DETAILED SOLUTIONS

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ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 20

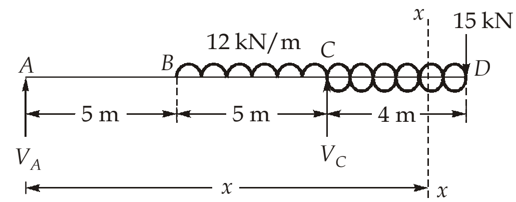
Full Syllabus Test 4 : Paper-II

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

***Q.18 :** *Marks will be awarded to all. [None of the options are correct.]*

***Q.99 :** *Answer has been Updated.*

1. (c)



Taking moments about A

$$12 \times 5 \times 7.5 + 15 \times 14 - V_C \times 10 = 0$$
$$\Rightarrow \quad V_C = 66 \text{ kN}$$
$$V_C + V_A = 60 + 15$$
$$\Rightarrow \quad V_A = 9 \text{ kN}$$

According to Macaulay's method.

$$EI\frac{d^2y}{dx^2} = -M = -9x + \frac{12\langle x-5\rangle^2}{2} - \frac{12\langle x-10\rangle^2}{2} - 66\langle x-10\rangle^1$$
$$\Rightarrow \quad M = 9x - 6\langle x-5\rangle^2 + 6\langle x-10\rangle^2 + 66\langle x-10\rangle^1$$

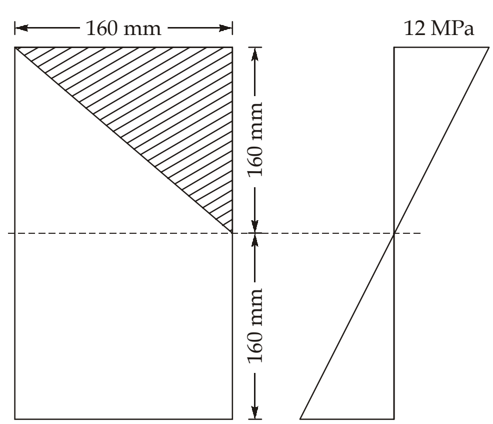
2. (a)

- A stable and statically determinate real beam will have a conjugate beam which is also stable and statically determinate.
- An unstable real beam will have statically indeterminate conjugate beam.
- A statically indeterminate real beam will have unstable conjugate beam.
- $(\text{Slope})_{\text{Real beam}} = (\text{Shear force})_{\text{conjugate beam}}$
- $(\text{Deflection})_{\text{Real beam}} = (\text{Bending moment})_{\text{conjugate beam}}$

3. (b)

1. Maximum principal stress theory (Rankine's theory)
2. Maximum principal strain theory (Saint Venant's theory)
3. Maximum shear stress theory (Guest's theory)
4. Maximum strain energy theory (Haigh's theory)
5. Maximum shear strain energy theory (Mises Hencky theory)

4. (c)



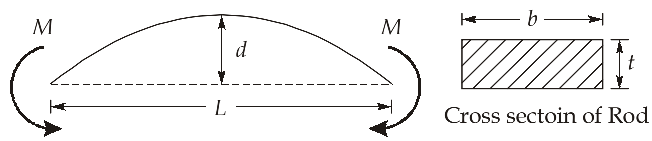
Maximum force resisted by shaded area.

$$C_{max} = \frac{\sigma_{max}}{y_{max}}(A\bar{y})_{\text{shaded area}}$$

$$= \frac{12}{160} \times \left(\frac{1}{2} \times 160 \times 160 \times \frac{2}{3} \times 160\right)$$

$$= 102400 \text{ N} = 102.4 \text{ kN}$$

5. **(d)**



$$\frac{M}{I_{NA}} = \frac{\sigma_{max}}{y_{max}} = \frac{E}{R}$$

Longitudinal surface strain

$$\because \quad \varepsilon = \frac{\sigma_{max}}{E} = \frac{y_{max}}{R}$$

$$\Rightarrow \quad \varepsilon = \frac{t}{2R} \quad \text{...(i)}$$

Where: R = Radius of curvature of circular arc

From the properties of chord of a circle,

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

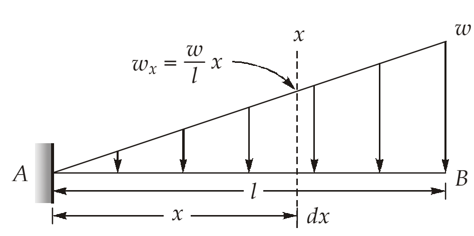
$$\Rightarrow \quad 2\,Rd \simeq \frac{L^2}{4} \quad (\because \; 2R >>> d)$$

$$\Rightarrow \quad 2R = \frac{L^2}{4d}$$

From equation (i),

$$\varepsilon = \frac{t}{(L^2/4d)} = \frac{4dt}{L^2}$$

6. **(b)**



$$EI\left(\frac{d^4y}{dx^4}\right) = -\,dF_x = w_x dx = +\,\frac{w}{l}x\,dx$$

Integrate both sides between A and B

$$EI\left(\frac{d^3y}{dx^3}\right) = \frac{w}{l}\int_0^l x dx = +\frac{w}{l}\left(\frac{l^2}{2}\right)$$

$$\Rightarrow \quad EI\left(\frac{d^3y}{dx^3}\right) = +\frac{wl}{2}$$

$$\text{Shear force at fixed end} = \frac{wl}{2}$$

7. (c)

The Brinell's Hardness Number (BHN) is given by :

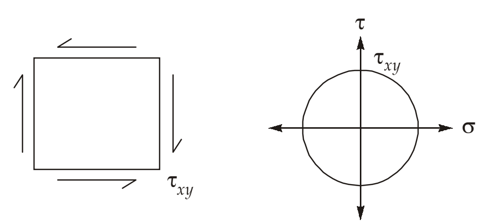
$$BHN = \frac{P}{\frac{\pi D}{2}\left(D-\sqrt{D^2-d^2}\right)}$$

Where
P = Standard load (N)
D = Diameter of steel ball (mm)
d = Diameter of the indent (mm)

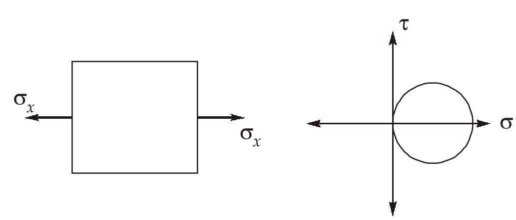
If d becomes smaller, $\sqrt{D^2-d^2}$ increases, which makes $\left(D-\sqrt{D^2-d^2}\right)$ smaller, thereby reducing the denominator. Therefore increases BHN.

8. (d)

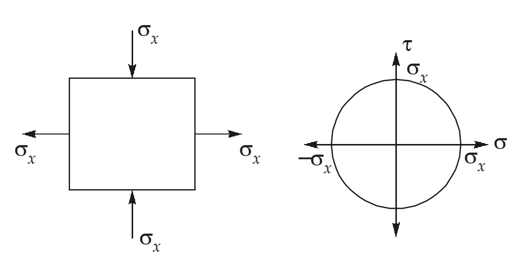
1. Pure shear



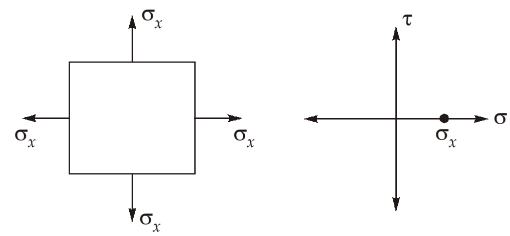
2. Uniaxial stress



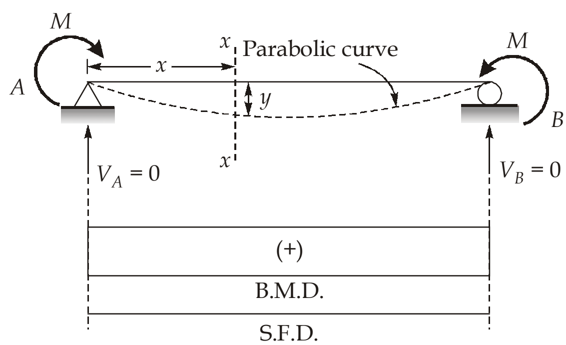
3. Equal and unlike stresses



4. Equal and like stresses



9. (a)



Now;

$$EI\frac{d^2y}{dx^2} = M$$

$\therefore$ $$EI\frac{dy}{dx} = Mx + C_1$$

and $$EIy = \frac{Mx^2}{2} + C_1x + C_2$$

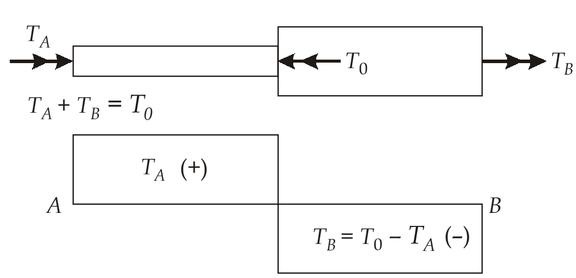
At $x = 0, y = 0 \Rightarrow C_2 = 0$

At $x = \frac{l}{2}, \frac{dy}{dx} = 0 \Rightarrow C_1 = -\frac{Ml}{2}$

$\therefore$ $$EIy = \frac{Mx^2}{2} - \frac{Ml}{2}x$$

This is the equation of a parabola.

10. (c)



Since both supports are fixed so, $\theta = 0$

$$\Rightarrow \quad \frac{T_A \times L_A}{GJ_A} - \frac{(T_0 - T_A)L_B}{GJ_B} = 0$$

$$\Rightarrow \quad \frac{T_A \times L_A}{J_A} = \frac{T_0 L_B}{J_B} - \frac{T_A L_B}{J_B}$$

$$\Rightarrow \quad T_A = \frac{T_0 L_B}{J_B\left[\dfrac{L_A J_B + L_B J_A}{J_A J_B}\right]} = \frac{T_0 L_B J_A}{[L_A J_B + L_B J_A]}$$

11. (d)

Given; $U = 64$ N-m $= 64 \times 10^3$ Nmm

$\delta = 64$ mm, $D = 8d$, $n = 10$

$G = 86 \times 10^3$ N/mm²

Now, $$U = \frac{1}{2}P\delta$$

$$\Rightarrow \quad 64 \times 10^3 = \frac{1}{2}P \times 64$$

$$\Rightarrow \quad P = 2000\ N$$

$$\text{Deflection, } \delta = \frac{64PR^3 n}{Gd^4}$$

$$\Rightarrow \quad 64 = \frac{64 \times 2000 \times (4d)^3 \times 10}{80 \times 10^3 \times d^4} \qquad (\because \ R = 4\,d)$$

$$\Rightarrow \quad d = 16 \text{ mm}$$

$$\therefore \quad \text{Diameter of coil } D = 8 \times 16 = 128 \text{ mm}$$

12. (a)

Given: $p = 2$ N/mm², $d = 1000$ mm, $f_a = 100$ N/mm²

Hoop stress in pipe

$$\sigma_h \le f_a$$

$$\Rightarrow \quad \frac{pd}{2t} \le f_a$$

$$\Rightarrow \quad \frac{2 \times 1000}{2 \times t} \le 100$$

$$\Rightarrow \quad t \ge 10 \text{ mm}$$

Minimum thickness of the metal required is 10 mm

13. (a)

Given; $P = 125$ kN, $L = 4000$ mm, $d = 50$ mm

$$\Delta_{\text{sudden load}} = 2\left(\frac{PL}{AE}\right)$$

$$= 2\left(\frac{125 \times 10^3 \times 4000}{\frac{\pi}{4} \times 50^2 \times 2 \times 10^5}\right)$$

$$= 2.55 \text{ mm}$$

NOTE:

For gradually applied load $\Delta = \dfrac{PL}{AE}$

For sudden applied load $\Delta = 2\left(\dfrac{PL}{AE}\right)$

For impact loading $\Delta = \dfrac{PL}{AE}\left(1+\sqrt{1+\dfrac{2hAE}{PL}}\right)$

Where $\left(1+\sqrt{1+\dfrac{2hAE}{PL}}\right)$ is called impact factor.

For sudden loading

$$h = 0, \text{ Impact factor} = 2$$

14. (a)

Degree of static indeterminacy

$$D_s = D_{Se} + D_{Si}$$

External indeterminacy

$$D_{se} = R_e - 3$$

where;

$$R_e = \text{Total number of external support reactions} = 8$$

$\Rightarrow$ $D_{se} = 8 - 3 = 5$

Internal indeterminacy

$$D_{si} = 3C - r_r$$

where;

$$C = \text{Number of closed loops} = 2$$

$$r_r = \Sigma(m' - 1) = 4 - 1 = 3$$

$\therefore$ $D_{si} = 3 \times 2 - 3 = 3$

$\therefore$ Total degree of static indeterminacy

$$D_s = 5 + 3 = 8$$

Alternate solution

Total degree of indeterminacy of 2D frame is given by:

$$D_s = (3\,m + R_e) - (3j + r_r)$$

where; $m = \text{Number of members} = 12$

$$R_e = \text{External support reactions} = 8$$

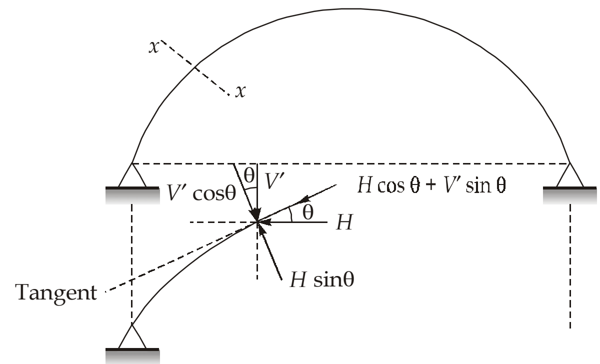
$$j = \text{Number of joints} = 11$$

$$r_r = \Sigma(m' - 1) = 4 - 1 = 3$$

$$D_s = (3\times12+8)-(3\times11+3)$$

$\Rightarrow$ $D_s = 8$

15. (b)



Normal thrust at section *x-x*.

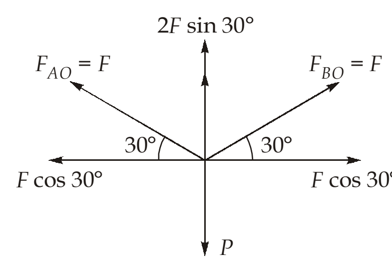
$$N = V' \sin\theta + H\cos\theta$$

Radial shear at the section *x-x*

$$F = V'\cos\theta - H\sin\theta$$

16. (c)

FBD of joint *O*:

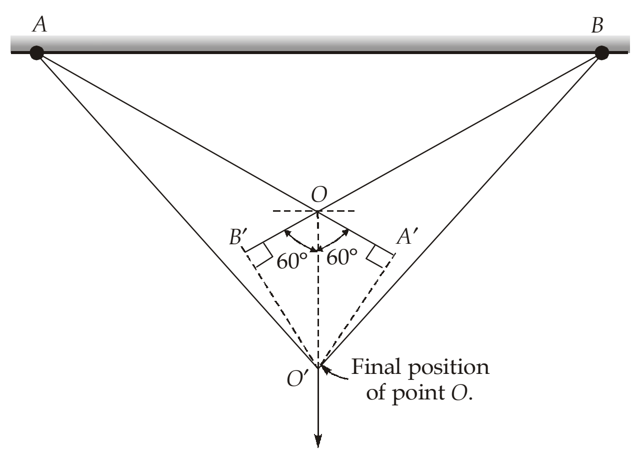


$\Sigma F_y = 0 \Rightarrow$

$$\Rightarrow \quad 2F\sin 30° = P$$

$$\Rightarrow \quad F = P$$

Deflected shape:



$$OA' = OB' = \frac{PL}{AE}$$

In $\Delta\ OA'O'$

$$\frac{OA'}{OO'} = \cos 60° = \frac{1}{2}$$

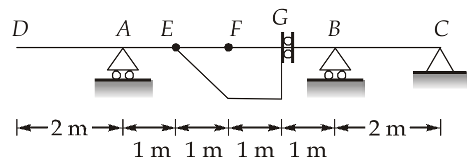
Vertical deflection at point *O*

$$OO' = 2\,(OA')$$

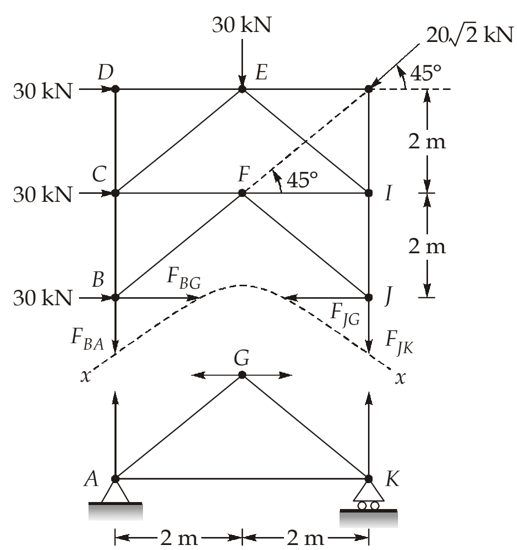
$$\Rightarrow \qquad OO' = 2\left(\frac{PL}{AE}\right)$$

17. (a)

According to Muller Breslau's principle



18. (*)



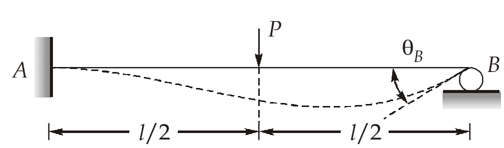
Taking moments about B of upper part of truss

$$F_{JK} \times 4 + 30 \times 2 + 30 \times 4 + 30 \times 2 + 20\sqrt{2} \times 0 = 0$$

$$\Rightarrow \qquad F_{JK} = -60 \text{ kN}$$

$$\therefore \qquad F_{JK} = 60 \text{ kN (Compressive)}$$

19. (c)



From slope deflection equation

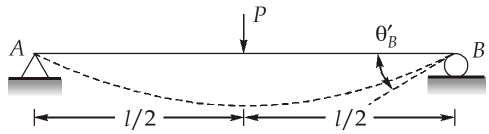
$$M_{BA} = \bar{M}_{BA} + \frac{2EI}{l}(2\theta_B + \theta_A)$$

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

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

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

Now fixed support gets converted into hinged support.



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

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

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

$\therefore$ θ_B increased by 100%

20. (c)

Force at A will be

$$(K + K) \times \delta = 2\,KL\theta$$

$\because$ θ is very small and thus $\sin\theta \simeq \tan\theta \simeq \theta$. M mass moment of inertia of rod about its C.G. axis is

$$I = \frac{ML^2}{12}$$

Therefore,
$$I_{mB} = \frac{ML^2}{12} + M\left(\frac{L}{2}\right)^2 = \frac{ML^2}{3}$$

If $\ddot{\theta}$ is the angular acceleration then using equation of motion

$$\frac{ML^2}{3} \times \ddot{\theta} = -2KL\theta \times 2 - K_1\theta$$

$$\therefore \qquad \ddot{\theta} + \frac{3}{ML^2}\left(2KL^2 + K_1\right)\theta = 0$$

Hence,
$$\omega = \sqrt{\frac{3\left(2KL^2 + K_1\right)}{ML^2}}$$

$$\therefore \qquad f = \frac{1}{2\pi}\sqrt{\frac{3\left(2KL^2 + K_1\right)}{ML^2}}$$

21. (c)

- Viscosity refers to the internal resistance of a fluid flow in liquids, it decreases with temperature because the molecules move apart and the cohesive forces weaken. In gases viscosity increases with temperature because gas molecules move faster thereby increasing the rate of momentum transfer between the layers.
- Liquid rises in a capillary tube when angle of contact is acute.

NOTE:

For : $0 \leq \theta < 90°$ (Concave meniscus and capillary rise)

For : $90 \leq \theta < 180°$ (Convex meniscus and capillary depression)

22. (b)

Given :
$$W = 20 \text{ MN}, w = 0.25 \text{ MN}, x = 8 \text{ m}$$
$$\tan\theta = \frac{0.15}{3} = 0.05$$

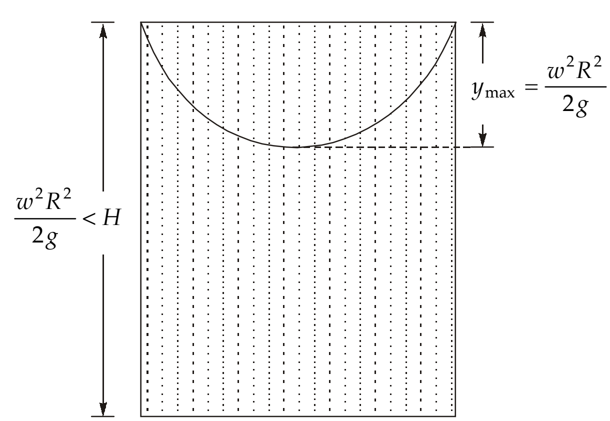
Metacentric height
$$GM = \frac{wx}{W\tan\theta} = \frac{0.25 \times 8}{20 \times 0.05}$$
$$\Rightarrow \quad GM = 2 \text{ m}$$

23. (d)

Moment of momentum equation is
$$T = \rho Q[(\Sigma v.r)_{out} - (\Sigma v.r)_{in}]$$
$$\therefore \quad T \propto Q^2 \qquad \because \quad v = \frac{Q}{A}$$
Now
$$\frac{T_2}{T_1} = \left(\frac{Q_2}{Q_1}\right)^2 = \left(\frac{2Q}{Q}\right)^2 = 4$$
$$\therefore \quad T_2 = 4 \times 15 = 60 \text{ Nm}$$

24. (a)

Pressure force on the top is equal to the weight of volume of liquid lying between the top of the vessel and the paraboloid.



For maximum pressure force on the top of cylinder, y should be maximum.

$$y_{max} = \frac{w^2R^2}{2g}$$

$$\therefore \quad F_{top} = \rho g \times (\text{Volume of paraboloid})$$

$$= \rho g \times \left(\frac{1}{2} \times \pi R^2 y_{max}\right)$$

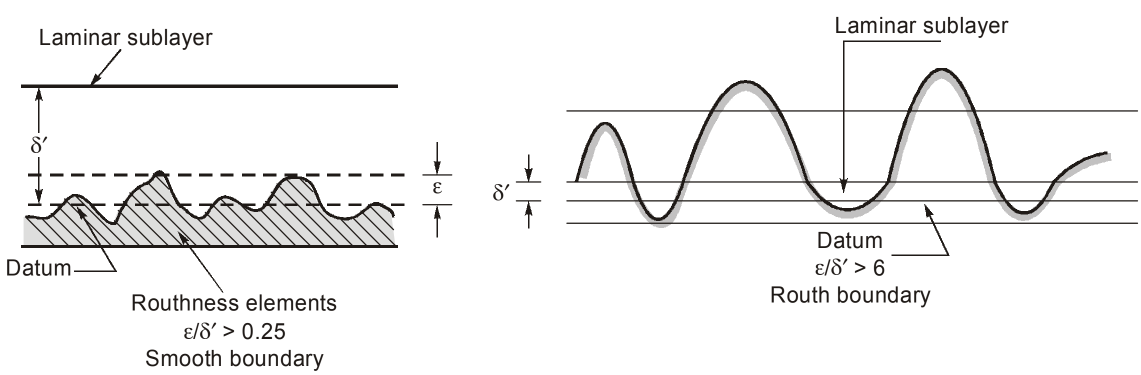
$$= \rho g \times \frac{1}{2} \times \pi R^2 \times \frac{\omega^2 R^2}{2g}$$

$$= \frac{\pi}{4}\rho\omega^2 R^4$$

25. (d)

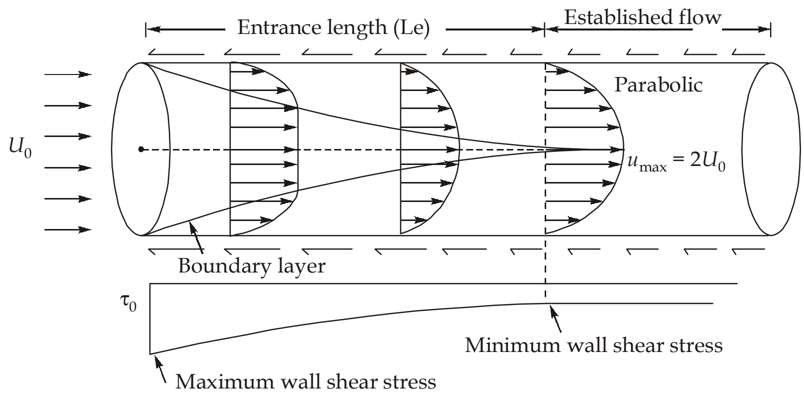
- Flownets are constructed only for irrotational and incompressible flow fields, where velocity potential and stream functions exist.
- In a flownet, ϕ-lines and ψ-lines are orthogonal streamlines which follow the flow direction and equipotential lines are perpendicular to them.
- In regions of higher velocity, ψ-lines and ϕ-lines get closer together, showing inversely proportional spacing.
- A flownet is symmetric with respect to flow direction reversal in irrotational flows. That means reversing flow direction does not change the shape or geometry of the flownet but only the direction of velocity vector reverses. Hence flownet does not change.

26. (b)



- When $\frac{\epsilon}{\delta'} > 0.25$ the pipe surface is called as hydraulically smooth.
- When $0.25 < \frac{\epsilon}{\delta'} < 6$ the pipe surface is called boundary in transition.
- when $\frac{\epsilon}{\delta'} > 6$ the pipe surface is classified as hydraulically rough.

27. (a)



- Boundary layer grows from the pipe wall and meet at the center of the pipe at the end of the entrance length.
- The wall shear stresses are maximum at the pipe entrance and minimum at the end of entrance length.

28. (b)

For a pipe flow, the head loss due to friction is given by

$$h_f = \frac{fLv^2}{2gD}$$

$$\nu \propto \frac{1}{\sqrt{f}}$$

$$\therefore \quad Q = Av$$

$$\therefore \quad Q \propto v \propto \frac{1}{\sqrt{f}}$$

Now, calculate the percentage error in Q

$$\%\text{Error} = \left(\frac{Q_{\text{new}} - Q}{Q}\right) \times 100 = \left(\frac{\frac{1}{f_{\text{new}}} - \frac{1}{\sqrt{f}}}{\frac{1}{\sqrt{f}}}\right) \times 100$$

$$= \left[\sqrt{\frac{f}{f_{\text{new}}}} - 1\right] \times 100 = \left[\sqrt{\frac{1}{1.21}} - 1\right] \times 100 = \left[\frac{1}{1.1} - 1\right] \times 100$$

$$= \left(\frac{10}{11} - 1\right) \times 100 = -9.09\%$$

–ve sign indicates that as friction factor increases, the corresponding discharge decreases.

29. (a)

Applying hydrostatic formula from A to B.

$P_A - 13600 \times 10 \times 0.4 + 1000 \times 10 \times 0.4 = P_B$

$\Rightarrow \quad 200.4 \times 10^3 - 54400 + 4000 = P_B$

$\Rightarrow \quad P_B = 150000 \text{ Pa}$

$\Rightarrow \quad R_B = 150 \text{ kPa}$

30. (b)

- Mach number is used in compressible flow, especially in supersonic flows such as rocket launching.
- Thoma's number is used in evaluating cavitation in pumps. It helps to determine whether cavitation will occur or not.
- Reynolds number governs laminar or turbulent flow relevant in motion of objects like submarines through a fluid.
- Weber's number is used in capillary action, such as capillary flow in soil.

31. (c)

$$\text{Power, } P = \eta\rho g Q H = 0.9 \times 10^3 \times 10 \times 300 \times 32$$
$$= 86400 \times 10^3 \text{ Watt}$$
$$= 86400 \text{ kW}$$

For a specific speed of 400, power produced per machine P_1 is :

$$400 = \frac{200\sqrt{P_1}}{(32)^{5/4}}$$

Squaring both sides

$$4(32)^{5/2} = P_1$$

$$\Rightarrow \quad P_1 = 4 \times 5792.62 = 23170.48 \text{ kW}$$

$$\therefore \text{ Number of turbines required, } n = \frac{86400}{23170.47} = 3.73 \simeq 4$$

32. (b)

33. (a)

Given: $y_1 = 0.5$ m, $y_2 = 2$ m

Relation between y_c and sequent depths is

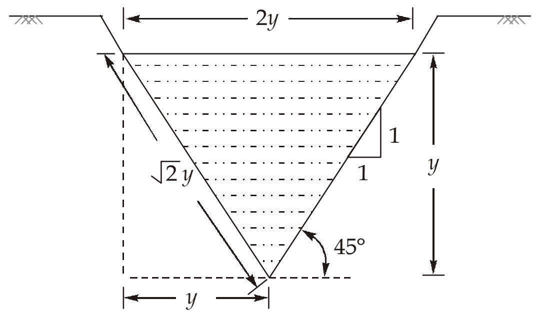
$$y_c^3 = \frac{y_1 y_2 (y_1 + y_2)}{2}$$

$$\Rightarrow \quad \frac{q^2}{10} = \frac{0.5 \times 2 \times 2.5}{2} \qquad \left(\because y_c^3 = \frac{q^2}{g}\right)$$

$$\Rightarrow \quad q = \sqrt{0.5 \times 25} = \frac{5}{\sqrt{2}}$$
$$= 0.707 \times 5 = 3.535 \text{ m}^3/\text{sec/m}$$

34. (a)

35. (b)



For most efficient triangular channel, side slope is (1H : 1V)

$$\text{Hydraulic radius, } R = \frac{A}{P}$$

$$\Rightarrow \qquad R = \frac{\frac{1}{2}(2y)\times y}{2\sqrt{2}y} = \frac{y}{2\sqrt{2}}$$

$$\therefore \qquad \frac{y}{R} = 2\sqrt{2}$$

$$\text{i.e.} \qquad y : R = 2\sqrt{2} : 1$$

36. (c)

The slope of the channel bed is small and consequently the component of weight of fluid in the flow direction is negligibly small.

37. (b)

$$\text{Central velocity} = C_v\sqrt{2gh}$$

$$= 0.98 \times \sqrt{2 \times 9.81 \times 0.06}$$

$$= 1.06 \text{ m/s}$$

$$\text{Mean velocity} = 0.85 \times 1.06 = 0.9 \text{ m/s}$$

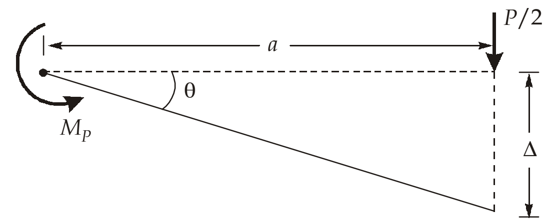
$$\therefore \qquad \text{Discharge, } Q = \frac{\pi}{4} \times 0.3^2 \times 0.9$$

$$= 0.064 \text{ m}^3\text{/s}$$

38. (c)

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

For overhang portion (QR):

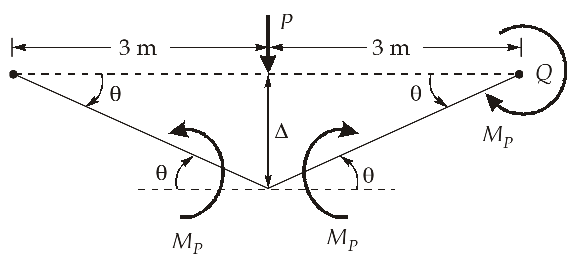


$$\frac{P}{2} \times \Delta = M_P \times \theta$$

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

$$\Rightarrow \quad M_P = \frac{Pa}{2} \quad \text{...(i)}$$

For span PQ:



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

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

$$\Rightarrow \quad M_P = P \quad \text{...(ii)}$$

From equation (i) and (ii)

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

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

39. (c)

Plastic analysis involves two main methods:

1. Static method (upper bound theorem) satisfies the equilibrium and yield conditions.
2. Kinematic method (lower bound theorem) satisfies the equilibrium and mechanism conditions.

40. (a)

Given: FOS = 1.5

Shape factor, S = 1.5 (For rectangular section)

$$\because \quad \text{FOS} = \frac{\text{Yield stress}}{\text{Permissible stress}}$$

With increase in permissible stress for wind and earthquake loads, the FOS will reduce to

$$\text{FOS}' = \frac{1.5}{1.25} = 1.2$$

$$\therefore \quad \text{Load factor} = (\text{FOS}') \times \text{Shape factor}$$

$$= 1.2 \times 1.5 = 1.8$$

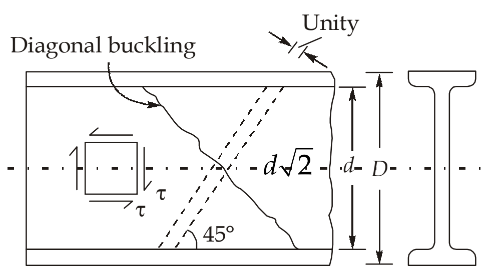
41. **(d)**

As per IS 800 : 2007, Table 22

Angle between fusion faces (θ)	k
60° – 90°	0.7
91° – 100°	0.65
101°106°	0.60
107° – 113°	0.55
114° – 120°	0.50

42. **(b)**

43. **(c)**



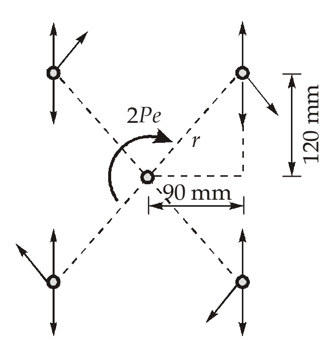
$$\text{Effective length} = \frac{d\sqrt{2}}{2} \qquad (\because \text{ Both ends are assumed to be fixed})$$

$$= \frac{d}{\sqrt{2}}$$

44. **(c)**

- Statement 1 may not always be valid in general context.
- Gusset spreads the loads, increases bearing area, reduces pressure on the concrete and stress on the base plate.
- Especially, when welded or closely bolted, gusset base offers lateral restraint and reduces the effective span of the base plate between load points, thus reducing bending.

45. **(d)**



$$r = \sqrt{120^2 + 90^2}$$

$\Rightarrow$ $$r = 150 \text{ mm}$$

Vertical force on each bolt due to direct load = 0

Force in bolt due to moment (2Pe) in bolt.

$$F_{bolt} = \frac{Tr}{\Sigma r_i^2} = \frac{(2 \times P \times 300) \times 150}{4(150)^2}$$

$\Rightarrow$ $$F_{bolt} = P$$

$$\text{Maximum force in bolt, } F_{max} = P$$

46. (a)

Strength of weld per mm length of weld = 0.7 × 6 × 100 = 420 N

Now
$$420 \times (l_{eff} \times 4) \geq 200000$$
$$(l_{eff})_{min} = 119.047 \text{ mm} \simeq 120 \text{ mm}$$

47. (a)

$$\text{Cost of truss/unit area, } t \propto \frac{1}{S}$$
$$\Rightarrow \quad t = \frac{C_1}{S}$$
$$\text{Cost of purlins/unit area, } p \propto S^2$$
$$\Rightarrow \quad p = C_2S^2$$
$$\text{Cost of roof covering/unit area, } r \propto S$$
$$\Rightarrow \quad r = C_3S$$

Overall cost
$$x = \frac{C_1}{S} + C_2S^2 + C_3S$$

For the overall cost to be minimum.
$$\frac{dx}{dS} = \frac{-C_1}{S^2} + 2C_2S + C_3 = 0$$
$$\Rightarrow \quad \frac{-C_1}{S} + 2C_2S^2 + C_3S = 0$$
$$\Rightarrow \quad -t + 2p + r = 0$$
$$\Rightarrow \quad t = 2p + r$$

If spacing is too large, the cost of purlins and roof covering increases significantly. Therefore, there is an optimal spacing (not infinite spacing) that minimizes total cost.

48. (b)

Where the cranes are manually operated there deflection limit is (L/500) not (L/600).

49. (b)

Refer IS 800 : 2007 (Table -3).

50. (b)

$$C_6H_6 + 7.5O_2 \rightarrow 6CO_2 + 3H_2O$$
$$\text{Theoretical oxygen demand} = \frac{7.5 \times 32}{78} \times 25 = \frac{240}{78} \times 25 = 76.92 \text{ mg}/l$$

51. (c)

1. **Synthetic organic components:** These include synthetic pesticides, detergents, food additives paints etc. Most of these compounds are toxic and bio-refractory organics i.e., they are resistant to microbial degradation.
2. Inorganic pollutants are non-bio-degradable. These pollutants include mineral acids, inorganic salts, trace elements, metals and its compounds, cyanides, sulphates etc. The accumulation of heavy metals may have adverse effect on aquatic flora and fauna and may pose a public health problem where contaminated organics are used for food.

3. Being lighter than water, the oil spreads over the surface of water, separating the contact of water with air, hence resulting in reduction of dissolved oxygen. Oil is responsible for endangering water birds and coastal plants due to coating of oils and adversely affecting the normal activities. It also results in reduction of light transmission through surface waters, thereby reducing the photosynthetic activity of the aquatic plants.
4. Waste water from fertilizer industry and sewage contains substantial concentration of nutrients like nitrogen and phosphorus. This waste water supply nutrients to receiving waters. High nitrogen levels in the receiving waters, becomes the part of water supply, causing a potential risk, especially to infants under six months. It results in decrease in the oxygen carrying capacity of the blood in infants (blue baby disease).

52. (b)

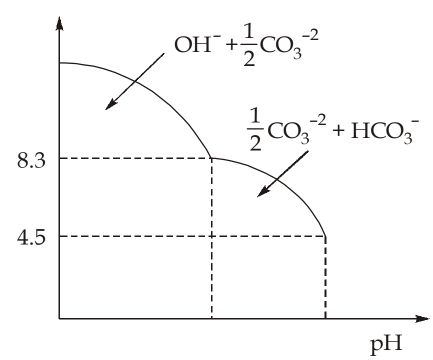
Initially at 25°C $\quad pH = 10$

Now $\quad pH + pOH = 14 \quad$ (At 25°C)

$\Rightarrow \quad pOH = 14 - 10 = 4$

$\therefore$ Caustic alkalinity, $\quad [OH^-] = 10^{-4}$ mol/l $= 10^{-4} \times 50$ g/l as $CaCO_3$

$= 5$ mg/l as $CaCO_3$



For 250 ml

$$[OH^-] = \frac{5}{4}\text{ mg} = 1.25 \text{ mg as } CaCO_3$$

Upto pH = 8.3 $\quad$ Acid consumed $= 8$ ml of 0.02 N H_2SO_4

$= 8$ mg of $CaCO_3$

$$\frac{1}{2}CO_3^{-2} = 8 - 1.25 = 6.75 \text{ mg as } CaCO_3$$

$$[CO_3^{-2}] = 13.5 \text{ mg}$$

Carbonate alkalinity $[CO_3^{-2}]$ in mg/litre as $CaCO_3$

$$= 13.5 \times \frac{1000}{250} = 54 \text{ mg}/l \text{ as } CaCO_3$$

53. (d)

Water sample is initially mixed with $MnSO_4$ and (NaOH + KI). If white precipitate is obtained, then no dissolved oxygen is present in water sample. If reddish brown precipitate is obtained then DO is present in water sample.

54. (d)

$$\eta = \frac{y_i - y_e}{y_i} \quad \text{...(i)}$$

$$\Rightarrow \quad \eta = \frac{100}{1 + 0.44\sqrt{\frac{Qy_i}{VF}}} \quad \text{...(ii)}$$

Here, F = 1

$$\frac{Qy_i}{V} = 0.25 \text{ kg/day/m}^3$$

$$\therefore \quad \eta = \frac{100}{1 + 0.44\sqrt{\frac{0.25}{1}}} = 81.96 \simeq 82\%$$

Using eq. (i) $\quad 0.82 = \dfrac{100 - y_e}{100}$

$$\Rightarrow \quad y_e = 18 \text{ mg}/l$$

55. (a)

- High TDS impact both industrial and domestic systems.
- Temperature affects conductivity of water.

56. (b)

Equation for the reaction,

$$Mg(OH)_2 \rightleftharpoons Mg^{+2} + 2OH^-$$

Solubility product equation,

$$k = [Mg^{+2}][OH^-]^2 = 9 \times 10^{-12}$$

If x is the number of moles of Mg^{+2}, then OH^- concentration is equal to $2x$.

$$\therefore \quad x \times (2x)^2 = 9 \times 10^{-12}$$

$$\Rightarrow \quad x = 1.3 \times 10^{-4} \text{ mol}/l$$

$\therefore$ Mg^{+2} in terms of mg/l as $CaCO_3$

$$= \frac{1.3 \times 10^{-4} \text{ mol}/l}{0.5 \text{ mol}/eq} \times 50000 \text{ mg/eq}$$

$$= 13 \text{ mg}/l \text{ as } CaCO_3$$

57. (d)

58. (b)

Phosphorous mainly enters aquatic systems via runoff from agricultural and urban areas.

59. (c)

60. (d)

61. (c)

62. **(d)**

As per IS 1893 (Part 1) : 2016, Cl. 6.4.2 and Table 2

Seismic zone	Seismic intensity	Z
II	Low	0.10
III	Moderate	0.16
IV	Severe	0.24
V	Very severe	0.36

63. **(d)**

As per IS 3370 (Part 2) : 2009, Cl. 6.3(a), (b), (c)

On liquid retaining faces, the tensile stresses due to the combination of direct horizontal tension and bending action shall satisfy the following condition:

$$\frac{\sigma_{ct'}}{\sigma_{ct}} + \frac{\sigma_{cbt'}}{\sigma_{cbt}} \leq 1$$

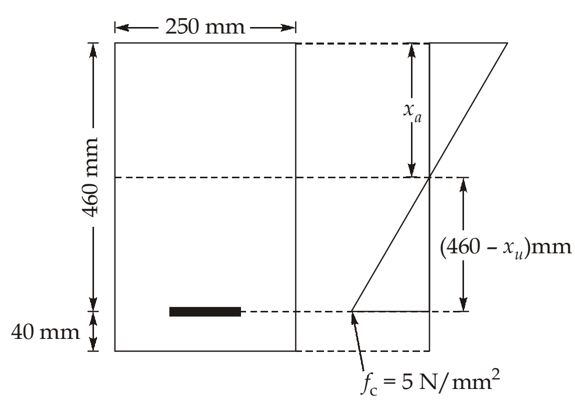
where, $\sigma_{ct'}$ = Calculated direct tensile stress in concrete

σ_{ct} = Permissible direct tensile stress in concrete

$\sigma_{cbt'}$ = Calculated tensile stress due to bending in concrete

σ_{cbt} = Permissible tensile stress due to bending in concrete

64. **(a)**



$$\frac{M}{I_{cr}} = \frac{f_c}{460 - x_u}$$

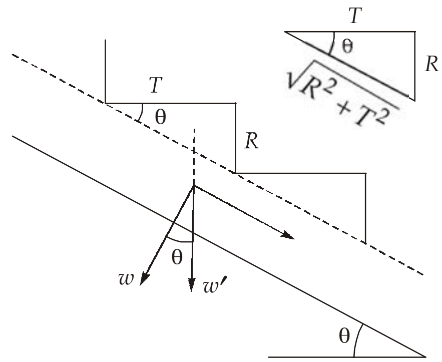
$$\Rightarrow \quad 460 - x_u = \frac{5 \times 5 \times 10^9}{100 \times 10^6}$$

$$\Rightarrow \quad 460 - x_u = 250$$

$$\Rightarrow \quad x_u = 210 \text{ mm}$$

65. (b)

Given:



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

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

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

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

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

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

66. (c)

As per IS 456 : 2000, (Cl. 34.4)

Permissible bearing pressure of concrete in direct compression is given by

$$\sigma_{br} = 0.45 f_{ck}\sqrt{\frac{A_1}{A_2}} \quad \text{(by LSM)}$$

where, $$\sqrt{\frac{A_1}{A_2}} \not> 2$$

$$A_1 = 2 \times 2 = 4 \text{ m}^2$$

$$A_2 = 0.8 \times 0.8 = 0.64 \text{ m}^2$$

$$\sqrt{\frac{A_1}{A_2}} = \sqrt{\frac{4}{0.64}} = 2.5 > 2$$

$$\therefore \quad \sqrt{\frac{A_1}{A_2}} = 2$$

$$\therefore \quad \sigma_{br} = 0.45 \times 25 \times 2$$

$$\Rightarrow \quad \sigma_{br} = 22.5 \text{ N/mm}^2$$

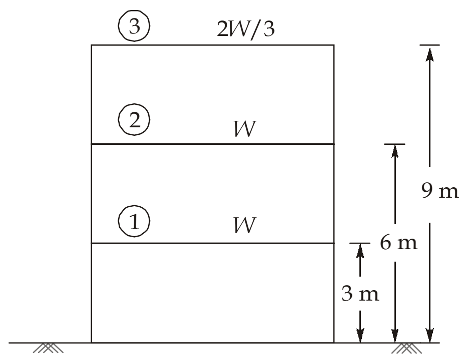
Note:
$$\sigma_{br} = \begin{cases} 0.45 f_{ck}\sqrt{\dfrac{A_1}{A_2}} & \text{(For LSM)} \\ 0.25 f_{ck}\sqrt{\dfrac{A_1}{A_2}} & \text{(For WSM)} \end{cases}$$

67. (b)

For post tensioned beam with unbounded tendoms, the ultimate flexural strength depends mainly on the effective stress in the tendons after all prestress losses.

68. (a)

Given:



As per IS 1893 (Part 1) : 2016, Cl. 7.7.1

Vertical distribution of base shear to different floor levels is given by:

Design lateral force at i^{th} floor

$$Q_i = V_B\left(\frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}\right)$$

$\therefore$ At 2^{nd} floor, $$Q_2 = 1100\left(\frac{W\times 6^2}{W\times 3^2 + W\times 6^2 + \dfrac{2W}{3}\times 9^2}\right)$$

$\Rightarrow$ $$Q_2 = 1100\times\frac{36}{99} = 400 \text{ kN}$$

69. (a)

Given: $$B = D = 300 \text{ mm}, l_{eff} = 5 \text{ m}$$

$$\lambda = \frac{l_{eff}}{B} = \frac{5000}{300} = 16.67 > 12$$

$\therefore$ $$\lambda > 12$$

So column is a long column.

As per IS 456:2000 (Cl. B.3.3)

Permissible stress is multiplied by a reduction factor.

$$C_r = 1.25 - \frac{l_{eff}}{48B} = 1.25 - \frac{5}{48 \times 0.3}$$
$$C_r = 0.9$$

$\therefore$ Permissible direct axial compressive stress in column = 0.9 × 8 = 7.2 MPa

70. (c)

As per IS 456: 2000, Cl. 26.2.5.3 and Cl 26.2.5.1(a)

- End-bearing splices shall be used only for bars in compression.
- Lap splices shall not be used for bars when bar diameter is greater than 36 mm.
- Splices in flexural members should not be at section where the bending moment is more than 50% of the moment of resistance and not more than half the bars shall be spliced at a section.

71. (a)

- In plain concrete members there is no reinforcement to resist tensile stresses. When subjected to torsion, diagonal tensile stresses develop leading to diagonal cracks. Since PCC is weak in tension, sudden failure occurs once cracking starts, without any warning.
- Shear force acts along with torsion and bending moment. In the presence of shear, a beam can develop combined stress conditions, leading to early cracking and reduced strength and beam fails at a lower strength.

72. (b)

73. (d)

Project managers wishes to have slack as it gives flexibility and also protection against when things go wrong.

It is not necessary that activity with zero slack must lie on critical path as there may exist another path with more variance and same project time.

74. (c)

For $P = 95\%$,

The value of Z is found by interpolation.

$$(Z)_{P = 95\%} = 1.5 + \left(\frac{1.8 - 1.5}{97 - 94}\right) \times (95 - 94) = 1.6$$

Now, $\frac{x - \mu}{\sigma} = Z$

$\Rightarrow$ $\frac{2S - \mu}{2.5} = 1.6$

$\Rightarrow$ $25 - \mu = 4$

$\Rightarrow$ $\mu = 21$ days = Total completion time

$\Rightarrow$ $7 + x + 6 = 21$

$x = 8$ days

75. (c)

- Testing accuracy is important, reliability is about the product's long-term performance, not the test itself.
- Dimensions refer to the size or physical measurements of a product not its reliability.

- Reliability closely relates to quality a more reliable product consistently meets performance expectation and quality standards.

76. (c)

Given:

$$\text{Normal duration} = 12 \text{ days}$$
$$\text{Normal cost} = \text{Rs. } 350$$
$$\text{Crash duration} = 10 \text{ days}$$
$$\text{Cost slope} = \text{Rs. } 80/\text{day}$$

$$\because \quad \text{Cost slope} = \left(\frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal duration} - \text{Crash duration}}\right)$$

$$\Rightarrow \quad 80 = \frac{\text{Crash cost} - 350}{12 - 10}$$

$$\Rightarrow \quad \text{Crash cost} = \text{Rs. } 510$$

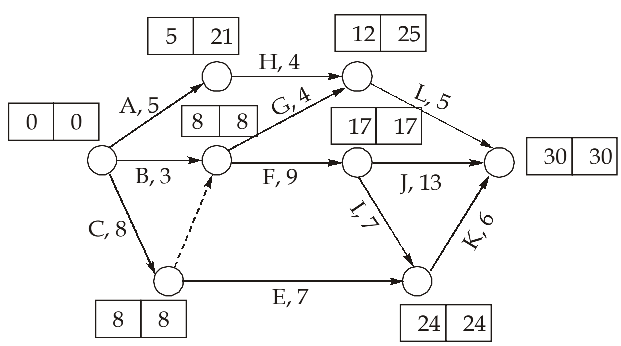
77. (a)

- Resource levelling is used when resources are limited.
- The objective is to adjust the start and finish dates of activities based on resource constraints.
- Project duration may increase because we cannot add extra resources to speed up the work.

Therefore in resources levelling,

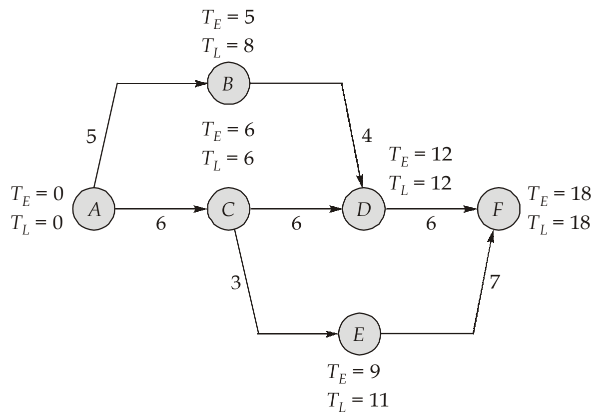
- resources are limited.
- project duration can change during resource levelling.

78. (c)



$$\text{Total project duration} = 30 \text{ weeks}$$
$$= 30 \times 7 = 210 \text{ days}$$

79. (b)



$$\text{Total float} = T_L \text{ for head event} - T_E \text{ for tail event} - \text{Duration of activity}$$

$$\therefore \quad \text{Total float of } C\text{-}E = 11 - 6 - 3 = 2 \text{ days}$$

$$\text{Free float} = T_E \text{ for head event} - T_E \text{ for tail event} - \text{Duration of activity}$$

$$\therefore \quad \text{Free float of activity } E\text{-}F = 18 - 9 - 7 = 2 \text{ days}$$

$\therefore$ Total float of C-E + Free float of E-F = 2 + 2 = 4 days

80. (d)

- The larger the return period, the greater the flood discharge, so 100 year flood discharge will be greater than 50 year flood discharge.
- 90% dependable flow is less than or equal to 50% dependable flow.

81. (b)

82. (d)

- Terracing reduces sediment inflow by controlling erosion.
- Sedimentation can increase flood levels by flattening the bed slope upstream.

83. (c)

84. (a)

$$\text{Risk, } \bar{R} = 1 - \left(1 - \frac{1}{T}\right)^n$$

Here, $n = 25$ years

and $T = 100$ years

$$\therefore \quad \bar{R} = 1 - \left(1 - \frac{1}{100}\right)^{25} = 1 - 0.99^{25}$$

85. (a)

Given: $k = 0.4$

$i = 4.5$ cm/h

$A = 90$ ha

$Q_{peak} = kiA$

$$= 0.4 \times \frac{4.5 \times 10^{-2}}{3600} \times 90 \times 10^4 = 4.5 \text{ m}^3/\text{s}$$

86. (d)

87. (c)

Using two point method,

$$\text{Average velocity, } V_{avg} = \frac{V_{0.2y} + V_{0.8y}}{2}$$

$$\text{Velocity at } 0.2y = 0.2 \times 2 = 0.4 \text{ m is } 0.6 \text{ m/s}$$

$$\text{Velocity at } 0.8y = 0.8 \times 2 = 1.6 \text{ m is } 0.2 \text{ m/s}$$

$$\therefore \quad V_{avg} = \frac{0.6 + 0.2}{2} = 0.4 \text{ m/s}$$

Now, area of triangular channel, $A = \frac{1}{2} \times B \times y = \frac{1}{2} \times 8 \times 2 = 8 \text{ m}^2$

where B is top width of channel,

$$\therefore \quad \text{Discharge, } Q = \text{Area} \times \text{Velocity}$$

$$\Rightarrow \quad Q = 8 \times 0.4$$

$$\Rightarrow \quad Q = 3.2 \text{ m}^3/\text{s}$$

88. (b)

Discharge required for Rabi season,

$$Q_R = \frac{\text{Given discharge}}{\text{Capacity factor} \times \text{Time factor}}$$

$$= \frac{0.7}{0.4 \times 0.5} = 3.5 \text{ m}^3/\text{s}$$

Discharge required for Kharif season,

$$Q_{kh} = \frac{0.9}{0.4 \times 0.5} 4.5 \text{ m}^3/\text{s}$$

Design discharge of the distributary at its head

$$Q = \max \begin{cases} Q_R \\ Q_{kh} \end{cases} = \max \begin{cases} 3.5 \\ 4.5 \end{cases} = 4.5 \text{ m}^3/\text{s}$$

89. (d)

90. (a)

As we know,

$$\text{Duty, } D = \frac{8.64B}{\Delta}$$

where, B = Base period in days

= 120 days

Δ = Delta i.e. Net depth of irrigation required (in m)

= 120 – 10 = 110 cm = 1.1 m

$$\therefore \quad D = \frac{8.64 \times 120}{1.1}$$
$$= 942.55 \text{ ha/cumec}$$

91. (b)

As we know,

$$\text{Sensitivity, } S = \frac{\frac{dq}{q}}{\frac{dy}{y}}$$

$$\frac{1}{3} = \frac{\frac{dq}{q}}{45\%}$$

$$\frac{dq}{q} = 15\%$$

92. (a)

93. (c)

94. (c)

95. (c)

Retarders decrease the rate of hydration thereby increasing the setting time.

96. (b)

97. (a)

Small size aggregates have large surface area than larger size aggregates and thus more surface area is available for bonding with cement thereby increasing the strength of concrete.

98. (d)

99. (a)

100. (c)

101. (b)

102. (d)

The spacing between contour lines depends upon the slope of the ground. In steep slopes, the spacing is small, but for gentle slopes, the spacing is large. If the contour lines are equally spaced, then they indicate a uniform slope.

103. (c)

The latitude is considered as positive when reckoned northward and negative when reckoned southward. Similarly, the departure is considered positive and negative when reckoned on eastward and westward respectively.

104. (d)

- Sag correction is always negative because the actual horizontal distance is less than the sagged (measured) distance.
- Limiting length of an offset depends on the scale of plotting.
- Error due to laying of the direction of offset is not always negligible.

105. (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 rule, volume of the embankment is given by

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

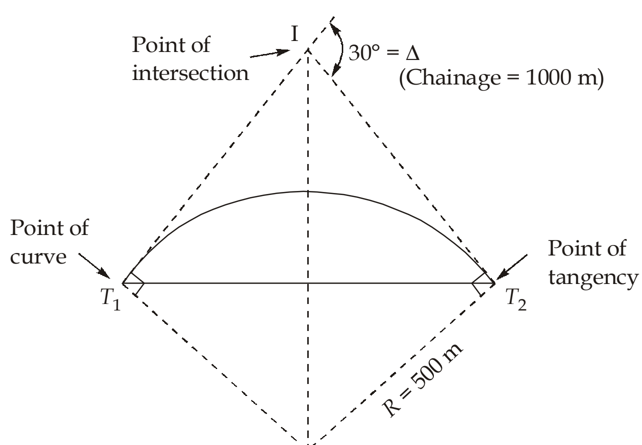
$$\Rightarrow \quad V = \frac{15}{3}\left[(15 + 12) + 4(18 + 30) + 2(24)\right]$$

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

106. (b)

Given: Radius of curve, R = 500 m

Chainage at intersection point = 1000 m



$$\text{Length of tangent} = R\tan\left(\frac{\Delta}{2}\right)$$

$$= 500 \times \tan 15° = 134 \text{ m}$$

Chainage of point of curve, T_1 = 1000 – Length of tangent

= 1000 – 134

= 866 m

Note: Chainage of point of curve, T_1 = Chainage of intersection point – Length of tangent

Chainage of point of tangency, T_2 = Chainage of point of curve + Length of curve

107. (b)

108. (a)

Given:

$$\text{Flying height, } H = 2200 \text{ m}$$
$$\text{Focal length of camera, } f = 300 \text{ mm}$$
$$\text{Elevation, } h = 400 \text{ m}$$
$$\text{Scale} = \frac{f}{H-h} = \frac{0.3}{2200-400}$$
$$\Rightarrow \quad \text{Scale} = \frac{1}{6000}$$
$$\Rightarrow \quad 1 \text{ cm} = 60 \text{ m}$$

109. (c)

$$D = kS + C = \left(\frac{f}{i}\right)S + (f+d)$$
$$\Rightarrow \quad 102.3 = \left(\frac{200}{5}\right)S + (0.2+0.1)$$
$$\Rightarrow \quad 102 = 40\,S$$
$$\Rightarrow \quad S = 2.55 \text{ m}$$

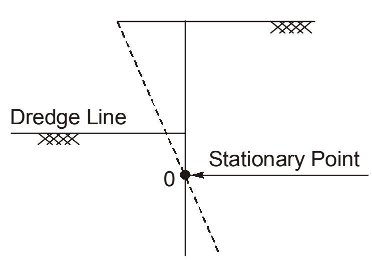
110. (c)

Standard Penetration Test (SPT) gives N-value which can be corrected for energy, overburden pressure and dilatancy in sequence. The corrected N-value is correlated with relative density and angle of shearing resistance for cohesionless soils; and unconfined compressive strength and consistency for cohesive soils.

Since the confining pressure increases with depth, the N values at shallow depths are underestimated and the N values at larger depths are overestimated.

111. (a)

Weep holes are provided to reduce build-up of hydrostatic pressure at the back of the wall. The wall friction decreases active earth pressure and increases passive earth pressure.



Above the dredge line, the pressure is active on the back of the wall. Near the embedded end, the pressure on the back of the wall will be passive as the wall moves towards the fill.

112. (b)

113. **(a)**

Terzaghi considered the failure surface at foundation level only but Meyerhof considered the failure surface at ground level.

114. **(d)**

Assuming foundation is at ground level.

$$\therefore \quad q_u = \cancelto{0}{cN_c} + \cancelto{0}{\gamma D_f N_q} + 0.5\,\gamma N_\gamma B$$

$$\text{For circular footing, } q_{\text{circle}} = 0.6\,B\gamma\,N_\gamma\,0.6 \times \gamma N_\gamma \times 4$$

$$\text{For rectangular footing, } q_{\text{rectangle}} = \left[1 - 0.2 \times \frac{4}{8}\right] \times \gamma N_\gamma \times 4$$

$$= 0.9\,\gamma N_\gamma \times 4$$

$$\therefore \quad \frac{q_{\text{circle}}}{q_{\text{rectangle}}} = \frac{0.6}{0.9} = 0.67$$

115. **(a)**

- The scale decreases from bottom to top. This is because when the hydrometer floats higher in a denser liquid, the reading is taken lower on the stem.
- It is used to determine the specific gravity of liquids.
- The meniscus correction is always positive.

116. **(c)**

Rate of seepage through the clay,

$$q = kiA$$

$$= 2 \times 10^{-6} \times \frac{3}{3} \times 1$$

$$= 2 \times 10^{-6}\ \text{m}^3/\text{sec}/\text{m}^2$$

$$= 1.2 \times 10^{-4}\ \text{m}^3/\text{min}/\text{m}^2$$

$$= 7.2 \times 10^{-3}\ \text{m}^3/\text{hr}/\text{m}^2$$

117. **(b)**

In falling head test, permeability is given by

$$k = \frac{aL}{At}\log_e\left(\frac{h_1}{h_2}\right) = \text{constant}$$

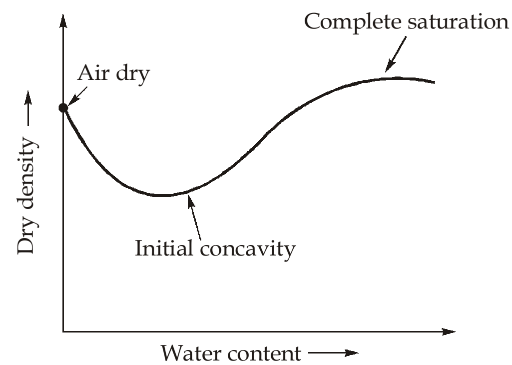
$$\therefore \quad \frac{aL}{A \times 5\,\text{min}}\log_e\left(\frac{400}{200}\right) = \frac{aL}{A \times t}\log_e\left(\frac{400}{100}\right)$$

$$\Rightarrow \quad \frac{1}{5}\log_e(2) = \frac{1}{t}\log_e(4)$$

$$\Rightarrow \quad \frac{1}{5} = \frac{2}{t}$$

$$\Rightarrow \quad t = 10\ \text{min.}$$

118. (c)



- Initial concavity in compaction curve for sandy soil is due to bulking of sand.
- Maximum dry unit weight in sandy soil results when the soil is either dry or completely saturated.
- Coarse grained soils do not adsorb water the way fine-grained soils do and hence the Lambe's double layer theory is not applicable for sands.

119. (d)

- Compression and flow occur only in vertical direction.
- Darcy's law is valid.
- The soil is homogeneous and completely saturated and soil grains are:
- There is a unique relationship, independent of time, between void ratio and effective stress, that is $\Delta e = -a_v \Delta\bar{\sigma}$, while a_v is assumed constant over the stress increment.

120. (d)

Let at depth z_0, the active earth pressure becomes equal to zero

$$p_a = k_a q + k_a \gamma Z - 2C\sqrt{k_a}$$

at $Z = Z_0$, $p_a = 0$

$$\Rightarrow \quad 0 = k_a q + k_a \gamma Z_0 - 2C\sqrt{K_a}$$

$$\Rightarrow \quad Z_0 = \frac{2C}{\gamma\sqrt{k_a}} - \frac{q}{\gamma} = \frac{1}{\gamma}\left(\frac{2C}{\sqrt{k_a}} - q\right)$$

Let critical depth of vertical cut is H_c,

$$\therefore \quad H_c = 2Z_0$$

$$\Rightarrow \quad H_c = \frac{2}{\gamma}\left(\frac{2C}{\sqrt{k_a}} - q\right)$$

121. (d)

Given: $k_x = 5.6 \times 10^{-6}$ m/sec, $k_y = 1.4 \times 10^{-6}$ m/sec

Transformed scale in horizontal direction (x-direction)

$$X_T = x\sqrt{\frac{k_y}{k_x}} = x\sqrt{\frac{1.4 \times 10^{-6}}{5.6 \times 10^{-6}}} = x\sqrt{\frac{1}{4}}$$

$$X_T = 0.5x$$

$$\text{Horizontal scale} = 0.5 \times \frac{1}{400} = \frac{1}{800}$$

122. (b)

Tests performed in Marshall method are:

1. Bulk specific gravity test to determine the compacted specimen's density.
2. Stability and flow test to assess the load carrying capacity (stability) and the deformation behaviour (flow).
3. Density and void analysis to evaluate air voids, voids in mineral aggregate (VMA) and voids filled with bitumen (VFB).

Note: Penetration and flow test is not part of the Marshall method. Penetration test is typically used for bitumen and not for the compacted mix specimen.

123. (c)

Methods for origin and destination study.

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

Methods for speed and delay method.

- Vehicle number method or license plate method.
- Interview technique.
- Elevated observation.
- Photographic technique.
- Floating car method.

124. (b)

Given:

$$n_1 = +\frac{1}{50} = 2\%$$

$$n_2 = -\frac{1}{20} = -5\%$$

$$\text{Deviation angle, } N = 0.02 - (0.05) = 0.07$$

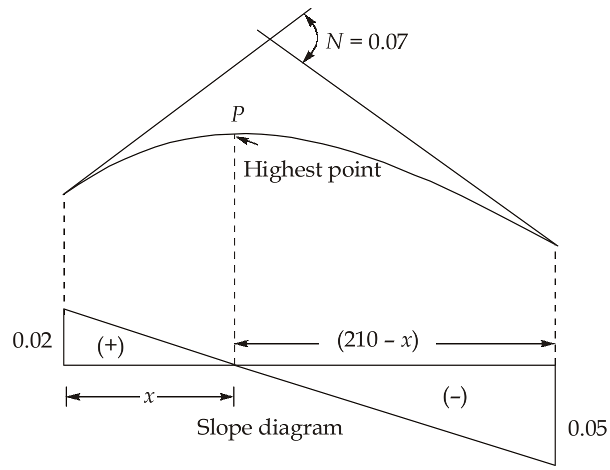
Position of highest point on the curve from beginning of the curve is given by

$$x = \frac{n_1 L}{N}$$

$$= \frac{0.02 \times 210}{0.07}$$

$$x = 60 \text{ m}$$

Alternate solution:



Curve is parabolic so slope diagram of curve will be linear.
Highest point lies on the curve where slope is zero.
From similar triangles property

$$\frac{x}{0.02} = \frac{210 - x}{0.05}$$

$$\Rightarrow \quad 5x = 2 \times 210 - 2x$$

$$\Rightarrow \quad x = 60 \text{ m}$$

125. (c)

Curve (a) or (d) → For flow value
Curve (b) → Percent voids filled with bitumen (VFB)
Curve (c) → Percent voids in total mix

126. (b)

$$\text{Traffic flow, } q = uk$$
$$= 60k - 0.75k^2$$

For maximum q,

$$\frac{dq}{dk} = 0$$

$$\Rightarrow \quad \frac{dq}{dk} = 60 - 1.5k = 0$$

$$\Rightarrow \quad k = 40$$

$$\therefore \quad u = 60 - 0.75 \times 40 = 30 \text{ km/h}$$

$$\therefore \quad q = 30 \times 40 = 1200 \text{ veh/h} = 1200 \text{ vph}$$

127. (a)

Pressure in the outer wheels of the vehicle will be more while turning on a non-superelevated road.
Hence, formation of pot holes on the outer edge is more frequent.

128. (b)

The road geometric in India are designed for:

(I) 30^{th} highest hourly traffic volume.

(II) 98^{th} percentile speed.

129. (d)

$$\text{Optimum cycle time, } C_0 = \frac{1.5L+5}{1-Y}$$

L = Total lost time per cycle = 13 sec

$$Y = y_1 + y_2$$

$$= \frac{500}{1500} + \frac{300}{1500} = \frac{800}{1500}$$

Therefore,

$$C_0 = \frac{1.5 \times 13 + 5}{1 - \frac{800}{1500}} = 52.5 \text{ sec} \simeq 53 \text{ sec}$$

130. (a)

Minimum radius of horizontal curve

Type of road	Plain terrain		Rolling terrain	
	Ruling (m)	Absolute (m)	Ruling (m)	Absolute (m)
NH or SH	360	230	230	155
MDR	230	155	155	90
ODR	155	90	90	60
VR	90	60	60	45

131. (d)

132. (b)

Given: Sleeper density = 18

Length of a rail for B.G. track = 12.8 m $\simeq$ 13 m (say)

Sleeper density = $m + x$

where, m = length of rail (in m)

$\therefore$ $18 = 13 + x$

$\Rightarrow$ $x = 5$

$\therefore$ Sleeper density = $m + 5$

133. (d)

- Coal ash can retain moisture and promote corrosion, making it unsuitable for steel or cast iron sleepers.
- Gravel ballast on soft or weak soil formation offers better load distribution and performance.
- The fine particles of sand can cause excessive wear on the rail head due to abrasion.

134. (c)

Conical surface is the imaginary surface that extends upward and outward from the periphery of the inner horizontal surface at a gentle slope forming a conical shape. It protects aircraft during turning and climbing after takeoff.

135. (a)

Given:

$$T_a = 25\ °\text{C}$$
$$T_m = 43\ °\text{C}$$

Airport reference temperature

$$\text{ART} = T_a + \left(\frac{T_m - T_a}{3}\right) = 25 + \left(\frac{43-25}{3}\right)$$
$$= 31°\ \text{C}$$

136. (a)

Number of points of potential conflicts depends on the number of lanes on intersecting lanes.

137. (d)

- Radial flow pumps have moderate specific speed not the highest. High specific speed (i.e., very large flow and low head) is generally handled more efficiently by axial flow pumps.
- For a pump, the specific speed N_s is defined as

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$$

where, N = rotational speed in rpm for maximum efficiency

Q = discharge (in m^3/sec)

H = net head developed (in m)

From the formula it is evident that by increasing discharge Q and reducing head H, will increase the specific speed N_S.

138. (c)

Flanges and web of rolled sections are so proportioned that local buckling failure does not occur prior to overall buckling of member.

139. (c)

- For concrete mix design, apart from meeting the criteria for characteristic strength, concrete must be workable in fresh state and impermeable and durable in hardened state.
- Nominal mix concrete is permitted only in ordinary concrete (i.e. upto M20 concrete).

140. (a)

141. (a)

$$T = \frac{\tau J}{R}$$

For a solid shaft

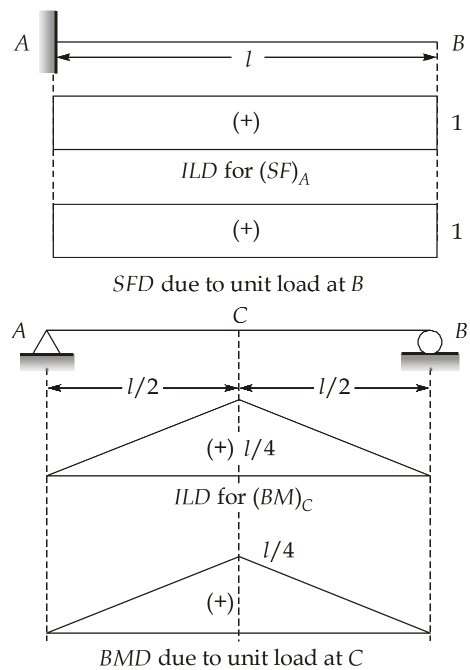
$$J = \frac{\pi D^4}{32}$$

For a hollow shaft $$J = \frac{\pi\left(D_0^4 - D_i^4\right)}{32}$$

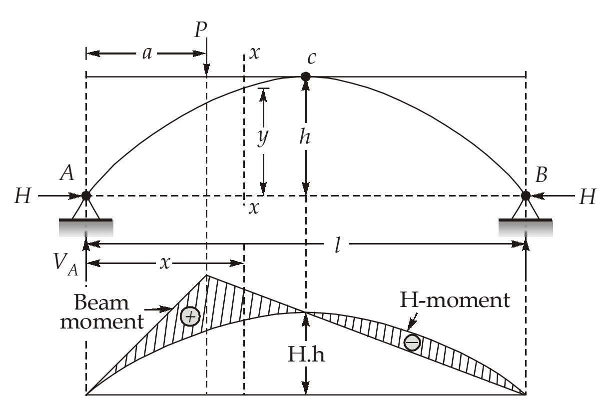
Because a hollow shaft has material removed from the center and is having more material away from centroidal axis. It provides greater resistance to torsion for the same weight.

Thus a hollow shaft is more efficient in resisting torsion and can transmit more torque than a solid shaft of the same weight and material.

142. (b)



143. (a)



At section x-x

$$(BM)_{\text{Arch}} = (BM)_{\text{Beam}} - Hy$$

$$\therefore \quad (BM)_{\text{Arch}} < (BM)_{\text{Beam}}$$

144. (c)

Consistency only refers to the degree of fluidity. Whereas workability refers to how easily concrete can be mixed, placed, compacted and finished without segregation.

145. (a)

Gypsum $CaSO_4 \times 2H_2O$

Plaster of paris $CaSO_4 \cdot \frac{1}{2}H_2O$

146. (d)

- When the bend angle decreases, the extension needed beyond the bend should generally be longer because a sharpen bend reduces anchorage.
- A larger bend angle (closer to 180°) does provide a better anchorage because the stress distribution is better and slip is reduced.

147. (a)

148. (a)

Spherical trigonometry : In spherical trigonometry, the curvature of earth is also taken into account. Here all measurements are done in terms of angles without any linear measurement. Thus distances are expressed as angle subtended at the centre of the sphere.

Spherical triangle : Spherical triangle is the triangle formed by the intersection of three great circles. The angles formed at the three vertices of the spherical triangle are called as spherical angles. The sum of angles of spherical triangle is more than two right angles i.e. 180° but less than six right angles i.e. 540°.

149. (d)

Volume of saturated soil sample at any time = (Initial thickness – settlement) × Area of sample. The volume is related to strain directly. The settlement depends on change in effective stress and not on the change in total stress.

150. (d)

As per IRC, maximum volume of traffic that a rotary can effectively handle is 3000 vehicles per hour entering from all the legs of the intersection.

■■■■