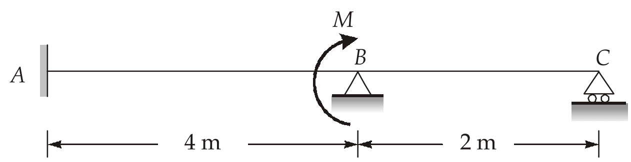


ILD for BM at C

Now,
$$(\text{BM})_C = \frac{1}{2} \times 12 \times \frac{8}{3} \times 15 = 240 \text{ kN-m}$$

10. (d)

Let, a moment 'M' is applied at B to produce unit rotation at B.



Now, in span AB,

$$\text{Stiffness at } B,\ k_{BA} = \frac{4EI}{4} = EI$$

In span BC,

$$\text{Stiffness at } B,\ k_{BC} = \frac{3EI}{2} = 1.5EI$$

So, total moment, $M = k_{BA} + k_{BC}$

$= EI + 1.5EI$

$= 2.5 \times 300$

$= 750$ kN-m

11. (d)

Deflection at midspan when load is at midspan is given by,

$$\Delta = \frac{Pl^3}{192EI}$$

$$= \frac{30 \times 12^3}{192 \times 60000}$$

$= 4.5 \times 10^{-3}$ m

$= 4.5$ mm

12. (c)

There are two methods of approximate analysis:

(i) Portal method for low rise buildings.

(ii) Cantilever method for tall buildings.

Both methods assume an inflection point located at mid height of each column and an inflection point located at the centre of each beam.

13. (c)

Order of flexibility matrix will be equal to degree of static indeterminacy, D_s of beam.

Now, $D_s = r_e - r$

where, $r_e = 3(\text{at } A) + 1(\text{at } B) + 2(\text{at } C)$

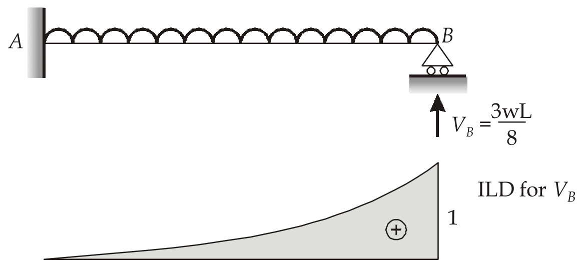
$= 6$

So, $D_s = 6 - 3 = 3$

14. (b)

Due to temperature rise in a three-hinged loaded parabolic arch, central rise increases and horizontal thrust decreases.

15. (d)



$$V_B = w \times \text{Area of ILD under UDL}$$

$$\Rightarrow \quad \frac{3wL}{8} = w \times \text{Area}$$

$$\text{Area} = \frac{3L}{8}$$

16. (a)

Order of stiffness matrix is equal to degree of kinematic indeterminacy.

17. (a)

$$\text{Degree of freedom, } D_k = 4(\theta_B, \theta_{C1}, \theta_{C2} \text{ and } \Delta_C)$$

18. (d)

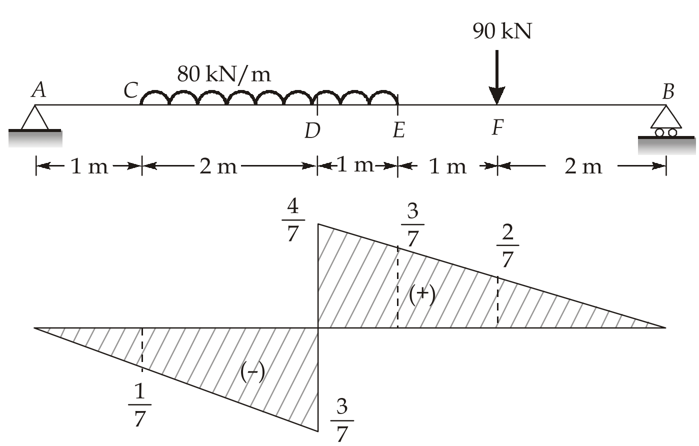
Degree of static indeterminacy,

$$D_s = m + r_e - 2j$$
$$= 7 + 3 - 2 \times 5$$
$$= 0$$

As the truss is statically determinate and so no force will be induced in members due to lack of fit.

19. (c)

Influence line diagram for shear force at D is shown in figure below.



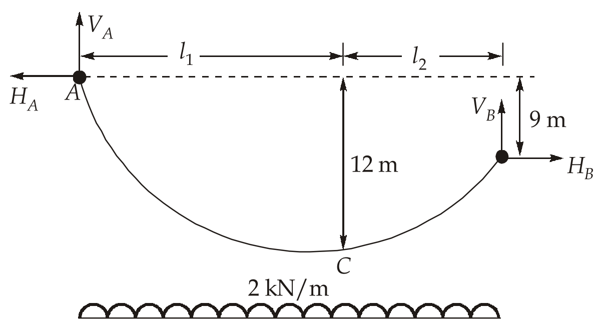
So, $$(\text{S.F.})_D = \left[\frac{-1}{2}\left(\frac{1}{7}+\frac{3}{7}\right)\times 2\right]\times 80 + \left[\frac{1}{2}\left(\frac{4}{7}+\frac{3}{7}\right)\times 1\right]\times 80 + 90\times\frac{2}{7}$$

$$= \frac{-320}{7} + \frac{280}{7} + \frac{180}{7}$$

$$= \frac{140}{7} = 20\text{ kN}$$

20. (c)

In cables,



$$\frac{l_1}{l_2} = \sqrt{\frac{y_c + d}{y_c}}$$

where $y_C + d = 12\text{ m}$

$\Rightarrow$ $y_c = 12 - 9 = 3\text{ m}$

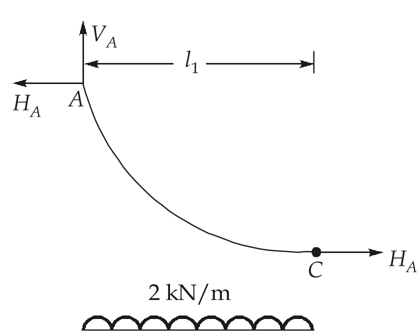
So, $$\frac{l_1}{l_2} = \sqrt{\frac{12}{3}} = 2$$

Also, $l_1 + l_2 = 30$

$\Rightarrow$ $2l_2 + l_2 = 30$

$\Rightarrow$ $l_2 = 10\text{ m and } l_1 = 20\text{ m}$

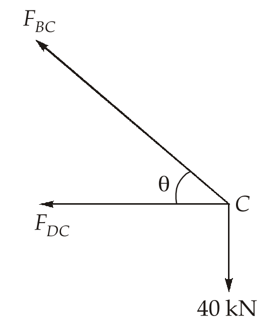
Now, in portion AC



$$V_A = 2l_1$$
$$= 2\times 20 = 40\text{ kN}$$

21. (a)

Considering joint C,



$$\tan\theta = \frac{3}{3}$$

$$\Rightarrow \quad \theta = 45°$$

$$\Sigma F_y = 0$$

$$\Rightarrow \quad F_{BC}\sin\theta - 40 = 0$$

$$\Rightarrow \quad F_{BC} = \frac{40}{\sin\theta} = 40\sqrt{2}\ \text{kN (Tensile)}$$

$$\Sigma F_x = 0$$

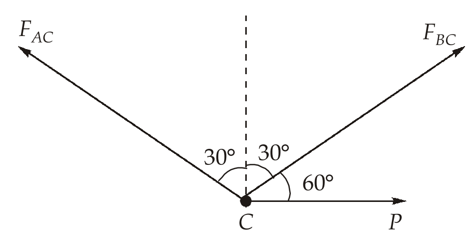
$$\Rightarrow \quad F_{DC} + F_{BC}\cos\theta = 0$$

$$\Rightarrow \quad F_{DC} + 40\sqrt{2}\times\frac{1}{\sqrt{2}} = 0$$

$$\Rightarrow \quad F_{DC} = -40\ \text{kN} = 40\ \text{kN (Compressive)}$$

24. (d)

Considering joining C,



$$\Sigma F_y = 0$$

$$\Rightarrow \quad F_{AC}\cos30° + F_{BC}\cos30° = 0$$

$$\Rightarrow \quad F_{AC} = -F_{BC}$$

$$\Sigma F_x = 0$$

$$\Rightarrow \quad F_{AC}\sin30° - F_{BC}\sin30° - P = 0$$

$$\Rightarrow \quad F_{AC}\times\frac{1}{2} - (-F_{AC})\times\frac{1}{2} = P$$

$$\Rightarrow \quad F_{AC} = P$$

$$\therefore \quad F_{BC} = -P = P\ \text{(Compressive)}$$

Similarly, when a unit load is applied at C,

$$k_{BC} = -1 \text{ and } k_{AC} = 1$$

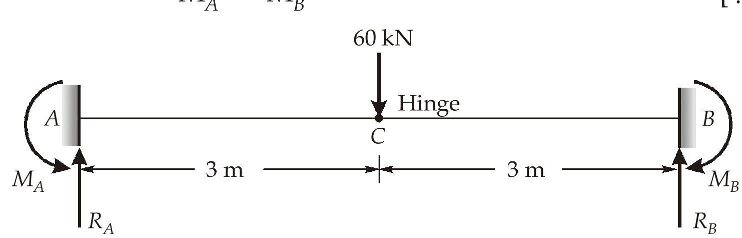
Now, horizontal deflection of C, $\Delta_{HC} = \left(\frac{PkL}{AE}\right)_{AC} + \left(\frac{PkL}{AE}\right)_{BC}$

$$= \frac{P\times1\times L}{AE} + \frac{(-P)(-1)\times L}{AE}$$

$$= \frac{2PL}{AE}$$

25. (b)

Now, $M_A = M_B$ [∵ Due to symmetry]



$$\Sigma M_C = 0 \quad \text{[from left]}$$

$$\Rightarrow \quad -M_A + R_A \times 3 = 0$$

$$\Rightarrow \quad M_A = R_A \times 3$$

where, $R_A = R_B = \dfrac{60}{2} = 30\,\text{kN}$ [∵ Due to symmetry]

So, $M_A = 30 \times 3 = 90$ kN-m

26. (d)

Fixed end moments:

$$M_{FAB} = \frac{-WL}{8} = \frac{-60\times 8}{8} = -60\,\text{kN-m}$$

$$M_{FBA} = \frac{WL}{8} = \frac{60\times 8}{8} = 60\ \text{kN-m}$$

$$M_{FBC} = M_{FCB} = 0$$

Slope deflection equation:

$$M_{BA} = M_{FBA} + \frac{2EI}{L}(2\theta_B + \theta_A)$$

$$= 60 + \frac{2EI}{8}(2\theta_B) \quad [\because \theta_A = 0]$$

$$= 60 + 0.5\,EI\theta_B \quad \text{...(i)}$$

$$M_{BC} = M_{FBC} + \frac{2EI}{L}(2\theta_B + \theta_C)$$

$$= \frac{2EI}{8}(2\theta_B)$$

$$= 0.5EI\,\theta_B \quad \text{...(ii)}$$

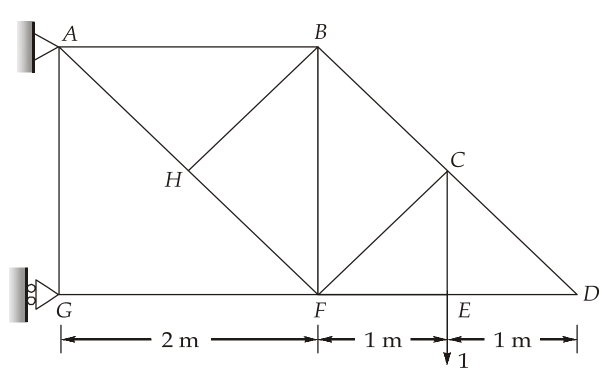
Now, $M_{BA} + M_{BC} = 0$

$$\Rightarrow \quad 60 + 0.5EI\theta_B + 0.5EI\theta_B = 0$$

$$\Rightarrow \quad \theta_B = \frac{-60}{EI}$$

27. (d)

To find vertical deflection of joint '*E*', apply a unit load at *E* and find force in *EF* due to this unit load.



Due to unit load at *E*, there will be no force in *CD*, *DE* and *EF*.

So, vertical deflection of joint F, $\Delta_{VF} = k_{EF} \times \Delta_{EF}$

$= 0 \times (-3) = 0$

30. (d)

BM is less in arch than beams for same loading at a particular section.

31. (c)

Given, $\bar{P} = 480 \text{ mm} = 48 \text{ cm}$

$\sigma_{n-1} = 12.5 \text{ cm}$

Coefficient of variation

$$C_V = \frac{\sigma_{n-1}}{\bar{P}} \times 100$$

$$= \frac{12.5 \times 100}{48} = 26.04\,\%$$

∴ Optimum number of raingaues required,

$$N = \left(\frac{C_v}{\varepsilon}\right)^2$$

$$= \left(\frac{26.04}{10}\right)^2 = 6.78$$

$\simeq$ 7 numbers of rain gauges

32. (a)

Depth of surface runoff,

$$Q = \frac{8 \times 10^7}{800 \times 10^6} \text{ m} = 0.1 \text{ m} = 10 \text{ cm}$$

∴ Infiltration depth = 20 cm – 10 cm = 10 cm

∴ (ϕ–index) × 4 hr = 10 cm

⇒ ϕ–index = 2.5 cm/hr

33. (c)

Muskingham method is used for reservoir routing.

34. (c)

Rate of evaporation increases with wind speed upto to critical speed beyond which any further increase in wind speed has no influence on evaporation rate.

35. (a)

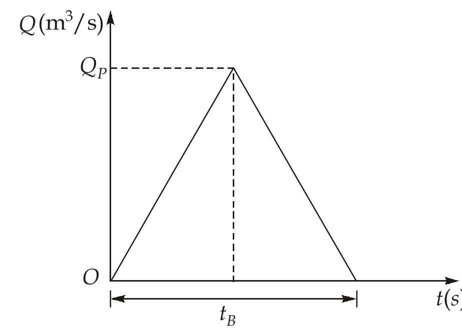
Equilibrium discharge, $Q_s = 2.778 \dfrac{A}{D} \text{ m}^3/\text{s}$

where A = Area of catchment in km^2

D = Duration in hours

∴ $Q_s = 2.778 \times \dfrac{360}{4} = 250.02 \text{ m}^3/\text{s} \,;\, 250 \text{ m}^3/\text{s}$

36. (d)



Here Q_p is peak discharge and t_B is time base

∴ For unit hydrograph, effective rainfall is 1 cm,

$$\therefore \quad \frac{\text{Area of DRH}}{\text{Area of basin}} = 1 \times 10^{-2} \text{ m}$$

$$\Rightarrow \quad \frac{\frac{1}{2} \times 18 \times t_B \times 3600}{108 \times 10^6} = 10^{-2}$$

$$\Rightarrow \quad t_B = \frac{108 \times 10^{6-2} \times 2}{18 \times 3600} \text{hours}$$

$$= \frac{100}{3} = 33.33 \text{ hours}$$

37. (b)

Since meteorological forecast is long range forecast whereas hydrological forecast is of short range, so it gives warning much earlier and therefore its reliability is more.

38. (c)

For same stage,

$$Q = k\sqrt{S}$$

$$\Rightarrow \quad 125 = k\sqrt{\frac{1}{8000}} \qquad \text{...(1)}$$

Also,

$$Q = k\sqrt{\frac{1}{5000}} \qquad \text{...(2)}$$

Dividing (1) by (2),

$$\frac{125}{Q} = \sqrt{\frac{5000}{8000}}$$

$$\Rightarrow \quad Q = 125 \times \sqrt{1.6}$$

$$= 158.1 \text{ m}^3/\text{s}$$

39. (a)

Muskingum routing equation is:

$$Q_2 = C_0 I_2 + C_1 I_1 + C_2 Q_1$$

where,

$$C_0 = \frac{0.5\Delta t - kx}{k + 0.5\Delta t - kx}$$

$$= \frac{0.5(3) - 12(0.10)}{12 + 0.5(3) - 12(0.1)} = \frac{0.3}{12.3} = 0.024$$

40. (b)

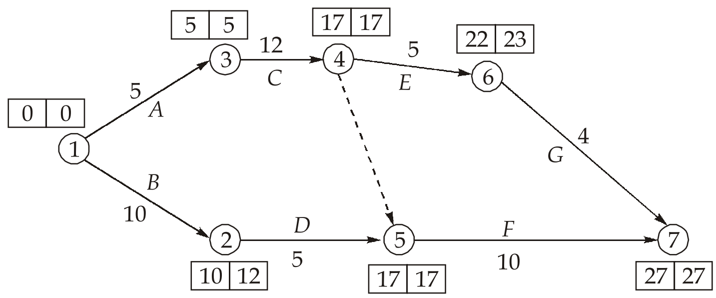
The presence of a reservoir in a stream considerably modifies the virgin-flow duration curve.

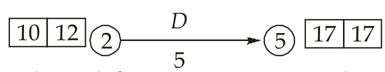
41. (c)

An event is represented by

Circle Rectangle Square Oval shape

42. (a)





EST = 10 days

LST = 12 days

EFT = 10 + 5 = 15 days

LFT = 17 days

Hence, for activity '*D*' earliest finish time (EFT) is 15 days.

43. (c)

t_0 = 8 days, t_m = 12 days, t_p = 18 days

$$\text{Expected time, } t_e = \frac{t_0 + 4t_m + t_p}{6}$$

$$= \frac{8 + 4 \times 12 + 18}{6} = 12.33 \text{ days}$$

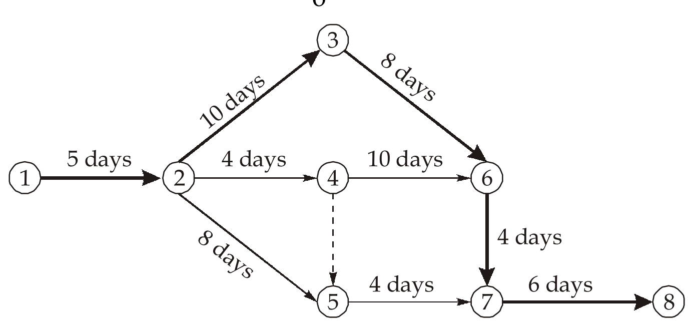
$$\text{Variance, } \sigma^2 = \left(\frac{t_p - t_0}{6}\right)^2$$

$$= \left(\frac{18 - 8}{6}\right)^2 = 2.78$$

44. (a)

Expected completion time of activity, t_E is given as

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



Path	Project completion time
1 – 2 – 3 – 6 – 7 – 8	5 + 10 + 8 + 4 + 6 = 33 days
1 – 2 – 4 – 5 – 7 – 8	5 + 4 + 0 + 4 + 6 = 19 days
1 – 2 – 4 – 6 – 7 – 8	5 + 4 + 10 + 4 + 6 = 29 days
1 – 2 – 5 – 7 – 8	5 + 8 + 4 + 6 = 23 days

The critical path should have maximum duration and hence critical path is along 1 – 2 – 3 – 6 – 7 – 8.

45. (c)

The concept of free float is based on the possibility that all events occurs at their earliest time.

46. (a)

Standard deviation of the critical path is given as

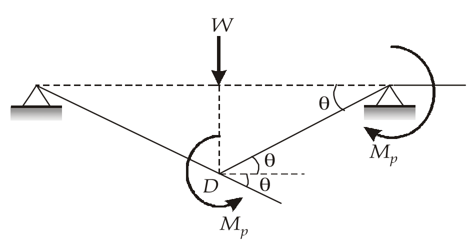
$$\sigma = \sqrt{(6)^2 + (6)^2 + (6)^2 + (6)^2} = 12 \text{ days}$$

52. (d)

Peak discharge for 3 hr UH will be larger than that for 4 hr UH, because both will be having equal amount of effective rainfall of 1 cm.

54. (a)

(i) For span AB,

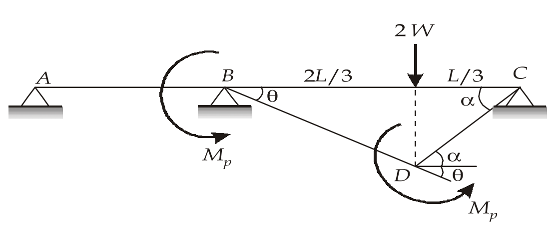


External workdone = Internal workdone

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

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

(ii) For span BC,



External workdone = internal workdone

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

$$\Rightarrow \quad \frac{2L}{3}\theta = \frac{L}{3}\alpha$$

$$\Rightarrow \quad \alpha = 2\theta$$

$$\therefore \quad 2W\left(\frac{2L}{3}\theta\right) = M_p\theta + M_p(\theta + 2\theta) = 4M_p\theta$$

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

Now collapse load, $W_u = \text{Min of}\left[\frac{6M_p}{L}, \frac{3M_p}{L}\right] = \frac{3M_p}{L}$

56. (b)

Flange angles must be unequal angles with longer legs connected to flange plates.

57. (c)

Self weight of a roof truss is given by

$$W_d = \left(\frac{l}{3} + 5\right) \times 10 \text{ N/m}^2$$

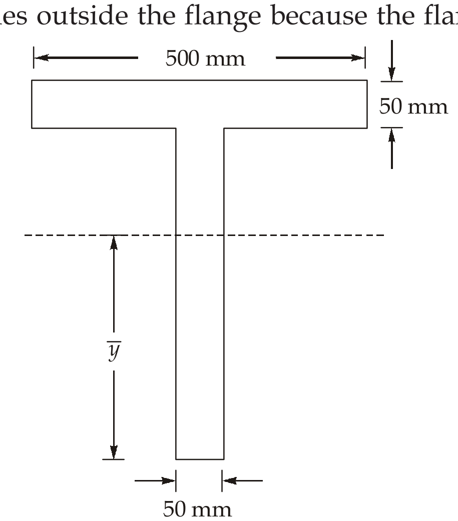
$$= \left(\frac{6}{3} + 5\right) \times 10 = 70 \text{ N/m}^2$$

59. (b)

Total area, $A = 500 \times 50 + 600 \times 50 = 55000 \text{ mm}^2$

Now, $\frac{A}{2} = \frac{55000}{2} = 27500 \text{ mm}^2$

Thus the plastic neutral axis lies outside the flange because the flange area is only 25000 mm^2.



$$\therefore \quad (50)(\bar{y}) = \frac{A}{2}$$

$$\Rightarrow \quad 50\bar{y} = 27500$$

$$\Rightarrow \quad \bar{y} = 550 \text{ mm}$$

∴ Plastic neutral axis lies at 550 mm from bottom.

60. (c)

The minimum thickness of rectangular slab base, t is given as

$$t = \sqrt{\frac{2.5w(a^2 - 0.3b^2)\gamma_{mo}}{f_y}}$$

$$= \sqrt{\frac{2.5 \times 5 \times (70^2 - 0.3 \times 70^2) \times 1.10}{250}} = 13.73 \text{ mm}$$

64. (c)

$$D = ks\cos^2\theta + C\cos\theta$$

$$\therefore \quad 80 = k[2.122 - 1.325]\cos^2(2°30') + C\cos(2°30')$$

$$\Rightarrow \quad 80 = 0.7962k + 0.999\, C \quad \text{...(i)}$$

Also

$$140 = k[2.382 - 0.985]\cos^2(1°\ 36°) + C\cos(1°\ 36°)$$

$$\Rightarrow \quad 140 = 1.3964k + 0.9996\, C$$

Solving above equations, we get, $k = 99.966 \simeq 100$

65. (b)

$$\text{Tangent length} = (R+S)\tan\frac{\phi}{2} + \frac{L}{2}$$

where, S = shift

$$= \frac{L^2}{24R}$$

$$= \frac{75^2}{24 \times 300} = 0.78 \text{ m}$$

$$\therefore \quad \text{Tangent length} = (300 + 0.78) \times \tan\frac{90°}{2} + \frac{75}{2} = 338.28 \text{ m}$$

67. (c)

- It can be used in strong current also.
- It provides continuous record of the soundings.

69. (d)

here, $\alpha = 0$ and $\theta = 25°\ 45'$

$$\sin\alpha = \sin\delta \operatorname{cosec}\theta$$

$$\Rightarrow \quad 0 = \sin\delta \operatorname{cosec} 25°\ 45'$$

$$\Rightarrow \quad \sin\delta = 0$$

$$\Rightarrow \quad \delta = 0°$$

71. (b)

$$\text{Difference of longitude} = 55°30'$$

$$55° = \frac{55}{15}\text{ hr} = 3\text{h } 40\text{ m } 0\text{ s}$$

$$30' = \frac{30}{15}\text{ hr} = 0\text{ h } 2\text{ m } 0\text{ s}$$

$$\text{Total} = 3\text{ h } 42\text{ m } 0\text{ s}$$

Since, the Greenwich meridian is west to the place,

$$\therefore \quad \text{GMT} = \text{LMT} - 3\text{h } 42\text{ m } 0\text{ s}$$

$$= 18\text{ h } 40\text{ m } 10\text{ s} - 3\text{h } 42\text{ m } 0\text{ s}$$

$$= 14\text{ h } 58\text{ m } 10\text{ s}$$

i.e. 2h 58 m 10 s PM.

72. (a)

The scale of the photograph is given by 12.5 cm = 1800 m or 1 cm = 144 m

Now,
$$S = \frac{f}{H-h}$$

$$\Rightarrow \quad \frac{1}{144} = \frac{15}{H-290}$$

$$\Rightarrow \quad H = 2450\text{ m}$$

Now if the average elevation is 950 m, then scale of the photograph is given by,

$$S = \frac{0.15}{2450-950} = \frac{1}{10000}$$

73. (b)

An aerial photograph is a 2D view of an object as it lies on a plane. However if photographs are available in stereo-pairs, it is possible to get a three dimensional view of the project. Stereoscopic vision essentially lends height or depth to the object in the photograph as it would have been by human eye.

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