Section : General Aptitude

01. The lecture was attended by quite _________ students, so the hall was not very _______.
(a) few, quite (b) a few, quite (c) few, quiet (d) a few, quiet

01. Ans: (d)

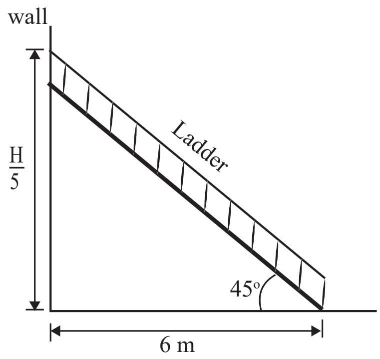
Sol: a few, quiet. Meaning a lot. Calm

End of Solution

02. On a horizontal ground, the base of a straight ladder is 6 m away from the base of a vertical pole. The ladder makes an angle of 45^0 to the horizontal. If the ladder is resting at a point located at one-fifth of the height of the pole from the bottom, the height of the pole is _____.
(a) 25 (b) 35 (c) 15 (d) 30

02. Ans: (d)

Sol:



A ladder is 6 m away from the base.

$$\tan 45^\circ = \frac{\text{Opposite side}}{\text{Adjacent side}}$$

$$1 = \frac{H/5}{6}$$

$$1 = \frac{H}{30}$$

H = 30 m

End of Solution

03. The CEO's decision to quit was as shocking to the Board as it was to _______.

(a) me (b) myself (c) I (d) my

03. Ans: (a)

Sol: preposition to be followed by pronoun in object form. me

End of Solution

04. If E = 10; J = 20; O = 30; and T = 40, what will be P + E + S + T?

(a) 120 (b) 164 (c) 82 (d) 51

04. Ans: (a)

Sol: E = 10, J = 20, O = 30, T = 40

P + E + S + T = 2[16 + 5 + 19 + 20] = 120

Logic:- 2[Letter's Number]

End of Solution

05. They have come a long way in _________ trust among the users.

(a) create (b) creation (c) created (d) creating

05. Ans: (d)

Sol: creating. use gerund after preposition.

End of Solution

06. A square has sides 5 cm smaller than the sides of a second square. The area of the larger square is four times the area of the smaller square. The side of the larger square is _________.

(a) 8.50 (b) 10.00 (c) 18.50 (d) 15.10

06. Ans: (b)

Sol: The side of small square is '5' cm less than larger one.

Area of large square is '4' times of area of small square.

Side of large square = x

side of small square = x - 5

Relation between Areas,

Area of large square = 4 times of Area of small square

$x^2 = 4 (x - 5)^2$

$x^2 = 4 (x - 10x + 25)$

$3x^2 - 40x + 100 = 0$

$3x^2 - 30x - 10x + 100 = 0$

$3x(x - 10) - 10(x-10) = 0$

$x - 10 = 0$ $\qquad$ $3x - 10 = 0$

$\therefore\ x = 10$ $\qquad$ $x = \frac{10}{3}$

Possible is $x = 10$

If $x = \frac{10}{3}$, we are getting negative.

so, x not existing.

Answer is $x = 10$

End of Solution

07. In a sports academy of 300 people, 105 play only cricket, 70 play only hockey, 50 play only football, 25 play both cricket and hockey, 15 play both hockey and football and 30 play both cricket and football. The rest of them play all three all three sports. What is the percentage of people who play at least two sports?

(a) 28.00 (b) 23.30 (c) 50.00 (d) 25.00

07. Ans: (d)

Sol: Total players = 300

$x = 300 - [105 + 70 + 30 + 50 + 26 + 15\ ]$

$x = 5$ players

% of players playing atleast

$$2.5 \text{ ports} = \frac{15+30+25+x}{300} \times 100$$

$$= \frac{70+5}{300} \times 100 = \frac{75}{3} = 25\%$$

End of Solution

08. P, Q, R, S and T are related and belong to the same family. P is the brother of S. Q is the wife of P. R and T are the children of the siblings P and S respectively. Which one of the following statements is necessarily FALSE?

(a) S is the sister-in-law of Q

(b) S is the brother of P

(c) S is the aunt of T

(d) S is the aunt of R

08. Ans: (c)

Sol: Male = +

Female = –

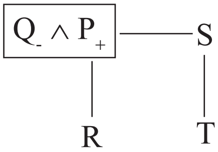
Couple = ∧

Parent, child = | P / Child

Siblings = " __ "

There symbols use for solutions

"S is Anut of T" is False because "S" is parent of "T".



End of Solution

09. The new cotton technology, Bollgard-II, with herbicide tolerant traits has developed into a thriving business in India. However, the commercial use of this technology is not legal in India. Notwithstanding that, reports indicate that the herbicide tolerant Bt cotton had been purchased by farmers at an average of Rs. 200 more than the control price of ordinary cotton, and planted in 15% of the cotton growing area in the 2017 Kharif season.

Which one of the following statements can be inferred from the given passage?

(a) Farmers want to access the new technology by paying high price

(b) Farmers want to access the new technology for experimental purposes

(c) Farmers want to access the new technology even if it is not legal

(d) Farmers want to access the new technology if India benefits from it

09. Ans: (b)

Sol: Only 15% land. So, farmers are experimenting.

End of Solution

10. "The increasing interest in tribal characters might be a mere coincidence, but the timing is of interest. None of this, though, is to say that the tribal hero has arrived in Hindi cinema, or that the new crop of characters represents the acceptance of the tribal character in the industry. The films and characters are too few to be described as a pattern."

What does the word 'arrived' mean in the paragraph above?

(a) went to a place (b) reached a terminus (c) attained a status (d) came to a conclusion

10. Ans: (c)

Sol: Means gained importance.

End of Solution

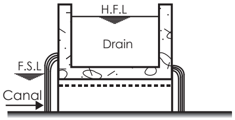
01. If the path of an irrigation canal is below the bed level of a natural stream, the type of cross-drainage structure provided is

(a) Sluice gate (b) Aqueduct (c) Super passage (d) Level crossing

01. Ans: (c)

Sol: Irrigation canal below the bed level of a natural stream

$\rightarrow$ Super passage



(b) Superpassage

End of Solution

02. Which one of the following is correct?

(a) $\lim_{x\to 0}\left(\frac{\sin 4x}{\sin 2x}\right) = 2$ and $\lim_{x\to 0}\left(\frac{\tan x}{x}\right) = 1$

(b) $\lim_{x\to 0}\left(\frac{\sin 4x}{\sin 2x}\right) = \infty$ and $\lim_{x\to 0}\left(\frac{\tan x}{x}\right) = 1$

(c) $\lim_{x\to 0}\left(\frac{\sin 4x}{\sin 2x}\right) = 1$ and $\lim_{x\to 0}\left(\frac{\tan x}{x}\right) = 1$

(d) $\lim_{x\to 0}\left(\frac{\sin 4x}{\sin 2x}\right) = 2$ and $\lim_{x\to 0}\left(\frac{\tan x}{x}\right) = \infty$

02. Ans: (a)

Sol: $$\operatorname*{lt}_{x\to 0} \frac{\sin 4x}{\sin 2x} = \operatorname*{lt}_{x\to 0}\left(\frac{\frac{\sin 4x}{x}}{\frac{\sin 2x}{x}}\right) = \frac{4}{2} = 2$$

and $\operatorname*{lt}_{x\to 0} \frac{\tan x}{x} = 1$

End of Solution

03. The interior angles of four triangles are given below:

Triangle	Interior Angles
P	$85^0, 50^0, 45^0$
Q	$100^0, 55^0, 25^0$
R	$100^0, 45^0, 35^0$
S	$130^0, 30^0, 20^0$

Which of the triangles are ill-conditioned and should be avoided in Triangulation Surveys?

(a) Both Q and R (b) Both Q and S (c) Both P and S (d) Both P and R

03. Ans: (b)

Sol: For an ill conditioned traingle in triangulation survey, any angle can be less than 38, and can be greater than 120°.

For traingles Q and S, the above condition is valid.

End of Solution

04. A catchment may be idealised as a rectangle. There are three rain gauges located inside the catchment at arbitrary locations. The average precipitation over the catchment is estimated by two methods: (i) Arithmetic mean (P_A), and (ii) Thiessen polygon (P_T). Which one of the following statements is correct?

(a) P_A is always great than P_T

(b) P_A is always equal to P_T

(c) P_A is always smaller than P_T

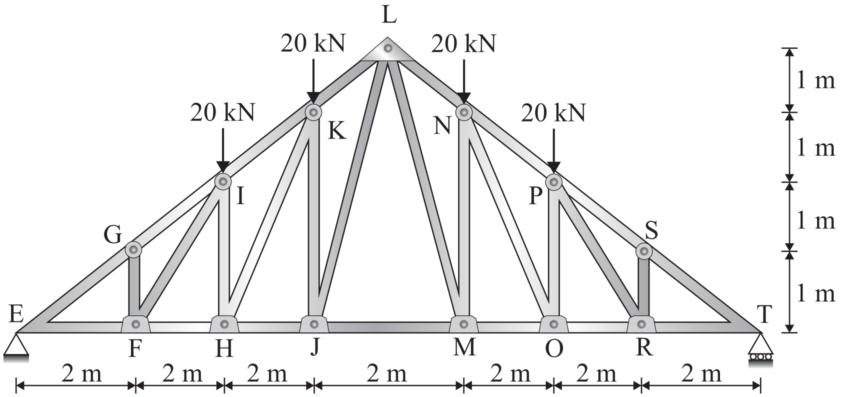
(d) There is no definite relationship between P_A and P_T

04. Ans: (d)

Sol: There is no definite relationship between P_A and P_T

End of Solution

05. A plane truss is shown in the figure (not drawn to scale):

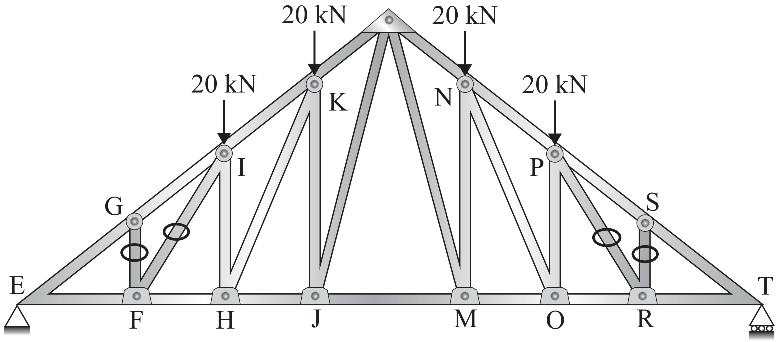


Which one of the options contains ONLY zero force members in the truss?

(a) FG, FH, HI, RS (b) FI, FG, RS, PR (c) FG, FI, HI, RS (d) FI, HI, PR, RS

05. Ans: (b)

Sol:



So zero force members are FI, FG, RS, PR

End of Solution

06. A simple mass-spring oscillatory system consists of a mass m, suspended from a spring of stiffness k. Considering z as the displacement of the system at any time t, the equation of motion for the free vibration of the system is $m\ddot{z} + kz = 0$. The natural frequency of the system is

(a) $\frac{k}{m}$ (b) $\frac{m}{k}$ (c) $\sqrt{\frac{k}{m}}$ (d) $\sqrt{\frac{m}{k}}$

06. Ans: (c)

Sol: $m\ddot{z} + kz = 0$

$\ddot{z} = \frac{-k}{m}.z$

Comparing with equation $a - \omega^2 .x$

$\Rightarrow \omega = \sqrt{\frac{k}{m}}$

End of Solution

07. An isolated concrete pavement slab of length L is resting on a frictionless base. The temperature of the top and bottom fibre of the slab are T_t and T_b, respectively. Given the coefficient of thermal expansion = α and the elastic modulus = E. Assuming $T_t > T_b$ and the unit weight of concrete as zero, the maximum thermal stress is calculated as

(a) $\frac{E\alpha(T_t - T_b)}{2}$ (b) $E\alpha(T_t - T_b)$ (c) $L\alpha(T_t - T_b)$ (d) zero

07. Ans: (d)

Sol: Due to frictionless, thermal stress developed in concrete pavement slab is zero

$\sigma_{th} = 0$

End of Solution

08. For a small value of *h*, the Taylor series expansion for f(x+h) is

(a) $f(x)+hf'(x)+\frac{h^2}{2!}f''(x)+\frac{h^3}{3!}f'''(x)+.....\infty$

(b) $f(x)-hf'(x)+\frac{h^2}{2}f''(x)-\frac{h^3}{3}f'''(x)+.....\infty$

(c) $f(x)+hf'(x)+\frac{h^2}{2}f''(x)+\frac{h^3}{3}f'''(x)+.....\infty$

(d) $f(x)-hf'(x)+\frac{h^2}{2!}f''(x)-\frac{h^3}{3!}f'''(x)+.....\infty$

08. Ans: (a)

Sol: We know that Taylor series for small h of f(x + h) is,

$$f(x+h)=f(x)+hf'(x)+\frac{h^2}{2!}f''(x)+\frac{h^3}{3!}f'''(x)+.....$$

End of Solution

09. The maximum number of vehicles observed in any five minute period during the peak hour is 160. If the total flow in the peak hour is 1000 vehicles, the five minute peak hour factor (round off to 2 decimal places) is ______

09. Ans: 0.52

Sol: Given actual flow in peak hour, $q_{actual} = 10^3$ veh/hr

peak 5 min rate = 160 veh/5min

Peak (5min)rate volume, $q_{peak\ rate} = \frac{160}{\left(5/60\right)} = 1920$ veh/hr

$\therefore$ peak hourly factor (PHF) for 5 min is

$$PHF_5 = \frac{q_{actual}}{q_{peak\ rate}} = \frac{10^3}{1920} = 0.52083 \approx 0.52$$

End of Solution

10. In a soil specimen, the total stress, effective stress, hydraulic gradient and critical hydraulic gradient are σ, σ′, i and i_c respectively. For initiation of quicksand condition, which one of the following statements is TRUE?

(a) $\sigma' \neq 0$ and $i = i_c$ (b) $\sigma = 0$ and $i = i_c$ (c) $\sigma' = 0$ and $i = i_c$ (d) $\sigma' \neq 0$ and $i \neq i_c$

11. Ans: (c)

Sol: Quick sand condition occurs if $\sigma' = 0$ and $i = i_c$

End of Solution

11. In a rectangular channel, the ratio of the velocity head to the flow depth for critical flow condition is

(a) $\frac{3}{2}$ (b) $\frac{2}{3}$ (c) $\frac{1}{2}$ (d) 2

11. Ans: (c)

Sol: For Critical flow $\Rightarrow$ Velocity Head is equal to half of hydraulic depth.

$$\frac{V^2}{2g} = \frac{D}{2} \quad \text{for rectangular channel } D = y$$

$$\frac{\frac{V^2}{2g}}{y} = \frac{1}{2}$$

End of Solution

12. A soil has specific gravity of its solids equal to 2.65. The mass density of water 1000 kg/m^3. Considering zero air voids and 10% moisture content of the soil sample, the dry density (in kg/m^3, round off to 1 decimal place) would be _______.

12. Ans: 2094.9

Sol: $G_s = 2.65$,

$\gamma_w = 1000$ kg/m^3

Degree of saturation, S = 100% (Zero air voids)

w = 10%

The dry density corresponding to zero air voids or 100% saturation, $\gamma_d = \dfrac{\gamma_w . G_s}{1 + w.G_s}$

$$= \frac{1000 \times 2.65}{1 + 0.1 \times 2.65}$$

$$= 2094.9 \text{ kg/m}^3$$

End of Solution

13. Which one of the following is a secondary pollutant?

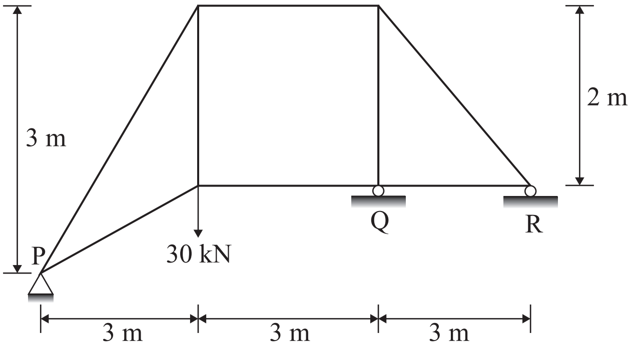
(a) Ozone (b) Volatile Organic Carbon (VOC) (c) Carbon Monoxide (d) Hydrocarbon

13. Ans: (a)

Sol: Ozone is a dangerous secondary air contaminant.

End of Solution

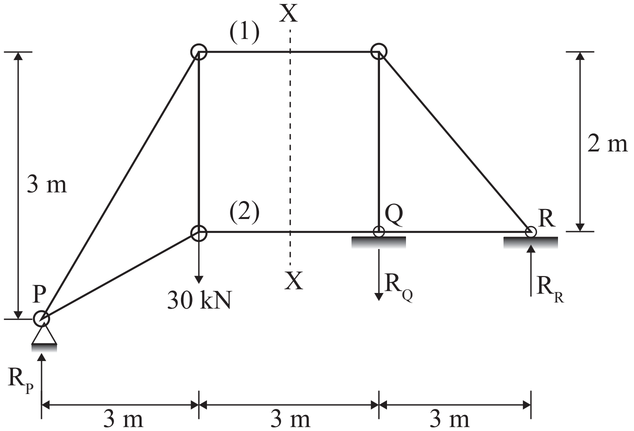
14. Consider the pin-jointed plane truss shown in the figure (not drawn to scale). Let R_P, R_Q and R_R denote the vertical reactions (upward positive) applied by the supports at P, Q and R respectively, on the truss. The correct combination of (R_P, R_Q, R_R) is represented by



(a) (30, –30, 30) kN (b) (10, 30, –10) kN (c) (20, 0, 10) kN (d) (0, 60, –30) kN

14. Ans: (a)

Sol:



Adopting method of sections and taking LHS of the section

$\Sigma F_y = 0$

$R_P = 30$ kN

For complete truss,

$\Sigma M_R = 0$

$9R_P - 30 \times 6 - R_Q \times 3 = 0$

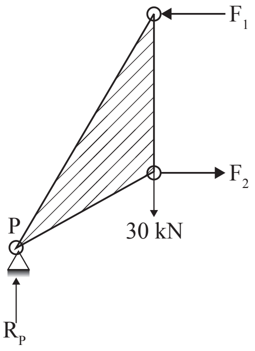
$R_Q = 30$ kN (↓)

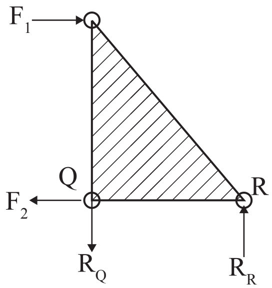
Taking RHS of section,

$\Sigma F_y = 0 \Rightarrow R_R = R_Q$

Thus, $R_Q = 30$ kN (↓),

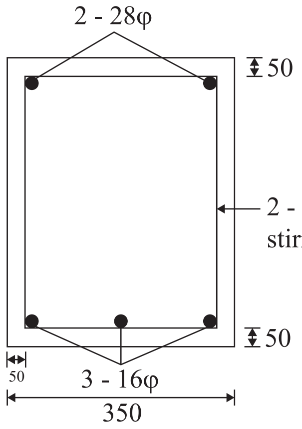
$R_R = 30$ kN (↑)





End of Solution

15. In the reinforced beam section shown in the figure (not drawn to scale), the nominal cover provided at the bottom of the beam as per IS 456 - 2000, is



All dimensions are in mm

(a) 50 mm (b) 30 mm (c) 36 mm (d) 42 mm

15. Ans: (b)

Sol: Nominal cover $= 50 - \frac{16}{2} - 12 = 30$ mm

Nominal cover is the distance from extreme concrete fibre to the surface of stirrup.

End of Solution

16. Consider a two-dimensional flow through isotropic soil along x direction and z direction. If h is the hydraulic head, the Laplace's equation of continuity is expressed as

(a) $\frac{\partial h}{\partial x} + \frac{\partial h}{\partial z} = 0$ (b) $\frac{\partial h}{\partial x} + \frac{\partial h}{\partial x}\frac{\partial h}{\partial z} + \frac{\partial h}{\partial z} = 0$

(c) $\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial x \partial z} + \frac{\partial^2 h}{\partial z^2} = 0$ (d) $\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial z^2} = 0$

16. Ans: (d)

Sol: The Laplace's equation of continuity for two dimensional flow in a soil is expressed as:

$k_x . \frac{\partial^2 h}{\partial x^2} + k_z \frac{\partial^2 h}{\partial z^2} = 0$ .... for anisotropic soil $[k_x \neq k_z]$

$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial z^2} = 0$ ....for isotropic soil $[k_x = k_z]$

End of Solution

17. The probability that the annual maximum flood discharge will exceed 25000 m^3/s, at least once in next 5 years is found to be 0.25. The return period of this flood event (in years, round off to 1 decimal place) is _______

17. Ans: 17.9

Sol: $Q \geq 25000\ m^3/s$, $n = 5$ years, $p_1 = 0.25$, $T = ?$

$p_1 = 1 - q^n$, $0.25 = 1 - q^n$, $q^5 = 1 - 0.25$

$5 \log(q) = \log(0.75)$

$q = 0.9441$

$q = 1 - p$,

$p = 1 - q = 0.0559$

$p = \frac{1}{T}$

$T = 17.89$ years

End of Solution

18. The coefficient of average rolling friction of a road is f_r and its grade is $+G\%$. If the grade of this road is doubled, what will be the percentage change in the braking distance (for the design vehicle to come to a stop) measured along the horizontal (assume all other parameters are kept unchanged)?

(a) $\frac{2f_r}{f_r + 0.01G} \times 100$ (b) $\frac{0.01G}{f_r + 0.02G} \times 100$ (c) $\frac{f_r}{f_r + 0.02G} \times 100$ (d) $\frac{0.02\,G}{f_r + 0.01G} \times 100$

18. Ans: (b)

Sol: Given $f_r \rightarrow$ co-efficient of rolling friction

$+G\% \rightarrow$ upward gradient

Break distance, $S_{b1} = \frac{v^2}{2g(f_r + 0.01G)}$

When gradient of road doubled, the break distance is, $S_{b2} = \frac{v^2}{2g(f_r + 0.01 \times 2G)} = \frac{v^2}{2g(f_r + 0.02G)}$

% change in break distance is $= \frac{S_{b1} - S_{b2}}{S_{b1}} \times 100$

$$= \frac{\left\{\frac{v^2}{2g(f_r + 0.01G)} - \frac{v^2}{2g(f_r + 0.02G)}\right\}}{\left\{\frac{v^2}{2g(f_r + 0.01G)}\right\}} \times 100$$

$$= \frac{\left\{\frac{(f_r + 0.02G) - (f_r + 0.01G)}{(f_r + 0.01G)(f_r + 0.02G)}\right\}}{\left\{\frac{1}{f_r + 0.01G}\right\}} \times 100$$

$$= \frac{0.01G}{f_r + 0.02G} \times 100$$

19. An element is subjected to biaxial normal tensile strains of 0.0030 and 0.0020. The normal strain in the plane of maximum shear strain is

(a) 0.0050 (b) Zero (c) 0.0025 (d) 0.0010

19. Ans: (c)

Sol: Normal strain in the plane of maximum shear strain

$\varepsilon_x = 0.0030$

$\varepsilon_y = 0.0020$

$\therefore$ Normal strain in the plane of maximum shear strain $\varepsilon_{avg} = \dfrac{\varepsilon_x + \varepsilon_y}{2} = \dfrac{0.0030 + 0.0020}{2}$

$= 0.0025$

End of Solution

20. A retaining wall of height H with smooth vertical backface supports a backfill inclined at an angle β with the horizontal. The backfill consists of cohesionless soil having angle of internal friction ϕ. If the active lateral thrust acting on the wall is P_a, which one of the following statements is TRUE?

(a) P_a acts at a height H/3 from the base of the wall and at an angle ϕ with the horizontal

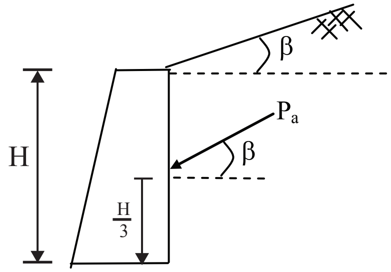
(b) P_a acts at a height H/2 from the base of the wall and at an angle ϕ with the horizontal

(c) P_a acts at a height H/3 from the base of the wall and at an angle β with the horizontal

(d) P_a acts at a height H/2 from the base of the wall and at an angle β with the horizontal

20. Ans: (c)

Sol:



End of Solution

21. For a given loading on a rectangular plain concrete beam with an overall depth of 500 mm, the compressive strain and tensile strain developed at the extreme fibers are of the same magnitude of 2.5×10^{-4}. The curvature in the beam cross-section (in m^{-1}, round off to 3 decimal places), is ________

21. Ans: 0.001

Sol: Simple bending equation

$$\frac{m}{I} = \frac{f}{y} = \frac{E}{R}$$

$$\frac{1}{R} = \frac{f}{E} \cdot \frac{1}{y}$$

$$= \frac{\varepsilon}{y} = \frac{2.5 \times 10^{-4}}{(0.5/2)} = 0.001\ \text{m}^{-1}$$

End of Solution

22. A completely mixed dilute suspension of sand particles having diameters 0.25, 0.35, 0.40, 0.45 and 0.50 mm are filled in a transparent glass column of diameter 10 cm and height 2.50m. The suspension is allowed to settle without any disturbance. It is observed that all particles of diameter 0.35 mm settle to the bottom of the column in 30s. For the same period of 30s, the percentage removal (round off to integer value) of particles of diameters 0.45 and 0.50 mm from the suspension is __________.

22. Ans: 100

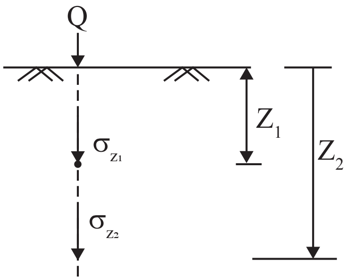
Sol: If particles of diameter 0.35 mm are completely removed (i.e., 100 % removed) then particles of size larger than 0.35 mm are also 100 % removed.

End of Solution

23. A concentrated load of 500 kN is applied on an elastic half space. The ratio of the increase in vertical normal stress at depths of 2 m and 4 m along the point of the loading, as per Boussinesq's theory, would be __________.

23. Ans: 4

Sol:



As per Boussinesq's equation,

The vertical stress below the ground level at a depth, Z, vertically below the load, σ_Z :

$$\sigma_Z = \frac{3}{2\pi} \cdot \frac{Q}{Z^2}$$

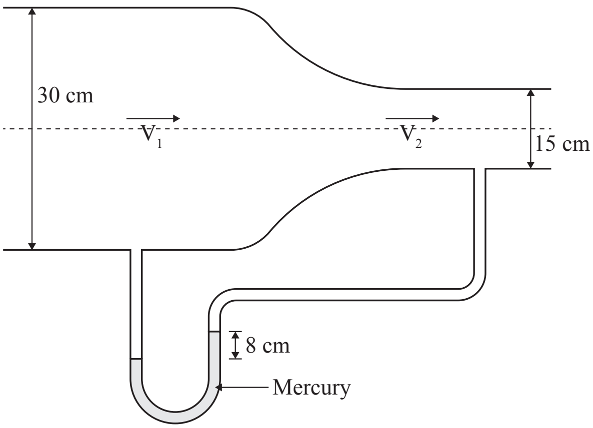
$$\sigma_Z \propto \frac{1}{Z^2}$$

$$\therefore \frac{\sigma_{Z1}}{\sigma_{Z2}} = \left[\frac{Z_2}{Z_1}\right]^2 \qquad Z_1 = 2\text{ m},\ Z_2 = 4\text{ m}$$

$$= \left[\frac{4}{2}\right]^2 = 4$$

End of Solution

24. A circular duct carrying water gradually contracts from a diameter of 30cm to 15 cm. The figure (nor drawn to scale) shows the arrangement of differential manometer attached to the duct .



When the water flows, the differential manometer shows a deflection of 8 cm of mercury (Hg). The values of specific gravity of mercury and water are 13.6 and 1.0m, respectively. Consider the acceleration due to gravity, $g = 9.81\text{ m/s}^2$. Assuming frictionless flow, the flow rate (in m^3/s, round off to 3 decimal places) through the duct is__

24 Ans : 0.081

Sol: Applying Bernoulli's equation for points (1) and (2)

$$\frac{P_1}{\gamma_w} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma_w} + \frac{V_2^2}{2g} + Z_2$$

where $Z_1 = Z_2$

$V_2 = 4V_1$ (as $d_1 = 2d_2$)

and $$\frac{(P_1 - P_2)}{\gamma_w} = 0.08\left(\frac{S_{Hg}}{S_w} - 1\right)$$

$$= 0.08 \times 12.6 \text{ m of water}$$

Thus, $\dfrac{V_2^2 - V_1^2}{2g} = \dfrac{P_1 - P_2}{\gamma_w} = 0.08 \times 12.6$

or $\dfrac{V_2^2}{2g}\left[1 - \dfrac{V_1^2}{V_2^2}\right] = 0.08 \times 12.6$

or $V_2^2\left(1 - \dfrac{1}{16}\right) = 0.08 \times 12.6 \times 2 \times 9.81$

or $V_2^2 = 0.08 \times 12.6 \times 2 \times 9.81 \times \dfrac{16}{15}$

$= 21.095$

$V_2 = 4.593$ m/s

Discharge = $\dfrac{\pi}{4} \times 0.15^2 \times 4.593 = 0.0816\ m^3/s$

End of Solution

25. Assuming that there is no possibility of shear buckling in the web, the maximum reduction permitted by IS 800-2007 in the (low-shear) design bending strength of a semi-compact steel section due to high shear is

(a) 50% (b) governed by the area of the flange (c) 25% (d) zero

25. Ans: (d)

Sol:

Design moment capacity of semi-compact section under low shear in case of lateral unrestrained steel section

$(M_d) = \beta_b Z_p f_{bd} = Z_e f_{bd}$

where,

$$\beta_b = \frac{Z_e}{Z_p}$$

f_{bd} = design bending stress

Design moment capacity of semi-compact section under high shear in case of lateral unrestrained steel section

$(M_{dv}) = \dfrac{f_y}{\gamma_{mo}} Z_p f_{bd} = Z_e f_{bd}$

∴ Hence, there is no reduction for semi-compact section.

However, for plastic and compact M_{dd} depends on moment resisting capacity of flange

$\{ M_{dd} = M_d - \beta (M_d - M_{fd})\} = 0$

End of Solution

26. A 0.80 m deep bed of sand filter (length 4m and width 3m) is made of uniform particles (diameter = 0.40 mm, specific gravity = 2.65, shape factor = 0.85) with bed porosity of 0.4. The bed has to be backwashed at flow rate of 3.60 m^3/min. During backwashing, if the terminal settling velocity of sand particles is 0.05 m/s, the expanded bed depth (in m, round off to 2 decimal places) is ________

26. Ans: 1.20 m

Sol: Given,

$z = 0.8$ m ,

$n = 0.4$ m

$$Q_B = 3.6\ m^3/min = = \frac{3.6}{60} m^3/sec = 0.06\ m^3/sec$$

$L = 4$ m ,

$B = 3$ m,

$$v_B = \frac{Q_B}{A_s} = \frac{Q_B}{L \times B}$$

$$= \frac{0.06}{4 \times 3} m/sec = 5 \times 10^{-3}\ m/sec$$

$v_s = 0.05$ m/sec

$v_B = v_s\ (n_e)^{4.5}$

$$(n_e)^{4.5} = \frac{v_B}{v_s} = \frac{5 \times 10^{-3}}{0.05}$$

$$n_e = \left(\frac{5 \times 10^{-3}}{0.05}\right)^{\frac{1}{4.5}} = 0.599 \simeq 0.6$$

$$\frac{z_e}{z} = \frac{1-n}{1-n_e}$$

$$\Rightarrow z_e = z\left(\frac{1-n}{1-n_e}\right)$$

$$\Rightarrow z_e = 0.8 \times \left(\frac{1-0.4}{1-0.6}\right) = 1.2\ m$$

End of Solution

27. Average free flow speed and the jam density observed on a road stretch are 60 km/h and 120 vehicles/km, respectively. For a linear speed-density relationship, the maximum flow on the road stretch (in vehicles/h) is ________.

27. Ans: 1800

Sol: Maximum Speed / Free flow speed, $V_m = 60$ kmph

Jam density, $K_m = 120$ kmph

for linear speed - density (Green shield's model) relationship,

max. flow, is $q_{max} = \frac{k_j}{2} \times \frac{V_f}{2}$

$q_{max} = \frac{120}{2} \times \frac{60}{2} = 1800$ veh/hr

End of Solution

28. A square footing of 4m side is placed at 1 m depth in a sand deposit. The dry unit weight (γ) of sand is 15 kN/m^3. This footing has an ultimate bearing capacity of 600 kPa. Consider the depth factors; $d_q = d_\gamma = 1.0$ and the bearing capacity factor; $N_\gamma = 18.75$. This footing is placed at a depth of 2 m in the same soil deposit. For a factor of safety of 3.0 as per Terzaghi's theory, the safe bearing capacity (in kPa) of this footing would be _____

28. Ans: (270)

Sol: As per Terzaghi's theory, the ultimate bearing capacity for a square footing considering depth factors: $d_q = d_\gamma = 1$ is as follows:

$q_u = 1.3\, CN_C + \gamma D_f N_q + 0.4\, \gamma B N_\gamma$

For sand, C = 0

$q_u = \gamma D_f\, N_q + 0.4\, \gamma B\, N_\gamma$

Given:

$\gamma = 15\ kN/m^3,\ \ B = 4\ m,\ \ N_\gamma = 18.75$

Initial condition: $D_f = 1m,\ \ q_u = 600\ kPa$

$q_u = \gamma D_f\, N_q + 0.4\, \gamma B\, N_\gamma$

$600 = 15 \times 1 \times N_q + 0.4 \times 15 \times 4 \times 18.75$

$\therefore N_q = 10$

If $D_f = 2m$, then, $q_u = \gamma D_f\, N_q + 0.4\, \gamma\, BN_\gamma$

$= 15 \times 2 \times 10 + 0.4 \times 15 \times 4 \times 18.75$

$= 750\ kN/m^2$

Net ultimate BC of soil, $q_{nu} = q_u - \gamma D_f$

$= 750 - 15 \times 2 = 720\ kN/m^2$

The gross safe BC or safe BC, $q_s = \frac{q_{nu}}{F} + \gamma D_f$

$= \frac{720}{3} + 15 \times 2$

$= 270$ kPa

29. A sample of air analysed at 0^0C and 1 atm pressure is reported to contain 0.02 ppm (parts per million) of NO_2. Assume the gram molecular mass of NO_2 as 46 and its volume at 0^0C and 1 atm pressure as 22.4 litres per mole. The equivalent NO_2 concentration (in microgram per cubic meter, round off to 2 decimal places) would be _______

29. Ans: 41.0714

Sol:

$k = 22.4, \qquad M = 46$

$$0.02 \text{ ppm of } NO_2 = 0.02 \times \frac{M}{k} \times 10^3 \ \mu g/m^3$$

$$= 0.02 \times \frac{46}{22.4} \times 10^3$$

$$= 41.0714 \ \mu g/m^3$$

End of Solution

30. A box measuring 50 cm × 50 cm × 50 cm is filled to the top with dry coarse aggregate of mass 187.5 kg. The water absorption and specific gravity of the aggregate are 0.5% and 2.5, respectively. The maximum quantity of water (in kg, round off to 2 decimal places) required to fill the box completely is _____

30. Ans: 50.94

Sol: $0.5 \times 0.5 \times 0.5$ (Box)

$= 0.125 \text{ m}^3$ (Total volume)

wt of aggregates = 187.5 kg

sp. gravity = 2.5 ⇒ Unit weight $= 2.5 \times 9.81 \text{ kN/m}^3$

$= 24.525 \text{ kN/m}^3$

$$\text{wt of water absorbed} = \frac{0.5}{100} \times 187.5 \text{ kg}$$

$= 0.9375$ kg

$$\text{vol of aggregate} = \frac{187.5 \times 9.81}{1000 \times 24.525}$$

$= 0.075 \text{ m}^3$

volume of voids = 0.125 - 0.075

$= 0.05 \text{ m}^3$

⇒ wt of water in voids $= 0.05 \times 1000$ kg

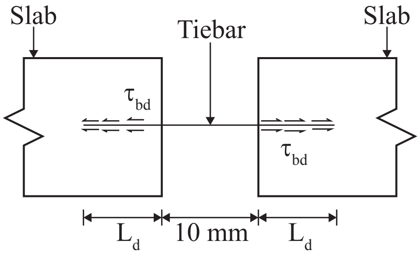
= 50 kg

wt of water required to fill the box = 50 + 0.9375

= 50.94 kg

31. Tie bars of 12 mm diameter are to be provided in a concrete pavement slab. The working tensile stress of the tie bars is 230 MPa, the average bond strength between a tie bar and concrete is 2 MPa, and the joint gap between the slabs is 10 mm. Ignoring the loss of bond and the tolerance factor, the design length of the tie bars (in mm, round off to the nearest integer) is ____________

31. Ans:700 mm



Sol:

$$L_d = \frac{\phi\sigma_{st}}{4\tau_{bd}} = \frac{12 \times 230}{4 \times 2} = 345 \text{ mm}$$

Length of tie bar = $L_d + 10 + L_d = 345 + 10 + 345$

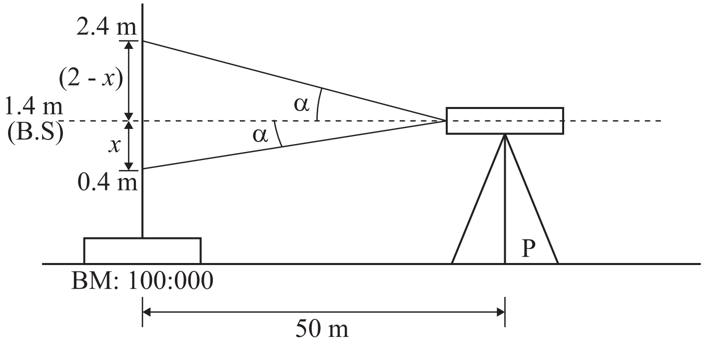
$= 700$ mm

End of Solution

32. A staff is placed on a benchmark (BM) of reduced level (RL) 100.000 m and a theodolite is placed at a horizontal distance of 50 m from the BM to measure the vertical angles. The measured vertical angles from the horizontal at the staff readings of 0.400 m and 2.400 m are found to be the same. Taking the height of the instrument as 1.400 m, the RL (in m) of the theodolite station is ________

32. Ans: 100

Sol:



$x = 50 \tan\alpha$;

$2 - x = 50 \tan\alpha$

$\therefore x = 2 - x$

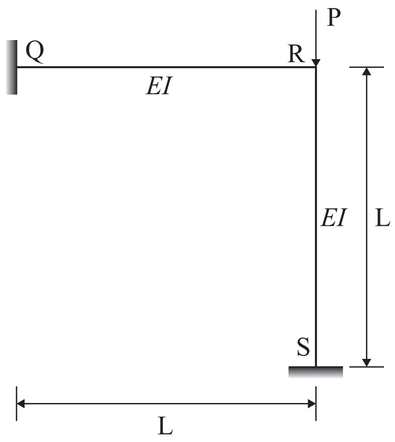
$2x = 2$;

$x = 1$ m

R.L of theodolite station (P): $100 + 1.4 - 0.1 - 0.4 = 100$ m

End of Solution

33. The rigid-jointed plane frame QRS showing in the figure is subjected to a load P at the joint R. Let the axial deformations in the frame be neglected. If the support S undergoes a settlement of $\Delta = \frac{PL^3}{\beta EI}$, the vertical reaction at the support S will become zero when β is equal to



(a) 3.0

(b) 0.1

(c) 48.0

(d) 7.5

33. Ans: (d)

Sol: Adopting moment distribution method:

Q	1/2	1/2	S
$\frac{-6EI\Delta}{\ell^2}$	$\frac{-6EI\Delta}{\ell^2}$	0	0
$\frac{+1.5EI\Delta}{L^2}$ ⟵	$\frac{+3EI\Delta}{L^2}$	$\frac{+3EI\Delta}{L^2}$ ⟶	$\frac{1.5EI\Delta}{L^2}$
$\frac{-4.5EI\Delta}{L^2}$	$\frac{-3EI\Delta}{L^2}$	$\frac{+3EI\Delta}{L^2}$	$\frac{-1.5EI\Delta}{L^2}$

Thus, final vertical reaction at S (both due f_0 sinking and P)

$$R_S = P - V = P - \frac{7.5EI}{L^3} \times \frac{PL^3}{\beta EI}$$

$$R_S = \frac{P - 7.5T}{\beta}$$ when β = reaction at S = 0

End of Solution

34. Consider two functions: $x = \psi \ln \phi$ and $y = \phi \ln \psi$. Which one of the following is the correction expression for $\frac{\partial \psi}{\partial x}$?

(a) $\frac{x \ln \phi}{\ln \phi \ln \psi - 1}$ (b) $\frac{x \ln \psi}{\ln \phi \ln \psi - 1}$

(c) $\frac{\ln \phi}{\ln \phi \ln \psi - 1}$ (d) $\frac{\ln \psi}{\ln \phi \ln \psi - 1}$

34. Ans: (d)

Sol: Taking the partial derivative with respect to x for the two equations, we get

$$1 - \frac{\partial \psi}{\partial x} \ln \phi + \frac{\psi}{\phi} \frac{\partial \phi}{\partial x}, \quad 0 = \frac{\phi}{\psi} \frac{\partial \psi}{\partial x} + \ln \psi \frac{\partial \phi}{\partial x}$$

From above two equations, we get

$$\frac{\partial \psi}{\partial x} = \frac{\ln \psi}{\ln \phi \ln \psi - 1}$$

Hence, option (d) is correct.

End of Solution

35. A reinforced concrete circular pile of 12 m length and 0.6 m diameter is embedded in stiff clay which has an undrained unit cohesion of 110 kN/m². The adhesion factor is 0.5. The net Ultimate Pullout (uplift) Load for the pile (in kN, round off to 1 decimal place) is ___________

35. Ans: 1328.9

Sol: The uplifting of pile is resisted by the side skin friction and the pile self weight which acts downwards.

Ultimate pull out load, $P_u = \pi D.L\alpha C + \text{weight of pile}$

$$= \left(\pi DL\alpha C + \frac{\pi}{4} D^2.L.\gamma_c\right)$$

where γ_c = unit wt. of concrete = 25 kN/m³

$P_u = \pi \times 0.6 \times 12 \times 0.5 \times 110 + \frac{\pi}{4} \times 0.6^2 \times 12 \times 25$

= 1328.894 kN say 1328.9 kN

End of Solution

36. Sedimentation basin in a water treatment plant is designed for a flow rate of 0.2 m³/s. The basin is rectangular with a length of 32 m, width of 8 m, and depth of 4 m. Assume that the settling velocity of these particles is governed by the Stoke's law. Given: density of the particles = 2.5 g/cm³; density of water = 1 g/cm³; dynamic viscosity of water = 0.01 g/(cm.s); gravitational acceleration = 980 cm/s². If the incoming water contains particles of diameter 25 μm (spherical and uniform), the removal efficiency of these particles is

(a) 78% (b) 51% (c) 65% (d) 100%

36. Ans: (c)

Sol:

$Q = 0.2\ m^3/sec, \quad L = 32\ m, \quad B = 8\ m, \quad H = 4\ m$

$\rho_p = 2.5\ gm/cc = 2500\ kg/m^3$

$\rho_w = 1\ gm/cc = 1000\ kg/m^3$

$\mu = 0.01\ gm/cm-sec = 1\times10^{-3}\ kg/m-sec$

$d = 25\ \mu m = 25\times10^{-6}\ m^2$

$g = 980\ cm/sec^2 = 9.8\ m/sec^2$

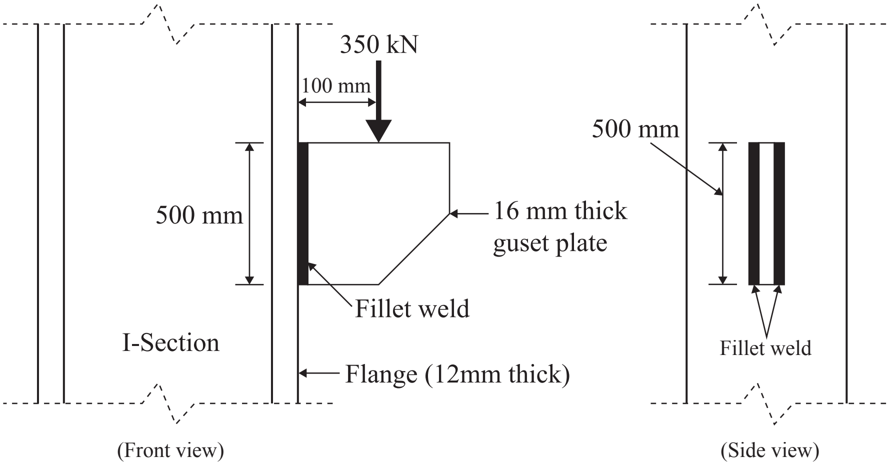
$$v_0 = \frac{Q}{A_s} = \frac{Q}{L\times B} = \frac{0.2}{32\times8} = 7.8125\times10^{-4}\ m/sec$$

$$v_s = \frac{g(\rho_p-\rho_w)d^2}{18\mu} = \frac{9.8(2500-1000)\times(25\times10^{-6})^2}{18\times(1\times10^{-3})} = 5.1041\times10^{-4}\ m/sec$$

$$\eta = \frac{v_s}{v_0}\times100 = \frac{5.1041\times10^{-4}}{7.8125\times10^{-4}}\times100 = 65.33\% \simeq 65\%$$

End of Solution

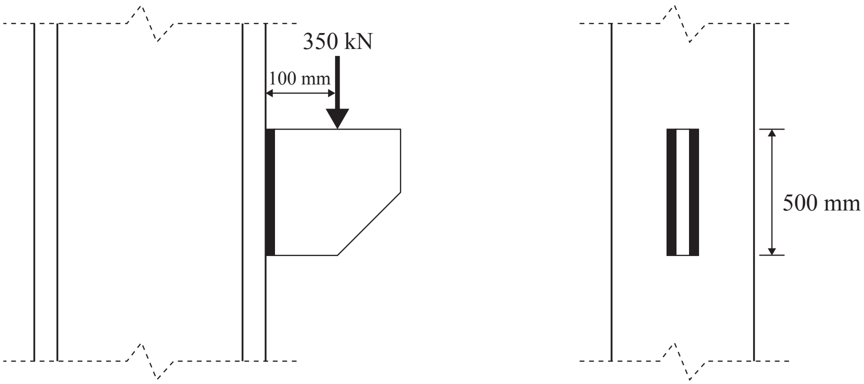
37. A 16 mm thick gusset plate is connected to the 12 mm thick flange plate of an I-section using fillet welds on both sides as shown in the figure (not drawn to scale). The gusset plate is subjected to a point load of 350 kN acting at a distance of 100 mm from the flange plate. Size of fillet weld is 10 mm.



The maximum resultant stress (in MPa, round off to 1 decimal place) on the fillet weld along the vertical plane would be ____________.

37. Ans:105.35 MPa

Sol:



Given:

Direct concentrated load (P) = 350 kN

Eccentricity (e) = 100 mm

Depth of weld (d_w) at each face = 500 mm

Size of weld (S) = 10 mm

Throat thickness of weld (t_t) = 0.7S = 7 mm

It is a case of combined shear (P) and Bending moment (M = P.e)

- Shear stress acting on weld due to direct shear force P, (q) = $\frac{P}{A_w}$

$$= \frac{P}{2d_w t_t}$$

$$= \frac{350 \times 10^3}{2 \times 500 \times 7} = 50 \text{ MPa}$$

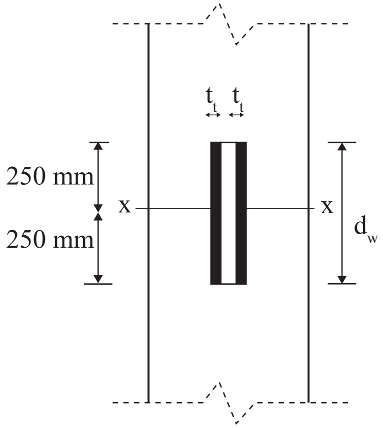
- Bending normal stress acting at i^{th} point from Neutral axis $[f_i] = \frac{M}{I}.y_i$

Maximum bending stress at extreme point in weld $[f] = \frac{M}{I}.y_{max}$

$$= \frac{P.e}{2 \times t_t . \frac{d_w^3}{12}} \times y_{max}$$

$$= \frac{350 \times 10^3 \times 100}{2 \times 7 \times \frac{(500)^3}{12}} \times 250$$

$$= 60 \text{ MPa}$$



As per IS800:2007. Maximum resultant stress an equivalent stress in fillet weld due to combined shear and bending stress $(f_{eq}) = \sqrt{f^2 + 3q^2}$

$$f_{eq} = \sqrt{60^2 + 3 \times 50^2} = 105.3 \text{ MPa}$$

End of Solution

38. Traffic on a highway is moving at a rate of 360 vehicles per hour at a location. If the number of vehicles arriving on this highway follows Poisson distribution, the probability (round off to 2 decimal places) that the headway between successive vehicles lies between 6 and 10 seconds is ____________

38. Ans: 0.18

Sol: $h_1 = 6$ seconds, $h_2 = 10$ seconds

given, avg. rate, $\lambda = \frac{360 \text{ veh}}{\text{hr}} = 360 \times \frac{1}{3600} = \frac{1}{10} \frac{\text{veh}}{\text{sec}}$

Probability that the headway is between h_1 & h_2 is given by,

$$P(h_1 \leq h \leq h_2) = e^{-\lambda h_1} - e^{-\lambda h_2}$$

$$= e^{-\frac{1}{10} \times 6} - e^{-\frac{1}{10} \times 10} = 0.1809 \approx 0.18$$

End of Solution

39. If the section shown in the figure turns from fully-elastic to fully-plastic, the depth of neutral axis (N.A), $\bar{y}$, decreases by

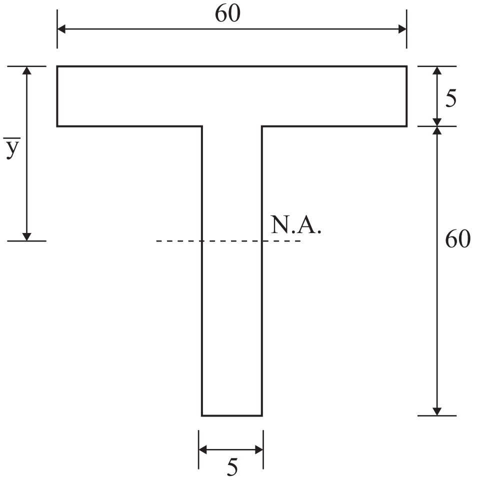
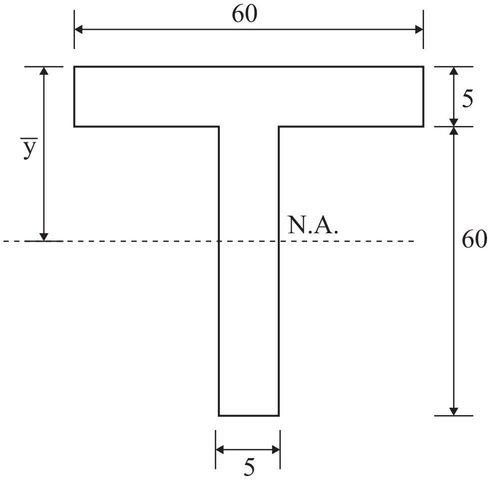


Figure not to scale
All dimension are in mm

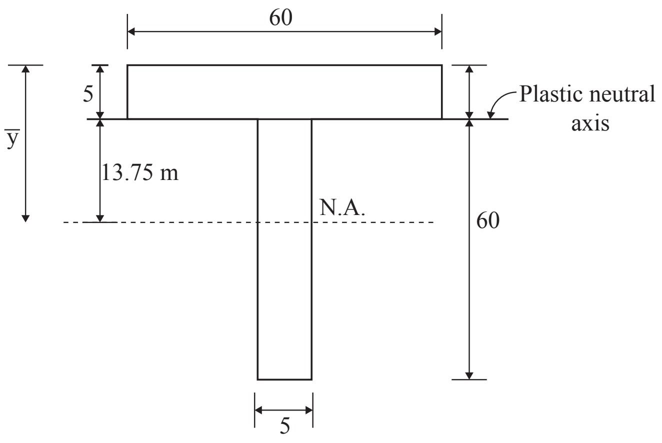
(a) 13.75 mm
(b) 12.25 mm
(c) 15.25 mm
(d) 10.75 mm

39. Ans: (a)

Sol:



$$\bar{y} = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2} = \frac{300 \times 2.5 + 300 \times 35}{300 + 300} = 18.75 \text{ m}$$



End of Solution

40. Consider a laminar flow in the x-direction between two infinite parallel plates (Couette flow). The lower plate is stationary and the upper plate is moving with a velocity of 1 cm/s in the x-direction. The distance between the plates is 5 mm and the dynamic viscosity of the fluid is 0.01 N-s/m^2. If the shear stress on the lower plate is zero, the pressure gradient, $\frac{\partial p}{\partial x}$, (in N/$m^2$ per m, round off to 1 decimal place) is ____________

40 Ans: 8.0

Sol: Given flow is a couette flow with pressure gradient

$$\mu = 0.01\ \text{N-s/m}^2$$

$$h = 5\ \text{mm}$$

$$\text{if } \tau_{y=0} = 0,\ \text{find } \frac{dp}{dx}$$

The velocity distribution, for the couette flow with pressure gradient is given by

$$u = \frac{wy}{h} - \frac{1}{2\mu}\frac{dp}{dx}\left[hy - y^2\right]$$

where w is the velocity of the top plate and h is the gap between the plates

$$\frac{du}{dy} = \frac{w}{h} - \frac{1}{2\mu}\frac{dp}{dx}\left[h - 2y\right]$$

$$\left.\frac{du}{dy}\right|_{y=0} = \frac{w}{h} - \frac{1}{2\mu}\frac{dp}{dx}h$$

$$\tau_{y=0} = \mu\left[\frac{w}{h} - \frac{1}{2\mu}\frac{dp}{dx}h\right]$$

$$\tau_{y=0} = \frac{w\mu}{h} - \frac{1}{2}\frac{dp}{dx}h$$

When $\tau_{y=0} = 0$, we will have

$$\frac{1}{2}\frac{dp}{dx}h = \frac{w\mu}{h}$$

$$\text{or } \frac{dp}{dx} = \frac{2w\mu}{h^2}$$

$$= \frac{2 \times 1 \times 10^{-2} \times 0.01}{(5 \times 10^{-3})^2} = 8.0 \text{ N/m}^2 \text{ per m}$$

End of Solution

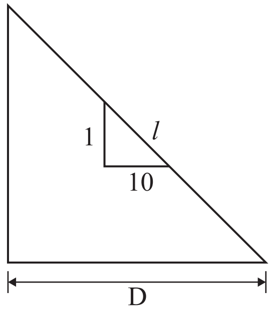
41. A survey line was measured to be 285.5 m with a tape having a nominal length of 30 m. On checking, the true length of the tape was found to be 0.05 m too short. If the line lay on a slope of 1 in 10, the reduced length (horizontal length) of the line for plotting of survey work would be

(a) 284.5 m (b) 285.6 m

(c) 285.0 m (d) 283.6 m

41. Ans: (d)

Sol:



L = 30 m, L′ = 30 – 0.05 = 29.95 m

L′ = 85.5 m

∴ Correct length

$$\ell = \ell' \times \frac{\ell'}{L} = 285.5 \times \frac{29.95}{30} = 285.024 \text{ m}$$

$$D = \ell \cos\theta$$

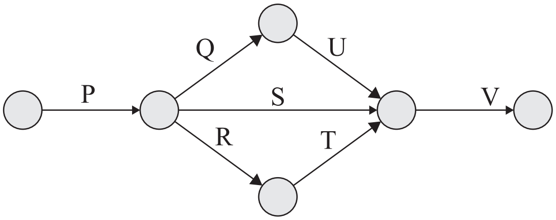
$$\cos\theta = \frac{10}{\sqrt{10^2 + 1^2}} = 0.995$$

∴ D = correct Horizontal length = $\ell \cos\theta$

$$= 285.024 \times 0.9950 = 283.6 \text{ m}$$

End of Solution

42. The network of a small construction project awarded to a contractor is shown in the following figure. The normal duration, crash duration, normal cost, and crash cost of all the activities are shown in the table. The indirect cost incurred by the contractor is INR 5000 per day.



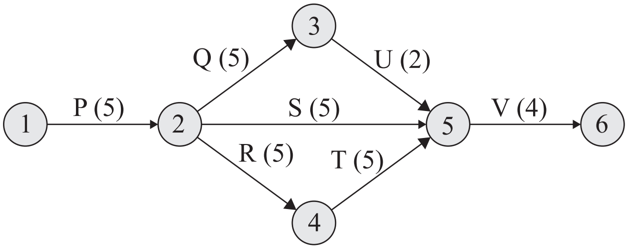
Activity	Normal duration (days)	Crash duration (days)	Normal cost (INR)	Crash cost (INR)
P	6	4	15000	25000
Q	5	2	6000	12000
R	5	3	8000	9500
S	6	3	7000	10000
T	3	2	6000	9000
U	2	1	4000	6000
V	4	2	20000	28000

If the project is targeted for completion in 16 days, the total cost (in INR) to be incurred by the contractor would be __________

42. Ans: 1,49,500

Sol:

Path	Duration
P - Q - U - V	17
P - S - V	16
P - R - T - V	18



Activity	Cost slope (Rs./day) = $\frac{\Delta C}{\Delta T}$
P	$\frac{25000-15000}{6-4} = 5000$
Q	$\frac{12000-6000}{5-2} = 2000$
R	$\frac{9500-8000}{5-3} = 750$
S	$\frac{10000-7000}{6-3} = 1000$
T	$\frac{9000-6000}{3-2} = 3000$
U	$\frac{6000-4000}{2-1} = 2000$
V	$\frac{28000-20000}{4-2} = 4000$

Indirect cost = Rs. 5000

Crashing possibility = 18 - 17 = 1 day

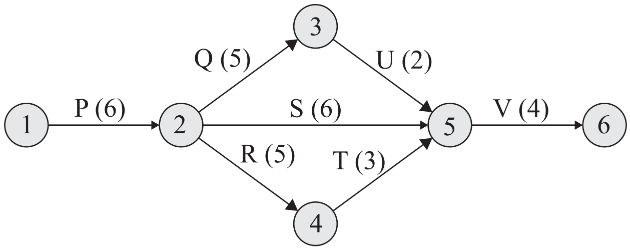
To reduce the project duration by 1 day, the following options available.

Option	Cost slope
P	5000
R	750
T	3000
V	4000

Best option : Crashing 'R' by 1 day.

After crashing 'R' by 1 day, the new network is as for follows.

Path	**Duration**
P - Q - U - V	17
P - S - V	16
P - R - T - V	17



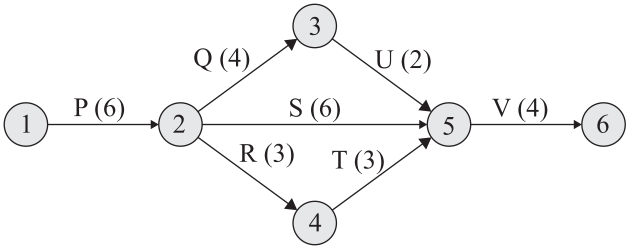
The reduce the project duration by 1 day

Option	Cost slope
P	5000
V	4000
Q & R	2000 + 750 = 2750
U & R	2000 + 750 = 2750
Q & T	2000 + 3000 = 5000
U & T	2000 + 3000 = 5000

After crashing Q & R by 1 day, the new network is as follows.

Path	Duration
P - Q - W - V	16
P - S - V	16
P - R - T - V	16

Project duration = 16 days.



Total project cost = Total normal cost + crashing cost of 'R' by 1 day + crashing cost of Q & R by 1 day + Indirect cost/day × Project duration

= 15000 + 6000 + 8000 + 7000 + 6000 + 4000 + 20000 + 750 × 1 + 2750 × 1 + 5000 × 16

= 1,49,500 /-

End of Solution

43. A wastewater is to be disinfected with 35 mg/L of chlorine to obtain 99% kill of micro-organisms. The number of micro-organisms remaining alive (N_t) at time t, is modelled by $N_t = N_o e^{-kt}$, where N_o is number of micro-organisms at t = 0, and k is the rate of kill. The wastewater flow rate is 36 m^3/h and k = 0.23 min^{-1}. If the depth and width of the chlorination tank are 1.5 m and 1.0 m, respectively, the length of the tank (in m, round off to 2 decimal places) is ________

43. Ans: 8.00

Sol: $N_t = N_0 . e^{-kt}$

$\therefore \eta = [1 - e^{-kt}]100$

$99 = [1 - e^{-0.23 \times t}]100$

$\therefore t = 20.22$ min

$Q = 36\ m^3/hr$

$V = Q \times t = \frac{36}{60} \times 20.22 = 12.0132$

$\text{Length} = \frac{V}{B \times H} = \frac{12.0132}{1 \times 1.5} = 8.008\ m \cong 8m$

44. A granular soil has a saturated unit weight of 20 kN/m^3 and an effective angle of shearing resistance of 30°. The unit weight of water is 9.81 kN/m^3. A slope is to be made on this soil deposit in which the seepage occurs parallel to the slope up to the free surface. Under this seepage condition for a factor of safety of 1.5, the safe slope angle (in degree, round off to 1 decimal place) would be ____________

44. Ans: 11.1

Sol: $\gamma_{sat} = 20\ \text{kN/m}^3$

$\gamma_w = 9.81\ \text{kN/m}^3$

$\therefore\quad \gamma' = \gamma_{sat} - \gamma_w = 10.19\ \ \text{kN/m}^3$

$\therefore\ \phi' = 30°, F = 1.5$

For infinite slope, the F.O. safety for seepage parallel to the slope in a granular soil (C = 0) is given below

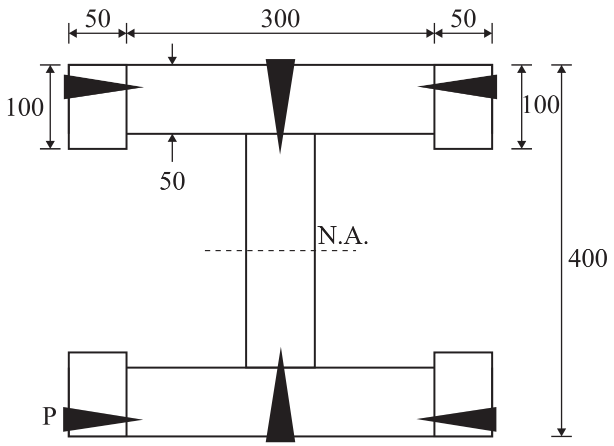
$$F = \frac{\gamma'}{\gamma_{sat}} \cdot \frac{\tan\phi'}{\tan i}$$

$$1.5 = \frac{10.19}{20} \frac{\tan 30}{\tan i}$$

$i = 11.095$ say $11.1°$

End of Solution

45. The cross-section of a built-up wooden beam as shown in the figure (not drawn to scale) is subjected to a vertical shear force of 8 kN. The beam is symmetrical about the neutral axis (N.A) shown, and the moment of inertia about N.A is 1.5×10^9 mm^4. Considering that the nails at the location P are spaced longitudinally (along the length of the beam) at 60 mm, each of the nails at P will be subjected to the shear force of



All demiensions are in mm

(a) 240 N (b) 120 N

(c) 60 N (d) 480 N

45. Ans: (a)

Sol: Shear stress acting at the joint at which the nail 'P' is resisting the shear.

$$\tau = \frac{FA\bar{y}}{Ib}$$

$$= \frac{(8\times10^3)(50\times100)(150)}{1.5\times10^9\times50}$$

$= 0.08\ N/mm^2$

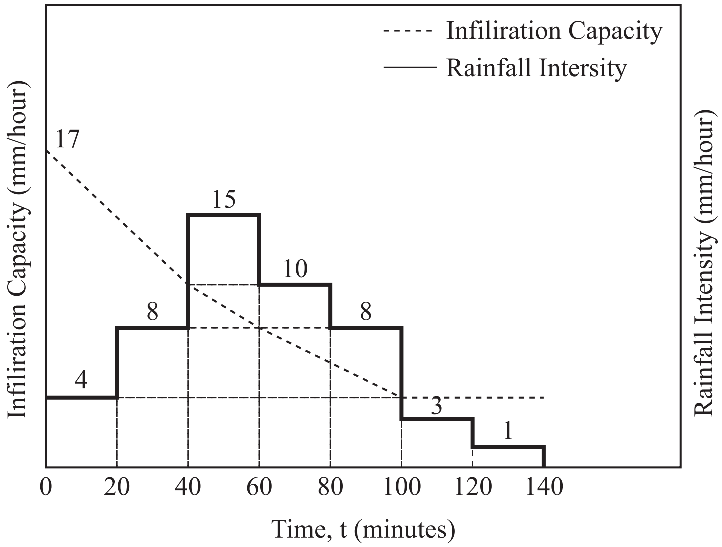
The shear force acting on nail at 'P'.

$F = (\tau)(60\times50)$

$= 240\ N$

End of Solution

46. The hyetograph of a storm event of duration 140 minutes is shown in the figure



The infiltration capacity at the start of this event (t = 0) is 17 mm/hour, which linearly decreases to 10 mm/hour after 40 minutes duration. As the event progresses, the infiltration rate further drops down linearly to attain a value of 4 mm/hour at t = 100 minutes and remains constant thereafter till the end of the storm event. The value of the infiltration index, ϕ (in mm/hour, round off to 2 decimal places), is ______________.

46. Ans: 7.00

Sol: $P_e = [15 + 10 + 1] \times \frac{20}{60} = 11\text{ m}$

$t_e = 20 + 20 + 20 = 60\text{ min} = 1\text{ hr}$

$$R = \left[5 \times \frac{20}{60} + \frac{1}{2} \times 2 \times \frac{20}{60}\right] + 2 \times \frac{20}{60} + \frac{1}{2} \times 4 \times \frac{40}{60}$$

$$= \frac{1}{60}\left[5 \times 20 + \frac{1}{2} \times 2 \times 20 + \frac{1}{2} \times 4 \times 40\right]$$

$$= 4\text{ mm}$$

$$\phi\text{ - index} = \frac{P_e - R}{t_e} = \frac{11 - 4}{\frac{60}{60}} = 7\text{ mm/hr}$$

End of Solution

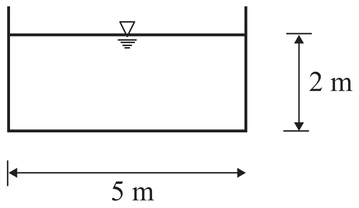
47. A rectangular open channel has a width of 5 m and a bed slope of 0.001. For a uniform flow of depth 2 m, the velocity is 2 m/s. The Manning's roughness coefficient for the channel is

(a) 0.033 (b) 0.017

(c)0.002 (d) 0.050

47. Ans: (b)

Sol:



Given: V = 2 m/sec, S = 0.001

$A = 5 \times 2 = 10\text{ m}^2$

$P = 5 + 2 + 2 = 9\text{ m}$

$$\text{Hydraulic mean radius (R)} = \frac{A}{P} = \left(\frac{10}{9}\right)$$

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$2 = \frac{1}{n}\left(\frac{10}{9}\right)^{2/3} (0.001)^{1/2}$$

$n = 0.0169 \simeq 0.017$

End of Solution

48. A one-dimensional domain is discretized into N sub-domains of width Δx with node numbers i = 0, 1, 2, 3, ... N. If the time scale is discretized in steps of Δt, the forward-time and centered space finite difference approximation at i^{th} node and n^{th} time step, for the partial differential equation $\frac{\partial v}{\partial t} = \beta \frac{\partial^2 v}{\partial x^2}$ is

(a) $\frac{v_i^{(n+1)} - v_i^{(n)}}{\Delta t} = \beta\left[\frac{v_{i+1}^{(n)} - 2v_i^{(n)} + v_{i-1}^{(n)}}{(\Delta x)^2}\right]$

(b) $\frac{v_{i+1}^{(n+1)} - v_i^{(n)}}{\Delta t} = \beta\left[\frac{v_{i+1}^{(n)} - 2v_i^{(n)} + v_{i-1}^{(n)}}{2\Delta x}\right]$

(c) $\frac{v_i^{(n)} - v_i^{(n-1)}}{\Delta t} = \beta\left[\frac{v_{i+1}^{(n)} - 2v_i^{(n)} + v_{i-1}^{(n)}}{(\Delta x)^2}\right]$

(d) $\frac{v_i^{(n)} - v_i^{(n-1)}}{2\Delta t} = \beta\left[\frac{v_{i+1}^{(n)} - 2v_i^{(n)} + v_{i-1}^{(n)}}{2\Delta x}\right]$

48. Ans: (a)

Sol: Given $\frac{\partial V}{\partial t} = \beta \frac{\partial^2 V}{\partial x^2}$

The centred space finite difference approximation at i^{th} node n^{th} time step is

$$\frac{V_i^{(n+1)} - V_i^{(n)}}{\Delta t} = \beta\left[\frac{V_{i+1}^{(n)} - 2V_i^{(n)} + V_{i-1}^{(n)}}{(\Delta x)^2}\right]$$

Hence, option (a) is correct.

End of Solution

49. Consider the ordinary differential equation $x^2\frac{d^2y}{dx^2} - 2x\frac{dy}{dx} + 2y = 0$. Given the values of y(1) = 0 and y(2) = 2, the value of y(3) (round off to 1 decimal place), is ______________.

49. Ans: 6

Sol: $x^2\frac{d^2y}{dx^2} - 2x\frac{dy}{dx} + 2y = 0 \quad y(1) = 0, y(2) = 2$

put $x = e^z$ (or) $z = \ln x$

$\theta = \frac{d}{dz} \quad xDy = \theta y, \; x^2D^2y = \theta(0-1)y$

the given D.E is equal to $\theta(\theta - 1)y - 2\theta y + 2y = 0$

$(\theta^2 - 3\theta + 2)\, y = 0$

$\frac{d^2y}{dz^2} - 3\frac{dy}{dz} + 2y = 0$

Auxiliary equations is $m^2 - 3m + 2 = 0$

$\Rightarrow m = 1, 2$

solutions is $y = c_1 e^z + c_2 e^{2z}$

$y = c_1x + c_2x^2$

$y(1) = 0 \Rightarrow 0 = c_1 + c_2$

$y(2) = 2 \Rightarrow 2 = 2c_1 + 4c_2$

By solving $c_1 = -1$, $c_2 = 1$

$\therefore\ y = -x + x^2$

$y(3) = -3 + 9 = 6$

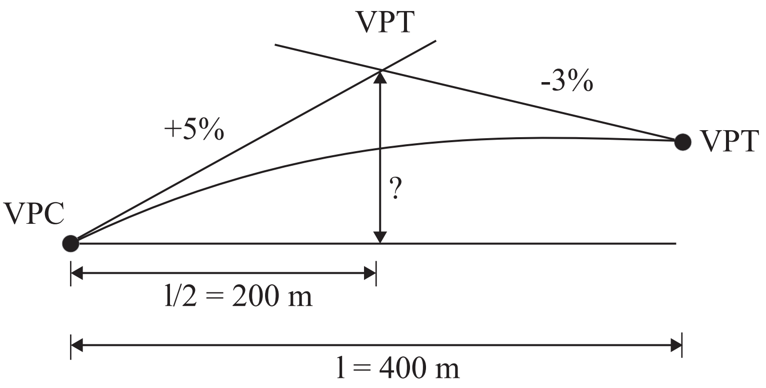
End of Solution

50. A parabolic vertical curve is being designed to join a road of grade +5% with a road of grade -3%. The length of the vertical curve is 400 m measured along the horizontal. The vertical point of curvature (VPC) is located on the road of grade +5%. The difference in height between VPC and vertical point of intersection (VPI) (in m, round off to the nearest integer) is ________

50. Ans: 10

Sol: Given, $N_1 = +5\%$, $N_2 = -3\%$

Length of summit curve is, $l = 400$ m



Vertical distance between VPC & VPI is $N_1 \times \frac{\ell}{2}$

$= \frac{5\%}{100} \times 200 = 10$ m

End of Solution

51. Which one of the following is NOT a correct statement?

(a) The function $\sqrt[x]{x}$, $(x > 0)$, has the global minima at $x = e$

(b) The function $|x|$ has the global minima at $x = 0$

(c)The function x^3 has neither global minima nor global maxima

(d) The function $\sqrt[x]{x}$, $(x > 0)$, has the global maxima at $x = e$

51. Ans: (a)

Sol: Let $y = \sqrt[x]{x}$, $\quad x > 0$

$$y = x^{\frac{1}{x}}$$
$$\ell ny = \ell nx^{\frac{1}{x}}$$
$$\ell ny = \frac{1}{x}\ell nx$$

$$\frac{1}{y}\frac{dy}{dx} = \frac{1}{x^2} - \frac{\ell nx}{x^2}$$

$$\frac{1}{y}\frac{dy}{dx} = \frac{1}{x^2}(1 - \ell nx)$$

$$\frac{dy}{dx} = \frac{y}{x^2}(1 - \ell nx)$$

put $\frac{dy}{dx} = 0 \Rightarrow \frac{y}{x^2}(1 - \ell nx) = 0$

$$\Rightarrow x = e$$

Now, $\frac{d^2y}{dx^2} = \frac{-y}{x^3} - \frac{2y}{x^3}(1 - \ell nx) + \frac{1}{x^2}(1 - \ell nx)\frac{dy}{dx}$

At $x = e$, $\frac{d^2y}{dx^2} = \left(\frac{-y}{x^3}\right)_{x=e} - \frac{2y}{x^3}(1 - \ell ne) + \frac{1}{x^2}(1 - \ell ne)\frac{dy}{dx}$

$$= \left(\frac{-x^{\frac{1}{x}}}{x}\right)_{at\ x=e}$$

$$= \frac{-e^{\frac{1}{e}}}{e} \quad 0$$

$\frac{d^2y}{dx^2}$ has maximum at $x = e$

End of Solution

52. For the following statements:

P: The lateral stress in the soil while being tested in an oedometer is always at rest.

Q: For a perfectly rigid strip footing at deeper depths in a sand deposit, the vertical normal contact stress at the footing edge is greater than that at its centre.

R: The corrections for overburden pressure and dilatancy are not applied to measured SPT-N values in case of clay deposits.

The correct combination of the statements is

(a) P-FALSE; Q-FALSE; R-FALSE

(b) P-FALSE; Q-FALSE;R-TRUE

(c) P-TRUE; Q-TRUE; R-FALSE

(d) P-TRUE; Q-TRUE; R-TRUE

52. Ans: (d)

Sol:

P: True

In the Oedometer test, stress is applied to the soil specimen along the vertical axis, while strain in the horizontal direction is prevented by the confining ring (a condition of zero lateral strain). Thus it simulates at-rest condition.

Q: True

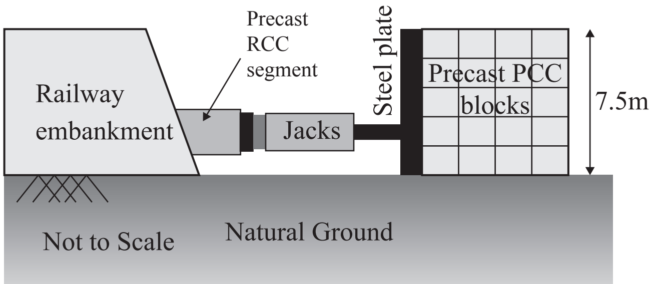
For a perfectly rigid footing resting on surface of sand deposit, the contact pressure distribution is zero at the edges and maximum at centre. However, for a very deep rigid footing on sand, the contact pressure distribution may tend to become like that of rigid footing on clayey soil, with edge contact stress greater than at its centre.

R: True

For cohesive soil, there is no need for overburden pressure correction (Peck et al 1974). For cohesionless soil at first overburden pressure correction is made, then if it is fine sand or silt under water table with N-value > 15, dilatancy correction is made.

End of Solution

53. A 3 m × 3 m square precast reinforced concrete segments to be installed by pushing them through an existing railway embankment for making an underpass as shown in the figure. A reaction arrangement using precast PCC blocks placed on the ground is to be made for the jacks.



At each stage, the jacks are required to apply a force of 1875 kN to push the segment. The jacks will react against the rigid steel plate placed against the reaction arrangement. The footprint area of reaction arrangement on natural ground is 37.5 m^2. The unit weight of PCC block is 24 kN/m^3. The properties of the natural ground are c = 17 kPa; $\phi = 25^\circ$ and $\gamma = 18$ kN/m^3. Assuming that the reaction arrangement has rough interface and has the same properties that of soil, the factor of safety (round off to 1 decimal place) against shear failure is ________

53. Ans: 2.0

Sol: Weight of Precast PCC block, W = volume × γ_c

$= 37.5 \times 7.5 \times 24 = 6750$ kN

Shear resistance below the Precast PCC block is, S = C.A + W.tanϕ

F.O safety against shear failure, $F = \frac{S}{T}$

$$F = \frac{C.A + W.\tan\phi}{T}$$

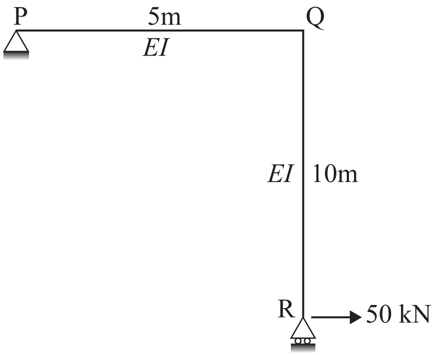
$$F = \frac{C.A + N.\tan\phi}{T} \qquad \text{(Since, N = W)}$$

$$= \frac{17 \times 37.5 + 6750 \times \tan 25^{\circ}}{1875}$$

$$= 2.0187 \text{ say } 2.0$$

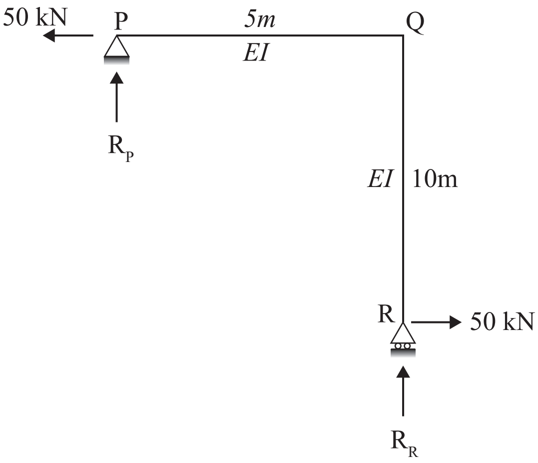
End of Solution

54. A portal frame shown in figure (not drawn to scale) has a hinge support at joint P and a roller support at joint R. A point load of 50 kN is acting at joint R in the horizontal direction. The flexural rigidity. EI of each member is 10^6 kNm^2. Under the applied load, the horizontal displacement (in mm, round off to 1 decimal place) of joint R would be ___________



54. Ans: 25 mm

Sol:



$\sum M_P = 0$ [Take clockwise as positive)

$R_R \times 5 - 50 \times 10 = 0$

$R_R = -100$ kN (↓)

$R_P = 100$ kN (↑)

$EI = 10^6$ kN-m²

Using unit load method:

The horizontal displacement at 'R'

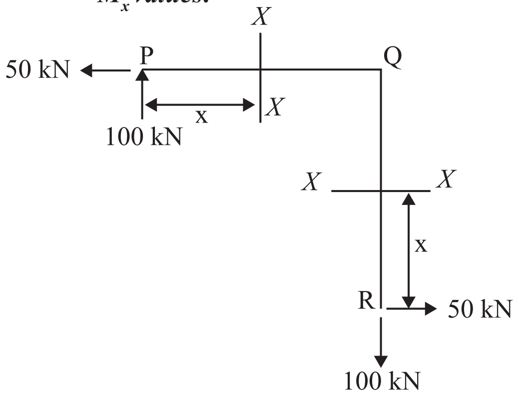
$$\delta_{HR} = \int_0^L \frac{M_x\, m_x}{EI} dx$$

where,

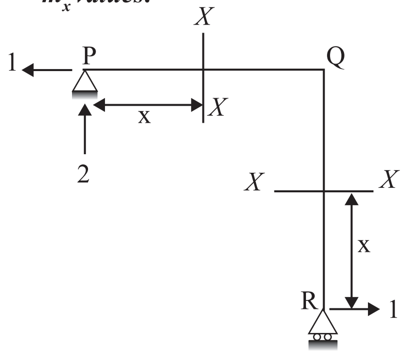
M_x = BM at X-X due to real loads

m_x = BM at X-X due to vertical unit load applied where we want to find the deflection.

M_x values:



m_x values:



$\sum M_R = 0$ [take Clockwise as positive]

$R_P \times 5 - 1 \times 10 = 0$

$R_P = 2$ kN (↑)

Sign conventions:

Sagging +ve

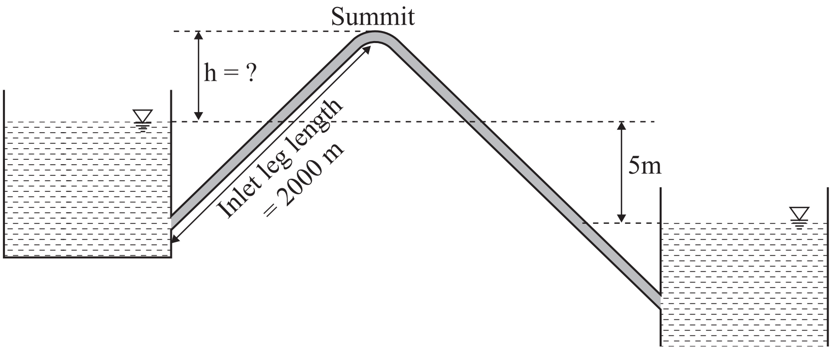
Hogging -ve

Member	M_x	m_x	$\int_0^L \frac{M_x m_x}{EI} dx$
PQ	100 x	2x	$\int_0^5 \frac{(100x)(2x)}{10^6} dx$
RQ	50 x	x	$\int_0^{10} \frac{(50x)(x)}{10^6} dx$

$$\delta_{HR} = \int_0^5 \frac{200x^2}{10^6}dx + \int_0^{10} \frac{50x^2}{10^6}dx = \frac{1}{40} = 0.025 \text{ m} = 25 \text{ mm}$$

End of Solution

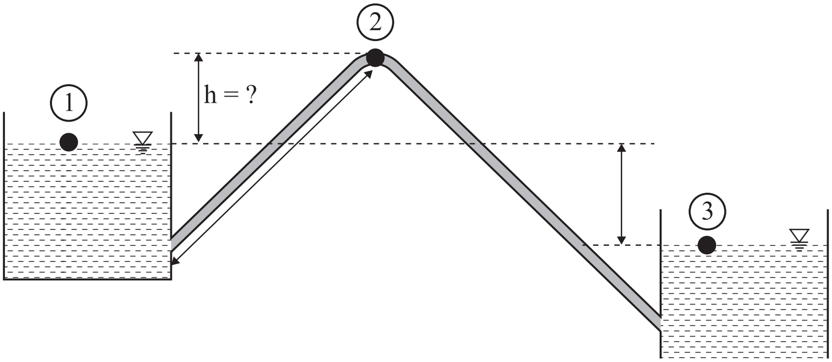
55. Two water reservoirs are connected by a siphon (running full) of total length 5000 m and diameter of 0.10 m, as shown below (figure not drawn to scale).



The inlet leg length of the siphon to its summit is 2000 m. The difference in the water surface levels of the two reservoirs is 5 m. Assume the permissible minimum absolute pressure at the summit of siphon to be 2.5 m of water when running full. Given: friction factor, f = 0.02 throughout, atmospheric pressure = 10.3 m of water, and acceleration due to gravity g = 9.81 m/s². Considering only major loss using Darcy-Weisbach equation, the maximum height of the summit of siphon from the water level of upper reservoir, h (in m, round off to 1 decimal place) is ______________.

55. Ans: 5.8 m

Sol:



Applying Bernoulli's equation between 1 & 3

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_3}{\rho g} + \frac{v_3^2}{2g} + z_3 + h_{f13}$$

$z_1 - z_3 = h_{f13}$ $\{\because P_1 = P_3 = P_{atm} \text{ and } v_1 = v_3 = 0\}$

$$5 = \frac{fLv^2}{2gd}$$

$$v^2 = \frac{5 \times 2 \times 9.81 \times 0.1}{0.02 \times 5000}$$

$v = 0.313$ m/s

Applying Bernoulli's equation between 1 & 2

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + h_{f12}$$

$$10.3 + 0 + 0 = 2.5 + \frac{0.313^2}{2 \times 9.81} + h + \frac{0.02 \times 2000 \times 0.313^2}{2 \times 9.81 \times 0.1}$$

$h = 5.798$ m

≈ 5.8 m

End of Solution