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GATE 2019
Civil Engineering

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Questions and Solutions

Date of Exam : 10/2/2019 (Forenoon)

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GENERAL APTITUDE

Q.1 If E = 10; J = 20; O = 30; and T = 40, what will be $P + E + S + T$?

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

Ans. (b)

According to given coding

$P = 32,\ E = 10,\ S = 38,\ T = 40$

$P + E + S + T = 32 + 10 + 38 + 40 = 120$

End of Solution

Q.2 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° 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_______meters.

(a) 15 (b) 25
(c) 35 (d) 30

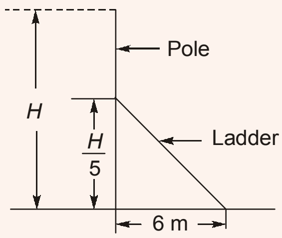
Ans. (d)

Here $\tan 45° = 1$

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

$H = 30$ m

Height of wall = 30 m



End of Solution

Q.3 They have come a long way in ________ trust among the users.

(a) Creating (b) Created
(c) Creation (d) Create

Ans. (a)

They have came long way in creating trust among the users.

End of Solution

Q.4 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

Ans. (d)

The lecture was attended by quite a few students so tha hall was not very quiet.

- quite a few indicates a fairly large number of units.
- quiet refer to making little or no noise.

End of Solution

Q.5 The CEO's decision to quit was as shocking to Board as it was to ________.

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

Ans. (c)

CEO's decision to quit was a shocking to the board as it was me.

- Board and me are receives of the action hence objective case of pronoun (me) is to be used.

End of Solution

Q.6 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________cm.

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

Ans. (d)

Let side of larger square = x
Side of smaller square = $(x - 5)$
Area of larger square = x^2
Area of smaller square = $(x - 5)^2$
Given, Area of larger square = 4 times of area of smaller square

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

$$\therefore \quad x = 10$$

Side of larger square = 10 cm

End of Solution

Q.7 "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) came to a conclusion (b) reached a terminus
(c) went to a place (d) attained a status

Ans. (d)

The paragraph deals with the increasing interest in tribal characters and further goes on to describe that tribal characters haven't attained any special status. There have been very few stories woven around these characters.

End of Solution

Q.8 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 for experimental purposes.
(b) Farmers want to access the new technology if India benefits from it.
(c) Farmers want to access the new technology even if it is not legal.
(d) Farmers want to access the new technology by paying high price.

Ans. (c)

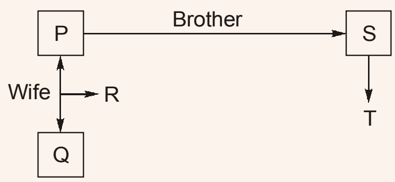
Farmers want to access the new technology even if it is not legal.
The argument emphasizes on the widespread use of the new cotton technology despite it being illegal. Detail about price is just an additional detail.

End of Solution

Q.9 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 aunt of R
(c) S is the brother of P
(d) S is the aunt of T

Ans. (d)



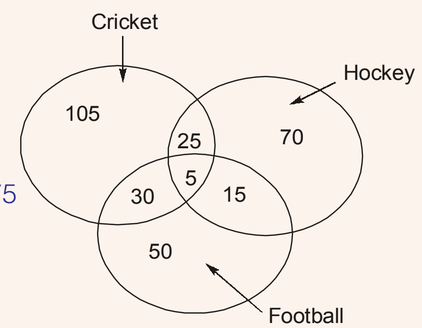
P is brother of S
P is male,
S is male or Female
S is sister-in-law of Q may be possible
S is brother of P may be possible
S is aunt of R may be possible
S is the aunt of T is impossible in this case because given T is child of S.

End of Solution

Q.10 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 sports. What is the percentage of people who play at least two sports?

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

Ans. (a)



All the three sports = 300 – 295
= 5

No. of players playing at least 2 sports
= 25 + 5 + 30 + 15 = 75

Percentage of players playing at least 2 sports

$$= \frac{75}{300} \times 100 = 25$$

End of Solution

■■■■

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CE	B	21-Feb-2019	Kalu Sarai Centre	3:00 PM to 9:00 PM
EE	A	22-Feb-2019	Lado Sarai Centre	7:30 AM to 1:30 PM
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CIVIL ENGINEERING

Q.1 A soil has specific gravity of its solids equal to 2.65. The mass density of water is 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_______.

Ans. (2094.9)

w = 10% and has zero air voids

$$\gamma_d = ?$$

$$\gamma_w = 1000 \text{ kg/m}^3$$

$$G = 2.65$$

Zero air voids

$\therefore$ $\eta_a = 0$ and $S = 1$

$\Rightarrow$ $Se = wG$

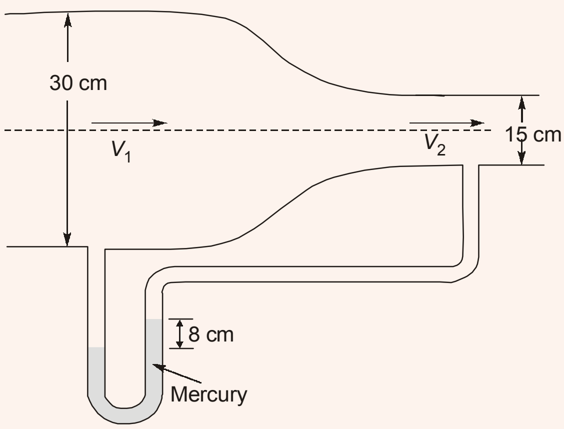
$$e = \frac{0.1 \times 2.65}{1} = 0.265$$

$$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.65 \times 1000}{1+0.265}$$

$$= 2094.86 \text{ kg/m}^3$$

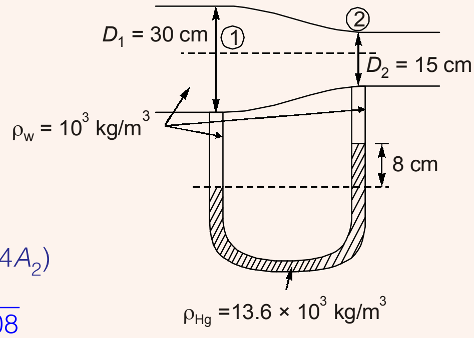
End of Solution

Q.2 A circular duct carrying water gradually contracts from a diameter of 30 cm to 15 cm. The figure (not 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 1.0, respectively. Consider the acceleration due to gravity, g = 9.81 m/s^2. Assuming frictionless flow, the flow rate (in m^3/s, round off to 3 decimal places) through the duct is ________.

Ans. (0.081)



$$Q = \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}}\sqrt{2gh}$$

$$h = x\left[\frac{\rho_{Hg}}{\rho_w} - 1\right] = 0.08(13.6 - 1)$$

$$= 1.008 \text{ m} \qquad (A_1 = 4A_2)$$

$$Q = \frac{4A_2 \times A_2}{\sqrt{16A_2^2 - A_2^2}} \times \sqrt{2 \times 9.81 \times 1.008}$$

$$= \frac{4}{\sqrt{15}} \times A_2 \times \sqrt{2 \times 9.81 \times 1.008}$$

$$= \frac{4}{\sqrt{15}} \times \frac{\pi}{4}(0.15)^2 \times \sqrt{2 \times 9.81 \times 1.008}$$

Q = 0.081 m^3/s (round off to 3 decimal place)

End of Solution

Q.3 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) $\frac{0.02G}{f_r + 0.01G} \times 100$

(b) $\frac{2f_r}{f_r + 0.01G} \times 100$

(c) $\frac{0.01G}{f_r + 0.02G} \times 100$

(d) $\frac{f_r}{f_r + 0.02G} \times 100$

Ans. (c)

Percentage change in Braking Distance $= \left(\frac{L_{B_1} - L_{B_2}}{L_{B_1}}\right) \times 100$

$$\%\Delta L_B = \frac{\frac{V^2}{254[f_r + 0.01G]} - \frac{V^2}{254[f_r + 0.02G]}}{\frac{V^2}{254[f_r + 0.01G]}}$$

$$= \frac{f_r + 0.02G - f_r - 0.01G}{(f_r + 0.01G)(f_r + 0.02G)} \times (f_r + 0.01G)$$

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

$$\%\Delta L_B = \left(\frac{0.01G}{f_r + 0.02G} \times 100\right)$$

End of Solution

Q.4 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_______.

Ans. (17.9)

$$\text{Risk} = 1 - q^n$$

$$\Rightarrow \quad 0.25 = 1 - (q)^5$$

$$\Rightarrow \quad q = 0.944087$$

$$\Rightarrow \quad 1 - p = 0.944087$$

$$\Rightarrow \quad 1 - \frac{1}{T} = 0.944087$$

$$\therefore \quad T \simeq 17.9 \text{ years}$$

End of Solution

Q.5 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) $\frac{m}{k}$

(b) $\frac{k}{m}$

(c) $\sqrt{\frac{m}{k}}$

(d) $\sqrt{\frac{k}{m}}$

Ans. (d)

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

$$\Rightarrow \quad \ddot{z} + \frac{k}{m}z = 0$$

Comparing with $\ddot{z} + \omega_n^2 z = 0$

We get $\omega_n = \sqrt{\frac{k}{m}}$.

End of Solution

Q.6 The interior angles of four triangles are given below:

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

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

(a) Both Q and S

(b) Both P and S

(c) Both Q and R

(d) Both P and R

Ans. (a)

For a well conditioned triangle.

The interior angle should not be less than 30°.

In this way, triangle '*Q*' & *S* having less angles (acute angle).

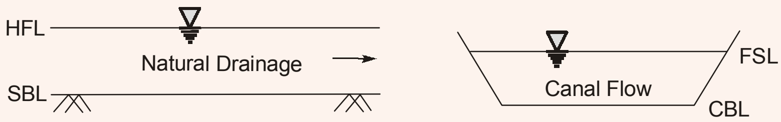
⇒ Q & S are ill-conditioned.

End of Solution

Q.7 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) Level crossing
(b) Super passage
(c) Aqueduct
(d) Sluice gate

Ans. (b)



where,

HFL: High Flood Level of Drain

SBL: Stream Bed Level

FSL: Full Supply Level of Canal

CBL: Canal Bed Level

Superpassage, as the given elevation condition suits CDW (as shown in diagram).

End of Solution

Q.8 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) $\dfrac{E\alpha(T_t - T_b)}{2}$
(b) $L\alpha(Tt_b - T_b)$
(c) $E\alpha(T_t - T_b)$
(d) Zero

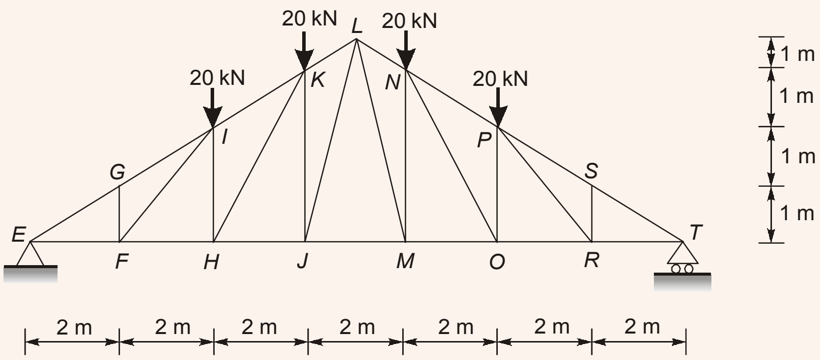
Ans. (d)

Frictionless base,

$$\sigma_{thermal} = 0$$

End of Solution

Q.9 A plane truss is shown in the figure (not drawn to scale).



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

(a) FG, FI, HI, RS (b) FI, FG, RS, PR

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

Ans. (b)

End of Solution

Q.10 Which one or the following is a secondary pollutant?

(a) Carbon Monoxide (b) Hydrocarbon

(c) Ozone (d) Volatile Organic Carbon (VOC)

Ans. (c)

Ozone is considered as secondary air pollutant.

End of Solution

Q.11 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 would be_______.

Ans. (4)

$$Q = 500 \text{ kN}$$

$$\sigma_z = \frac{3}{2\pi}\frac{Q}{z^2} \quad \text{(Just below the loading)}$$

$$\frac{\sigma_{z_1}}{\sigma_{z_2}} = \frac{\frac{3}{2\pi} \times \frac{500}{2^2}}{\frac{3}{2\pi} \times \frac{500}{4^2}} = \frac{16}{4} = 4.$$

End of Solution

Q.12 Consider a two-dimensional flow tlrough isotropic soil along x-direction and z-direction. If h is the hydraulic head, the Laplace's equation of continuity is expressed as

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

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

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

Ans. **(d)**

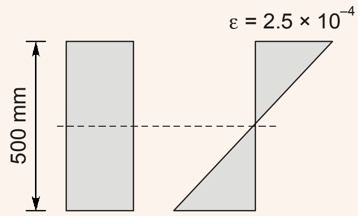
$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial z^2} = 0$$

End of Solution

Q.13 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________.

Ans. **(0.001)**

Given: $D = 500$ mm



$$\text{Strain} = \frac{\text{Stress}}{E} = \frac{f}{E}$$

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

$$\Rightarrow \quad \frac{E}{R} = \frac{f}{y}$$

$$\Rightarrow \quad \frac{1}{R} = \frac{f/E}{y} = \frac{\epsilon}{y} = \frac{2.5 \times 10^{-4}}{250} = 1 \times 10^{-6} = 0.001$$

End of Solution

Q.14 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?

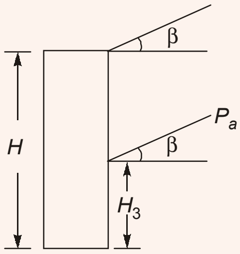
(a) P_a acts at a height $\frac{H}{3}$ from the base of the wall and at an angle ϕ with the horizontal

(b) P_a acts at a height $\frac{H}{2}$ from the base of the wall and at an angle ϕ with the horizontal

(c) P_a acts at a height $\frac{H}{3}$ from the base of the wall and at an angle β with the horizontal

(d) P_a acts at a height $\frac{H}{2}$ from the base of the wall and at an angle β with the horizontal

Ans. (c)



P_a will act at $\frac{H}{3}$ from base, at an angle of 'β' with horizontal.

End of Solution

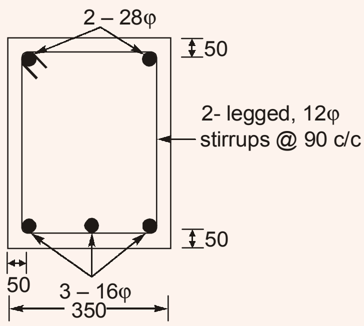
Q.15 A completely mixed dilute suspension of sand particles having diameters 0.25, 0.35, 0.40. 0.45 and 0.50 mm are filled in a transparent glass column of diameter 10 cm and height 2.50 m. The suspension is allowed to settle without any disturbance. It is observed that all particles of diameter 0.35 mm settle to the bottom of the column in 30 s. For the same period of 30 s. The percentage removal (round off to integer value) of particles of diameters 0.45 and 0.50 mm from the suspension is_______.

Ans. (100)

Since sand particle of size 0.35 mm settles to the bottom of the column in 30 sec particles having size greater than 0.35 mm i.e. 0.45 and 0.50 mm will also settle in suspension at the bottom of column by 100% in 30 sec, infact these bigger sized particle will settle by 100% in less than 30 sec. So answer is 100%.

End of Solution

Q.16 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) 30 mm
(b) 50 mm
(c) 42 mm
(d) 36 mm

Ans. (a)

$$\text{Nominal cover} = \text{Effective cover} - \frac{\phi_m}{2} - \phi_{st}$$

$$= 50 - \frac{16}{2} - 12 = 30 \text{ mm}$$

End of Solution

Q.17 Which of the following is correct?

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

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

Ans. (d)

$$\lim_{x \to 0}\frac{\sin 4x}{\sin 2x} = \lim_{x \to 0}\frac{4x}{2x}\frac{\sin 4x}{4x} \times \frac{2x}{\sin 2x} = \frac{4}{2} = 2$$

$$\lim_{x \to 0}\frac{\tan x}{x} = 1$$

End of Solution

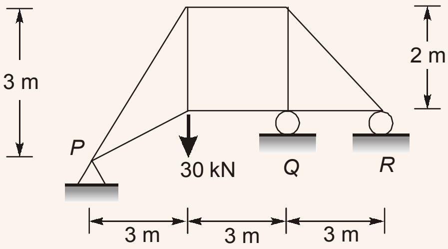
Q.18 The maximum number of vehicles observed in any five minute period during the peak hour is 160. If the total flow in the peak hour is 1000 vehicles, the five minute peak hour factor (round off to 2 decimal places) is_______.

Ans. (0.52)

$$PHF_5 = \frac{\text{Peak hour flow}}{\left(\frac{60}{5}\right) \times V_5(\text{max.})} = \frac{1000}{\frac{60}{5} \times 160} = 0.52$$

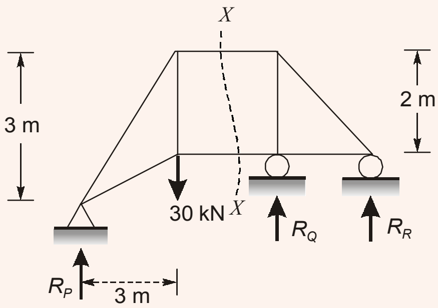
End of Solution

Q.19 Consider the pin-jointed plane truss shown in 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) (10, 30, –10) kN
(b) (30, –30, 30) kN
(c) (20, 0, 10) kN
(d) (0, 60, –30) kN

Ans. (b)



Using, $\Sigma F_V = 0$

$$R_P + R_R + R_Q = 30 \text{ kN} \quad \text{... (i)}$$

Taking moment about P, $\Sigma M_P = 0$

$$\Rightarrow \quad (30 \times 3) - R_Q \times 6 - R_R \times 9 = 0$$

$$\Rightarrow \quad 2R_Q + 3R_R = 30 \quad \text{... (ii)}$$

Again considering the equilibrium of RHS of section X-X

$\Sigma F_V = 0$

$$\therefore \quad R_R = -R_Q \quad \text{... (iii)}$$

Using (i), (ii) and (iii)

$$R_P = 30 \text{ kN}$$

$$R_Q = -30 \text{ kN}$$

$$R_R = +30 \text{ kN}$$

End of Solution

Q.20 For a small value of h, the Taylor series expansion for $f(x + h)$ is

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

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

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

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

Ans. **(c)**

Taylor series of $f(x + h)$ at x.

$$f(x+h) = f(x) + (x+h-x)f'(x) + \frac{(x+h-x)^2}{2!}f''(x) + \ldots$$

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

End of Solution

Q.21 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) Zero
(b) governed by the area of the flange
(c) 50%
(d) 25%

Ans. **(a)**

As per IS 800 : 2007

For semi compact section

(i) In low shear case ($V \le 0.6\ V_d$)

$$M_d = Z_e f_y / \gamma_{mo}$$

(ii) In high shear case ($V > 0.6\ V_d$)

$$M_d = Z_e f_y / \gamma_{mo}$$

So reduction is zero.

End of Solution

Q.22 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) Zero
(b) 0.0050
(c) 0.0010
(d) 0.0025

Ans. **(d)**

$$\epsilon_x = 0.0030$$
$$\epsilon_y = 0.0020$$

Normal strain in the plane of maximum shear strain

$$= \frac{\epsilon_x + \epsilon_y}{2} = 0.0025$$

End of Solution

Q.23 In a rectangular channel, the ratio of the velocity head to the flow depth for critical flow condition, is

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

Ans. (b)

$$\text{Critical velocity head} = \frac{V_C^2}{2g} = \frac{Q_c^2}{2gA^2} \quad \text{...(i)}$$

For a critical flow

$$\frac{Q_c^2 T}{gA^3} = 1$$

$$\therefore \quad \frac{Q_c^2}{gA^2} = \frac{A}{T} \quad \text{...(ii)}$$

From (i) and (ii), $\frac{v_c^2}{2g} = \frac{A}{2T}$

$$\therefore \quad \text{For Rectangular channel } \left(\frac{v_c^2}{2g}\right) = \frac{B \cdot Y_c}{2B} = \frac{Y_c}{2}$$

$$\therefore \quad \frac{v_c^2/2g}{Y_c} = \frac{1}{2}$$

End of Solution

Q.24 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) $\sigma' = 0$ and $i = i_c$
(b) $\sigma' \neq 0$ and $i = i_c$
(c) $\sigma' \neq 0$ and $i \neq i_c$
(d) $\sigma = 0$ and $i = i_c$

Ans. (a)

For quick sand condition

(i) Effective stress $(\bar{\sigma}) = 0$

(ii) $i = i_c$

i - Hydraulic gradient

i_c - Critical hydraulic gradient

$$i_c = \frac{\gamma_{sub}}{\gamma_w} = \frac{G_s - 1}{1 + e}$$

End of Solution

Q.25 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 smaller than P_T
(b) P_A is always equal to P_T
(c) There is no definite relationship between P_A and P_T
(d) P_A is always greater than P_T

Ans. (c)

The result from Thiessen polygon method is more accurate than arithmetic mean method. But there is no any close relationship between values obtained by Thiessen polygon method and Arithmetic mean method.

$\therefore$ There is no any relation between P_A and P_T.

End of Solution

Q.26 A one-dimensional domain is discretized into N sub-domains of width Δx with node numbers $i = 0, 1, 2, 3, \ldots.., N$. 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) $\frac{v_{i+1}^{(n+1)} - v_i^{(n)}}{\Delta t} = \beta\left[\frac{v_{i+1}^{(n)} - 2v_i^{(n)} + v_{i-1}^{(n)}}{2\Delta x}\right]$

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

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

Ans. (c)

$$\Delta t = \text{time step}$$

$\frac{\partial v}{\partial t}$ at i^{th} node and n^{th} time step is given by

$$\Delta_{v_t}^{(n)} \Rightarrow \frac{\partial v}{\partial t} = v_i^{(n)} - v_i^{(n-1)} \quad \ldots(i)$$

$\frac{\partial_v^2}{\partial_x^2}$ at i^{th} node and n^{th} true step is given by

$$\frac{\partial_v^2}{\partial_x^2} = \frac{v_{i+1}^{(n)} - 2v_i^{(n)} + v_{i-1}^{(n)}}{(\Delta x)^2} \quad \ldots(ii)$$

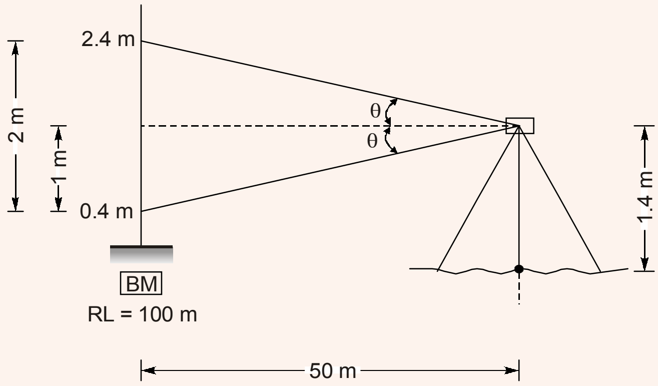
Substituting eq. (i) and (ii) is given PDE

We get,
$$\frac{v_i^{(n)} - v_i^{(n-1)}}{\Delta t} = \beta\frac{v_{i+1}^{(n)} - 2v_i^{(n)} + v_{i-1}^{(n)}}{(\Delta x)^2}$$

End of Solution

Q.27 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_______.

Ans. (100)



HI = RL of BM + BS

= 100 + (0.4 + 1)

= 101.4

RL of Theodolite station

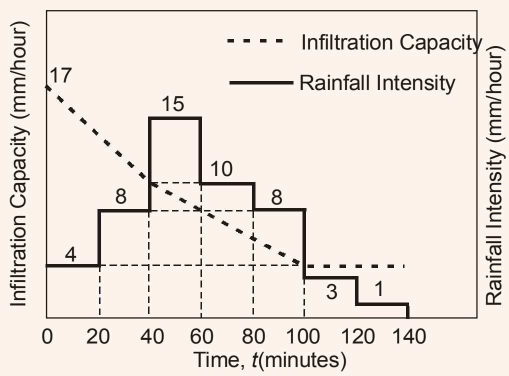
= HI-height

= 101.4 − 1.4

= 100 m

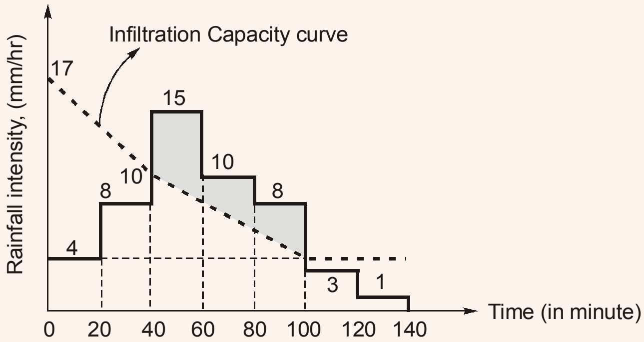
End of Solution

Q.28 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______.

Ans. (7.25)



$$P = (4 + 8 + 15 + 10 + 8 + 3 + 1) \times \frac{20}{60} = 16.33 \text{ minutes}$$

$$Q = (15-10)\times\frac{20}{60} + (10-8)\times\frac{20}{60} + (8-6)\times\frac{20}{60} + \frac{1}{2}\times 2\times\frac{20}{60} + \frac{1}{2}$$

$$+\frac{1}{2}\times 2\times\frac{20}{60} + \frac{1}{2}\times 2\times\frac{20}{60} = 4 \text{ mm}$$

$$\text{W-index} = \frac{P-Q}{t} = \frac{16.33-4}{\frac{140}{60}} = 5.28 \text{ mm/hr}$$

Since, $\phi \geq W$

Assume, ϕ = 5.28 mm/hr

$$\Rightarrow \quad \text{Corrected, } \phi = \frac{16.33 - 4 - 4\times\frac{20}{60} - 3\times\frac{20}{60} - 1\times\frac{20}{60}}{\left(\frac{140-30-20-20}{60}\right)} = 7.2475 \text{ mm/hr}$$

End of Solution

Q.29 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________.

Ans. (1800)

$$V_f = 60 \text{ kmph}$$

$$k_j = 120 \text{ veh/km}$$

$$\text{Max flow} = \frac{1}{4}V_s \times k_s = \frac{1}{4}\times 60\times 120$$

$$= 1800 \text{ veh/hr}$$

End of Solution

Q.30 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_______.

Ans. (0.18)

$$\lambda = 360 \text{ veh/hr}$$

$$= \frac{360}{3600} = \frac{1}{10} \text{ veh/sec}$$

$$P(6 \text{ to } 10) = e^{-\lambda t_1} - e^{-\lambda t_2}$$

$$= e^{-\left[\frac{1}{10}\times 6\right]} - e^{-\left[\frac{1}{10}\times 10\right]} = 0.18$$

End of Solution

Q.31 Sedimentation basin in a water treatment plant is designed for a flow rate of 0.2 m^3/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 Stokes' law. Given: density of the particles = 2.5 g/cm^3, density of water = 1 g/cm^3, dynamic viscosity of water = 0.01 g/(cm.s) gravitational acceleration = 980 cm/s^2. If the incoming water contains particles of diameter 25 μm (spherical and uniform), the removal efficiency of these particles is

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

Ans. (d)

$$\text{Flow rate, } Q_0 = 0.2 \text{ m}^3\text{/sec}$$

$$\text{Plan area, (PA)} = LB = 32 \times 8 = 256 \text{ m}^2$$

$$\text{(OFR) over flow rate} = \frac{Q_0}{PA} = \frac{0.2}{256} = 7.8125 \times 10^{-4} \text{ m/sec}$$

Now, settling velocity of particle of size 25 μm be u_s

$$u_s = \frac{(G-1)\gamma_w d^2}{18\mu} = \frac{(2.5-1)9.81\times 10^{-3}\left(25\times 10^{-6}\right)^2}{18\times 0.01\times 10^{-3}\times 10^{2}}$$

$$= 5.10 \times 10^{-4} \text{ m/sec}$$

$$\eta_{removal} = \frac{u_s}{OFR}\times 100 = \frac{5.10\times 10^{-4}}{7.8125\times 10^{-4}}\times 100$$

$$= 65.28\% \simeq 65\%$$

End of Solution

Q.32 A 0.80 m deep bed of sand filter (length 4 m and width 3 m) 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 a 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________.

Ans. (1.21)

Head loss of expanded bed = Head loss of unexpanded bed

$$D'(1-\eta')(G-1) = D(1-\eta)(G-1)$$

$$D'(1-\eta') = D(1-\eta)$$

$$D' = \frac{D(1-\eta)}{(1-\eta')}$$

Now,
$$\eta' = \left(\frac{v_B}{v_s}\right)^{0.22}$$

Backwash velocity, $v_B = \dfrac{Q_B}{P_A} = \dfrac{Q_B}{LB}$

$$\eta' = \left(\frac{3.6}{4\times 3\times 60\times 0.05}\right)^{0.22} = 0.602$$

$$D' = 0.8\frac{(1-0.4)}{(1-0.602)} = 1.21\,\text{m}$$

End of Solution

Q.33 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 $\sqrt[x]{x}, (x > 0)$, has the global maxima at $x = e$

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

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

Ans. (a)

Let $y = x^{1/x}$

$$\log y = \frac{\log x}{x}$$

$$y = e^{\frac{\log x}{x}}$$

y maximum (or) minimum when,

$$f(x) = \frac{\log x}{x} \text{ is maximum (or) minimum}$$

(1) $$f'(x) = \frac{x\left(\frac{1}{x}\right) - \log x}{x^2} = \frac{1-\log x}{x^2}$$

(2) $$f'(x) = 0$$

$\Rightarrow$ $$1 - \log x = 0$$

$$\log x = 1$$
$$x = e$$

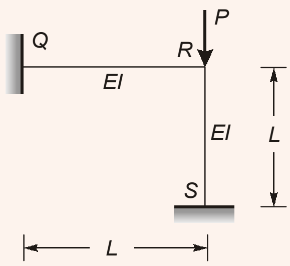
(3) $$f''(x) = \frac{x^2\left(-\frac{1}{x}\right) - 2x(1-\log x)}{x^4} = \frac{-3x + 2x\log x}{x^4}$$

(4) $$f''(e) = -\frac{e}{e^4} < 0 \text{ (max)}$$

∴ $y = \sqrt[x]{x}$ is maximum at $x = e$

End of Solution

Q.34 The rigid-jointed plane frame QRS shown in figure is subjected to 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 be become zero when β is equal to



(a) 7.5
(b) 3.0
(c) 48.0
(d) 0.1

Ans. (a)

Assume 'R' sinks by Δ.

Sway analysis:

$$M_{FQR} = \frac{-6EI\delta}{l^2}$$

$$M_{FRQ} = \frac{-6EI\delta}{l^2}$$

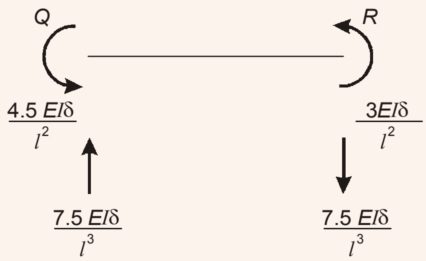
$$M_{FRS} = M_{FSR} = 0$$

D.F. at R | 0.5 | 0.5 |

End moment distribution,

	Q	R (0.5)	R (0.5)	S
FEM	$\frac{-6EI\delta}{l^2}$	$\frac{-6EI\delta}{l^2}$	0	0
Balance		$\frac{3EI\delta}{l^2}$	$\frac{3EI\delta}{l^2}$	
COM	$\frac{1.5EI\delta}{l^2}$			$\frac{1.5EI\delta}{l^2}$
Final end moments	$\frac{-4.5EI\delta}{l^2}$	$\frac{-3EI\delta}{l^2}$	$\frac{3EI\delta}{l^2}$	$\frac{1.5EI\delta}{l^2}$

Sway force

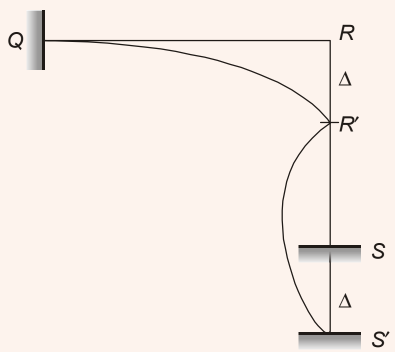


So, Sway force, $P = \frac{7.5EI\delta}{l^3}$

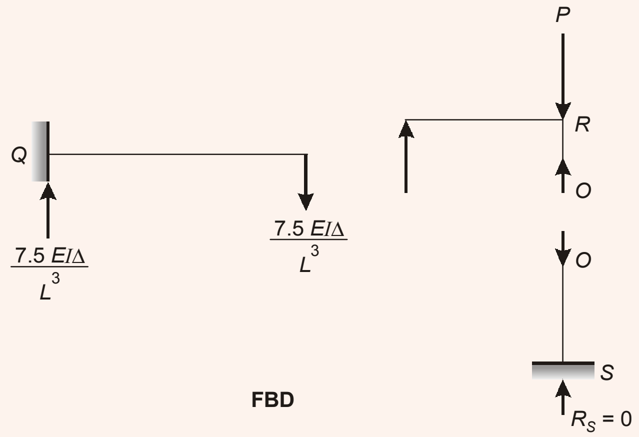
So, $\delta = \frac{Pl^3}{7.5EI}$

$\therefore$ $\beta = 7.5$

Alternate method:



Elastic Curve



FBD

$$\Sigma F_v = 0 \text{ (At joint R)}$$

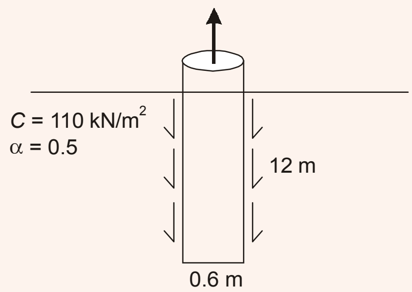
$\therefore$ $P = \frac{7.5EI\Delta}{L^3}$

$\therefore$ $\Delta = \frac{PL^3}{7.5EI}$

End of Solution

Q.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/m^2. The adhesion factor is 0.5. The Net Ultimate Pullout (uplift) Load for the pile (in kN, round off to 1 decimal place) is________.

Ans. (1244.1)



$$\text{Net ultimate pullout} = \alpha \bar{C} A_s = 0.5 \times 110 (\pi d L)$$
$$= 0.5 \times 110 (\pi \times 0.6 \times 12)$$
$$= 1244.1 \text{ kN}$$

End of Solution

Q.36 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

	P	Q	R
(a)	True	True	False
(b)	False	False	True
(c)	False	False	False
(d)	True	True	True

Ans. (d)

For rigid footings resting on a surface of cohesionless soil the settlement must be uniform and the pressure distribution is zero at the edges and maximum at the centre but for very deep rigid footing on sand the contact pressure distribution may be more like that of rigid footing on cohesive soil i.e., more at edges than at center.

Hence statement Q is true.

End of Solution

Q.37 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) 0.050 (b) 0.002
(c) 0.033 (d) 0.017

Ans. (d)

Manning's equation is given by

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

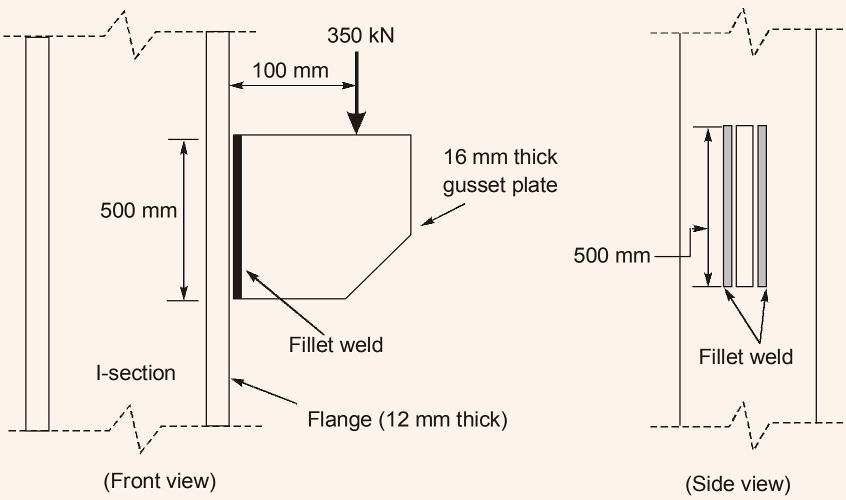
$$\Rightarrow \quad 2.0 = \frac{1}{n}\left(\frac{BY}{B+2Y}\right)^{2/3} \times S^{1/2}$$

$$\Rightarrow \quad 2.0 = \frac{1}{n}\left(\frac{5\times 2}{5+(2\times 2)}\right)^{2/3} \times (0.001)^{1/2}$$

$$\Rightarrow \quad n = 0.01696 = 0.017$$

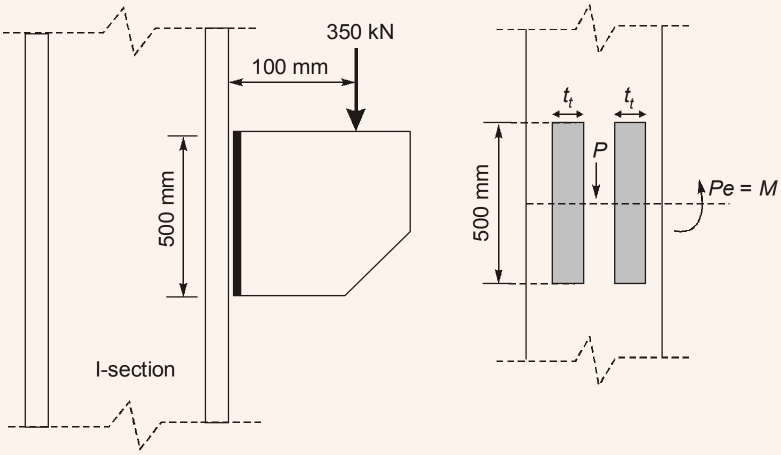
End of Solution

Q.38 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 figure (not drawn to scale). The gusset plate is subjected to point 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_______.

Ans. (78.10)



P = 150 kN, e = 100 mm

t_t = Effective throat thickness

t_t = 0.7S

S = Size of weld = 10 mm

$\therefore$ $t_t = 0.7 \times 10 = 7$ mm

Shear stress due to direct force, $q = \dfrac{350 \times 10^3}{2 \times 500 \times 7}$ MPa = 50 MPa

Normal stress due to bending, $f_b = \dfrac{My}{I}$

$$f_b = \frac{Pe \times d/2}{2 \times \dfrac{t_t d^3}{12}} = \frac{250 \times 10^3 \times 100 \times 500/2}{2 \times 7 \times 500^3/12} \text{ MPa}$$

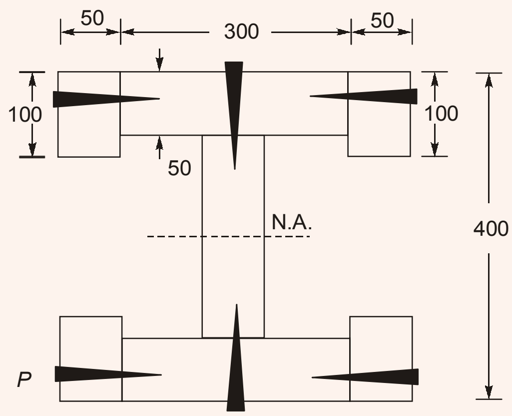
$$= 60 \text{ MPa}$$

Resultant stress, $f_e = \sqrt{f_b^2 + q^2} = \sqrt{60^2 + 50^2}$

$$= 78.10 \text{ MPa}$$

End of Solution

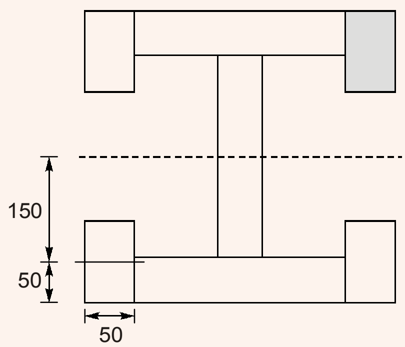
Q.39 Cross section of a built-up wooden beam as shown in figure (not drawn to scale) is subjected to a vertical shear force of 8 kN. The beam is symmetrical about the neutral axis (NA), shown, and the moment of inertia about N.A. is 1.5×10^9 mm^4. Considering that the nails at the location P are spaced 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 dimensions are in mm

(a) 240 N
(b) 480 N
(c) 60 N
(d) 120 N

Ans. (a)



Shear flow, $q = \frac{SA\bar{y}}{I} = \frac{8000 \times 50 \times 100 \times 150}{1.5 \times 10^9} = 4$ N/mm

Distance between two nails l = 60 mm

$\therefore$S.F. resisted by each nail = $q \times l$ = 240 N

End of Solution

Q.40 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________.

Ans. (700)

$$L_T = \frac{\phi \sigma_{st}}{2\tau_{bd}} = \frac{12\text{mm} \times 230 \text{ MPa}}{2 \times 2 \text{ MPa}} = 690 \text{ mm}$$

The design length of tie bar = 690 + 10 = 700 mm

End of Solution

Q.41 Consider the functions: $x = y \ln\phi$ and $y = \phi \ln y$. which one of the following the correct expression for $\frac{\partial\psi}{\partial x}$?

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

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

Ans. (a)

$x = \psi \ln\phi,$ $y = \phi \ln\psi$

Partially differentiating w.r.t x

$$1 = \psi_x \ln\phi + \frac{\psi}{\phi}\phi_x \quad \text{... (i)}$$

$$0 = \phi_x \ln\psi + \frac{\phi}{\psi}\psi_x$$

$$\Rightarrow \frac{\phi}{\psi} = \frac{-\phi_x \ln\psi}{\psi_x}$$

$$\Rightarrow \frac{\phi}{\psi\phi_x} = \frac{-\ln\psi}{\psi_x} \quad \text{... (ii)}$$

Put (ii) in (i)

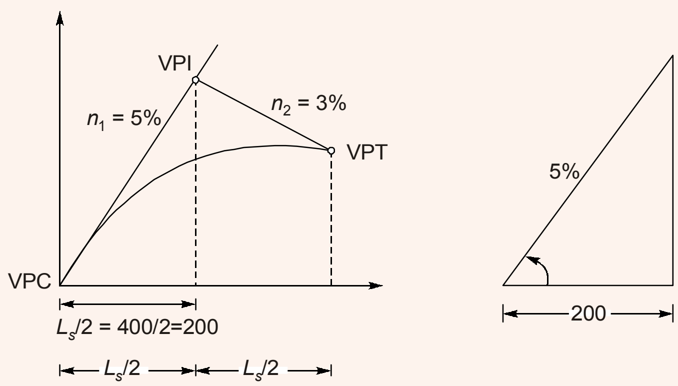
$$1 = \psi_x \ln\phi - \frac{\psi_x}{\ln\psi} = \psi_x\left[\frac{\ln\phi\ln\psi - 1}{\ln\psi}\right]$$

$$\psi_x = \left[\frac{\ln\psi}{\ln\phi\ln\psi - 1}\right]$$

End of Solution

Q.42 A parabolic vertical curve is being designed to join a road of grade +5% with a road of grade –3%. The length of die vertical curve is 400 m measured along the horizontal, The vertical point of curvature (VPC) is located an 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_______.

Ans. (10)



$$\tan\theta = 5\% = \frac{5}{180} = \frac{x}{200}$$

$$\frac{5}{100} = \frac{x}{200}$$

$$\Rightarrow \quad x = 10 \text{ m}$$

End of Solution

Q.43 A sample of air analysed at 0°C 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°C 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_______.

Ans. (41.07)

$$1 \text{ ppm of } NO_2 = \frac{1 \text{ part of } NO_2}{10^6 \text{ parts of air}}$$

$$= \frac{1\,m^3 \text{ of } NO_2}{10^6\,m^3 \text{ of air}}$$

At STP i.e. 0°C (273°K) and 1 atm P, volume of 1 mole of NO_2 = 22.4 litres.

at STP i.e. 0°C (273°K) and 1 atm P

22.4 litres of NO_2 has mass of 46 gm

$$1 \text{ litre of } NO_2 \text{ has mass of } = \frac{46}{22.4} = 2.053 \text{ gm}$$

1000 litres or 1 m^3 has mass of = 2053.57 gm

$$\therefore \quad 1 \text{ ppm of } NO_2 = \frac{2053.57 \text{ gm}}{10^6\,m^3}$$

$$= \frac{2053.57 \times 10^6}{10^6}\,\mu g/m^3$$

$$1 \text{ ppm of } NO_2 = 2053.57\,\mu g/m^3$$

$$\therefore \quad 0.02 \text{ ppm of } NO_2 = 2053.57 \times 0.02 = 41.07\,\mu g/m^3$$

End of Solution

Q.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_______.

Ans. (11.1)

$$\gamma_{sat} = 20 \text{ kN/m}^3 \quad \phi' = 30 \quad \gamma_w = 9.81 \text{ kN/m}^3$$

$$\text{FOS} = 1.5$$

Seepage at GL

$$FOS = \frac{\gamma'}{\gamma_{sat}} \times \frac{\tan\phi}{\tan\beta}$$

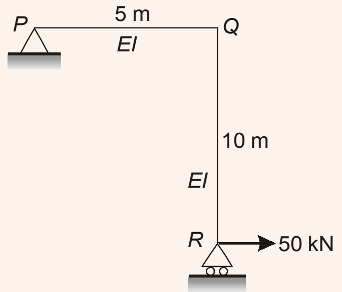
$$1.5 = \frac{(20 - 9.81)}{20} \times \frac{\tan 30}{\tan\beta}$$

$$\tan\beta = 0.196$$

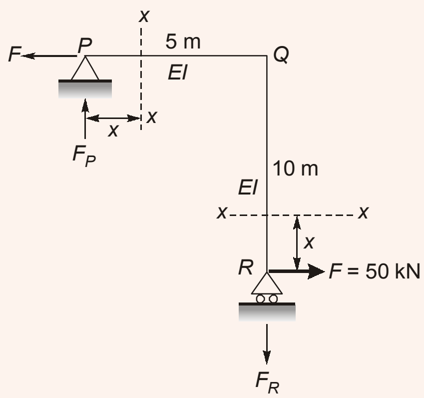
$$\beta = 11.089° \simeq 11.1°$$

End of Solution

Q.45 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_______.



Ans. (25)



$$\Sigma M_P = 0$$

$$F \times 10 - F_R \times 5 = 0$$

$$F_R = 2F = F_P$$

$$\Delta_R = \frac{\partial U}{\partial F} = \frac{\partial U_{PQ}}{\partial F} + \frac{\partial U_{QR}}{\partial F}$$

$$= \frac{1}{EI}\int M_{xPQ} \times \frac{\partial M_{xPQ}}{\partial F} dx + \frac{1}{EI}\int M_{xQR} \times \frac{\partial M_{xQR}}{\partial F} dx$$

$$M_{x_{PQ}} = F_P \times x = 2F \cdot x$$

$$\frac{\partial M_{x_{PQ}}}{\partial F} = 2x$$

$$M_{x_{QR}} = Fx$$

$$\frac{\partial M_{x_{QR}}}{\partial F} = x$$

$$\therefore \qquad \Delta R = \frac{1}{EI}\int_0^5 4Fx^2 dx + \frac{1}{EI}\int_0^{10} Fx^2 dx$$

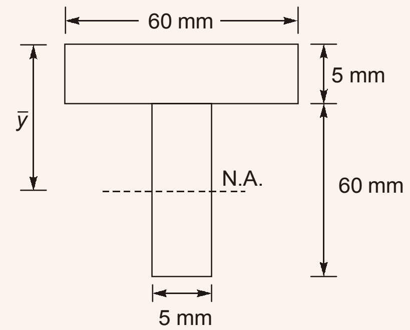
$$= \frac{4F}{EI}\left[\frac{x^3}{3}\right]_0^5 + \frac{F}{EI}\left[\frac{x^3}{3}\right]_0^{10}$$

$$= \frac{200}{EI} \times \frac{125}{3} + \frac{50}{EI} \times \frac{1000}{3} = \frac{25000}{EI}$$

$$= \frac{25000}{10^6} \text{ m} = 25 \text{mm}$$

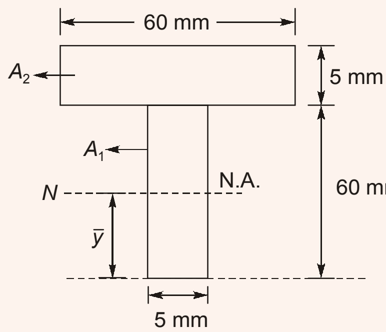
End of Solution

Q.46 If the section shown in figure turns from fully elastic to fully plastic, the depth of neutral axis (NA), $\bar{y}$, decreases by



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

Ans. (d)



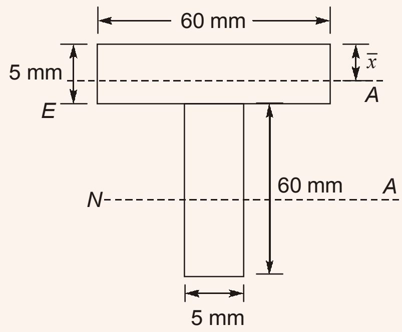
$$\bar{y} = \frac{A_1\bar{y}_1 + A_2\bar{y}_2}{A_1 + A_2}$$

$$= \frac{60 \times 5 \times \frac{60}{2} + 60 \times 5 \times \left(60 + \frac{5}{2}\right)}{60 \times 5 + 60 \times 5} = 46.25 \text{ mm}$$

NA - Neutral axis

The section is unsymmetrical about the NA and hence the equal area axis (EA) has to be located

Let, $\bar{x} \leq 5$ mm



$$60 \times \bar{x} = \frac{(60 \times 5) + 60 \times 5}{2}$$

$$\bar{x} = 5 \text{ mm}$$

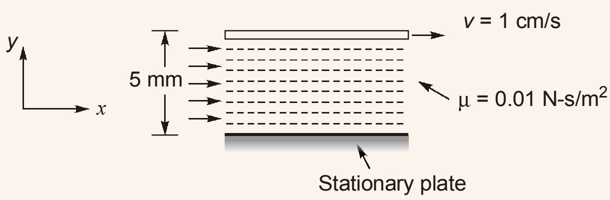
$\therefore$ NA shifts by, $60 - \bar{y} = 60 - 46.25$

$= 13.75$ mm

End of Solution

Q.47 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_______.

Ans. (8.0)



Given, $\tau_{\text{lower plate}} = 0$

Velocity distribution equation for Couette flow

$$u = -\frac{1}{2\mu}\left(\frac{\partial P}{\partial x}\right)(Hy - y^2) + \frac{V}{H} \times y$$

Now shear distribution at wall

$$\tau_0 = \mu \cdot \left.\frac{du}{dy}\right|_{y=0}$$

$$0 = \mu \cdot \frac{d}{dy}\left[-\frac{1}{2\mu}\left(\frac{\partial P}{\partial x}\right)(Hy - y^2) + \frac{V}{H} \cdot y\right]_{y=0}$$

$$0 = -\frac{1}{2\mu}\left(\frac{\partial P}{\partial x}\right)H + \frac{V}{H}$$

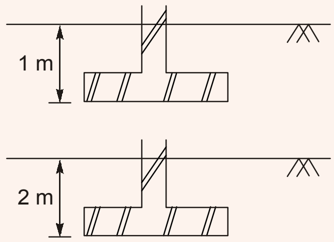
$$\frac{H}{2\mu}\left(\frac{\partial P}{\partial x}\right) = \frac{V}{H}$$

$$\left(\frac{\partial P}{\partial x}\right) = \frac{2\mu V}{H^2} = \frac{2(0.01)(0.01)}{(0.005)^2} = 8.0 \text{ N/m}^2\text{/m}$$

End of Solution

Q.48 A square footing of 4 m 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_______.

Ans. **(270)**



$$\gamma = 15 \text{ kN/m}^3$$
$$q_0 = 600 \text{ kPa}$$
$$d_q = d_\gamma = 1.0$$
$$N_\gamma = 18.75$$
$$q_u = 1.3\, CN_C + \gamma D_f N_q + 0.4 B\gamma N_\gamma$$
$$600 = 15 \times 1 \times N_q + 0.4(4) \times 15 \times 18.75$$
$$N_q = 10$$
$$\text{FOS} = 3$$
$$q_{\text{safe}} = ??$$
$$q_u = 1.3 CN_C + \gamma D_f N_q + 0.4 B\gamma N_\gamma$$
$$= 0 + 15 \times 2 \times 10 + 0.4 \times 4 \times 15 \times 18.75 = 750 \text{ kN/m}^2$$

$$q_s = \frac{q_u - \bar{\sigma}}{FOS} + \bar{\sigma} = \frac{q_u - \gamma D_f}{FOS} = \frac{750 - 15 \times 2}{3} + 15 \times 2$$
$$= 270 \text{ kN/m}^2$$

End of Solution

Q.49 A box measuring 50 cm x 50 cm x 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_______.

Ans. **(50.94)**

Given,

$$\text{Volume of box} = 50 \times 50 \times 50$$
$$= 0.5^3 \text{ m}^3 = 0.125 \text{ m}^3$$

Mass of dry coarse aggregate = 187.5 kg
Water absorption = 0.5%
Specific gravity = 2.5
Water required to fill the box = ?

We know,

Volume of particles of Ingredients = Total volume (air free)

$$\frac{\text{Mass of Coarse Aggregate(kg)}}{G_{CA}} + \frac{\text{Mass of water (kg)}}{G_w} = 0.125 \times 1000$$

$$\frac{187.5}{2.5} + \frac{M_w}{1} = 125$$

$$M_w = 50 \text{ kg}$$

But addition water loss in absorption = $\frac{0.5}{100} \times 187.5 = 0.9375$ kg

Total water to be added = 50 + 0.94 = 50.94 kg

End of Solution

Q.50 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_______.

Ans. (8.01)

$$N_t = N_0 e^{-kt}$$

$$\%\text{kill} = \frac{N_0 - N_t}{N_0} \times 100$$

$$99 = \frac{N_0 - N_0 e^{-kt}}{N_0} \times 100$$

$$e^{-kt} = 0.01$$

$\Rightarrow$ $$-kt = \ln(0.01)$$

$$t = \frac{4.602}{0.23} = 20.022 \text{ min}$$

Now, Volume of tank, $V = Q_0 \times t$

$$V = \frac{36 \times 20.022}{60} = 12.01 \text{m}^3$$

Also, $V = LBH$

$$L = \frac{V}{BH} = \frac{12.01}{1 \times 1.5} = 8.01 \text{m}$$

End of Solution

Q.51 A survey line was measured to be 285.5 m with a tape having a nominal length of 30 m. On checking, the time 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) 285.6 mm
(b) 284.5 mm
(c) 283.6 mm
(d) 285.0 mm

Ans. **(c)**

Given:

Measured length = 285.5 m
Designated tape length = 30 m
Actual tape length = 30 – 0.05 = 29.95 m
Slope along measurement = 1 in 10.

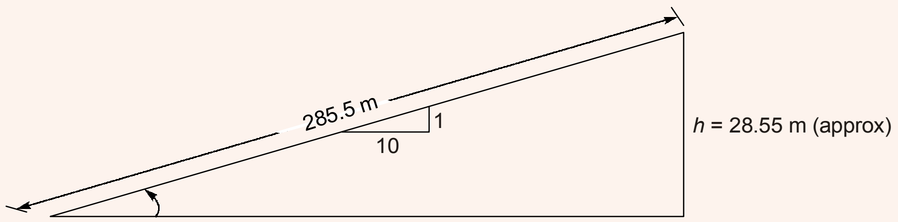
1. Standardization correction,

Actual tape length $l' < l$ (hence negative correction)

Correction per tape length = 29.95 – 30 = –0.05 m

$$\text{Total correction} = \frac{285.5}{30} \times 0.05 = 0.4758 \text{ (negative)}$$

2. Slope correction:



$$\text{Approximate slope correction} = -\frac{h^2}{2l} = \frac{28.55^2}{285.5 \times 2} = 1.4275 \text{ (negative)}$$

Total correction = –(1.4275 + 0.4758)
= –1.9033

Correct length = Measured length – Correction
= 285.5 – 1.9033 = 283.596 = 283.6 m

End of Solution

Q.52 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________.

Ans. **(6)**

$$[xD^2 - 2xD + 2]y = 0$$

Put, $x = e^z$

$$xD = D_1$$

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ADMISSION OPEN

$$x^2D^2 = D_1(D_1 - 1)$$

$$[D_1(D_1 - 1) - 2D_1 + 2]y = 0$$

$$[D_1^2 - 3D_1 + 2]y = 0$$

AE: $m^2 - 3m + 2 = 0$

$m = 1, 2$

$$y = C_1 e^z + C_2 e^{2z}$$

$$e^z = x$$

$$y = C_1 x + C_2 x^2$$

$y(1) = 0$ $\quad y(2) = 2$

$$y(1) = C_1 + C_2 = 0$$

$$y(2) = 2C_1 + 4C_2 = 2$$

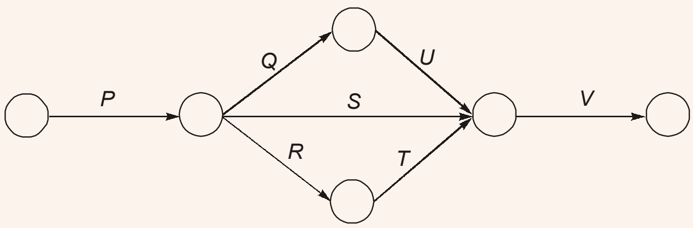
$C_1 = -1, C_2 = 1$

$$y = x^2 - x$$

$$y(3) = 6$$

End of Solution

Q.53 The network of a small construction project awarded to a contractors 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 in INR 5000 per day.

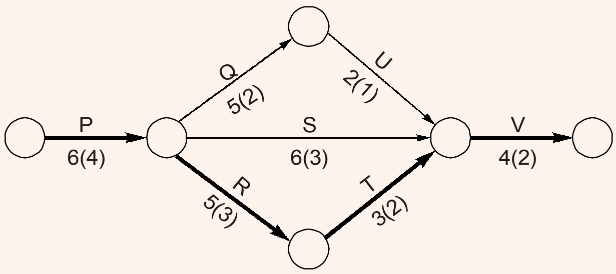


Activity	Normal Duration (days)	Crash Duration (days)	Normal cost (INR)	Crash Cost (INR)
P	6	4	15000	25000
Q	5	2	6000	12000
R	5	3	8000	9500
S	6	3	7000	10000
T	3	2	6000	9000
U	2	1	4000	6000
V	4	2	20000	28000

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

Ans. (149500)

Activity	t_n (days)	t_c (days)	C_n (INR)	C_c (INR)	Cost slope $C_s = \frac{C_c - C_n}{t_n - t_c}$
P	6	4	15000	25000	INR 5000/*d*
Q	5	2	6000	12000	INR 2000/*d*
R	5	3	8000	9500	INR 750/*d*
S	6	3	7000	10000	INR 1000/*d*
T	3	2	6000	9000	INR 3000/*d*
U	2	1	4000	6000	INR 2000/*d*
V	4	2	20000	28000	INR 4000/*d*



Considering normal durations, the total cost of the project

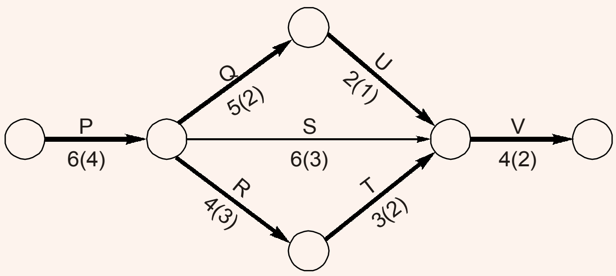
TC = DC + IC

= INR 66000 + INR 5000 × 18

= INR 156000

Stage-I: Crash activity R by 1 day

∴ Project becomes

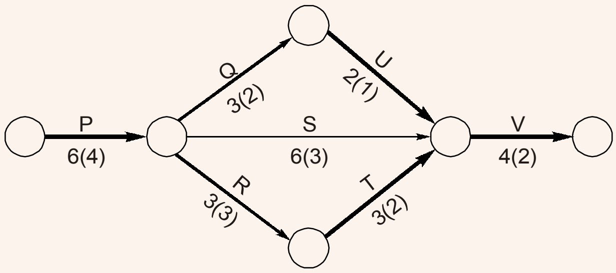


TC = (INR 6600 + INR 750) + INR 5000 × 17

= 151750

Stage-II: Crash activity Q&R (or U&R) by 1 day

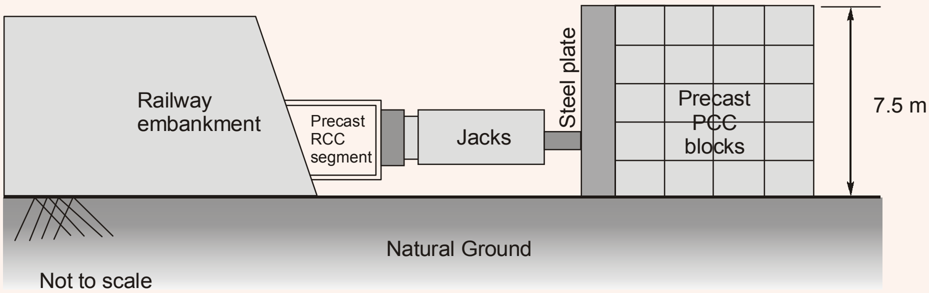
∴ Project becomes



TC = (INR 66750 + INR 2000 + INR 750) + (INR 5000 × 16)
= 149500

End of Solution

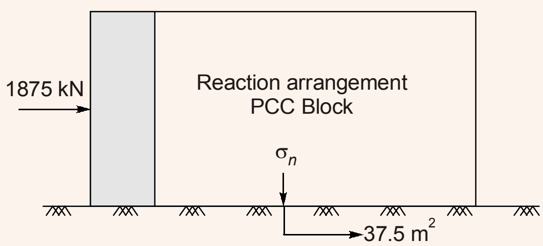
Q.54 A 3 m × 3 m square precast reinforced concrete segments to be installed by pushing them through an existing railway embankment for making an underpass as shown in the figure. A reaction arrangement using precast PCC blocks placed on the ground is to be made for the jacks.



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. ϕ = 25° and γ = 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_______.

Ans. (1.9)

$$\text{FOS} = \frac{S}{\tau} = \frac{c + \bar{\sigma}_n \tan\phi}{\tau}$$



$$\tau = \frac{\text{Jack force}}{\text{Area}} = \frac{1875\text{kN}}{37.5\text{ m}^2} = 50\text{ kN/m}^2$$

Shear strength of soil

$$S = c + \bar{\sigma}_n \tan\phi$$

$$\sigma_n = \frac{7.5 \times 37.5 \times \gamma_{concrete}}{\text{Area}}$$

$$\sigma_n = \frac{7.5 \times 37.5 \times 24}{37.5} = 168\text{ kN/m}^2$$

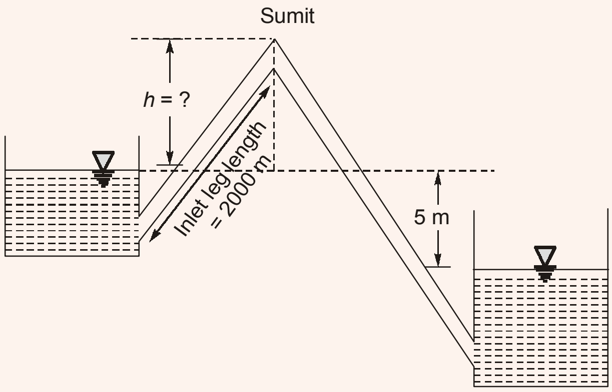
$$S = c + \bar{\sigma}_n \tan\phi = 17 + 168 \times \tan 25°$$

$$S = 95.34\text{ kPa}$$

$$\text{FOS} = \frac{S}{\tau} = \frac{95.34}{50} = 1.906 = 1.9$$

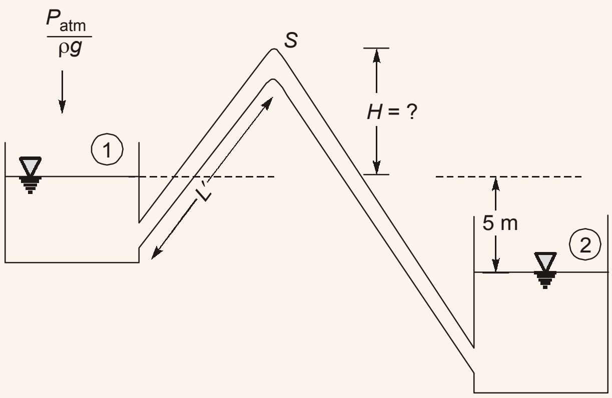
End of Solution

Q.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/s^2. Considering only major loss using Darcy-Weisback 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________.

Ans. (5.8)



Given: $L = 5000$ m, $D = 0.1$ m, $L' = 2000$ m, $\frac{P_S}{\rho g} = 2.5$ m of H_2O, $f = 0.02$,

$\frac{P_{atm}}{\rho g} = 10.3$ m of H_2O, $g = 9.81$ m/s^2

Consider only major losses

Apply energy equation between (1) and (2)

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_{f(1-2)}$$

$$5 = h_{f\,(1-2)}$$

$$5 = \frac{fLV^2}{2gD} = \frac{(0.02)\times(5000)}{0.1}\frac{V^2}{2g}$$

$$\frac{V^2}{2g} = 0.005 \text{ m}$$

Apply energy equation between (1) and (S)

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_S}{\rho g} + \frac{V_S^2}{2g} + z_S + h_{f(1-S)}$$

$$10.3 + 0 + 0 = 2.5 + 0.005 + H + \frac{fL'}{D}\frac{V_S^2}{2g}$$

$$10.3 = 2.505 + H + \frac{(0.02)(2000)}{0.1}\times(0.005)$$

$$10.3 = 2.505 + H + 2$$

$$H = 5.795$$

$H = 5.8$ m (upto 1 decimal place)

End of Solution

■■■■