GENERAL APTITUDE

1. Getting to the top is __________ than staying on top.

(A) much easy (B) more easy (C) easiest (D) easier

Key: (D)

2. Consider two rectangular sheets, Sheet M and Sheet N of dimensions 6cm × 4cm each

Folding operation 1: The sheet is folded into half by joining the short edges of the current shape.

Folding operation 2: The sheet is folded into half by joining the long edges of the current shape.

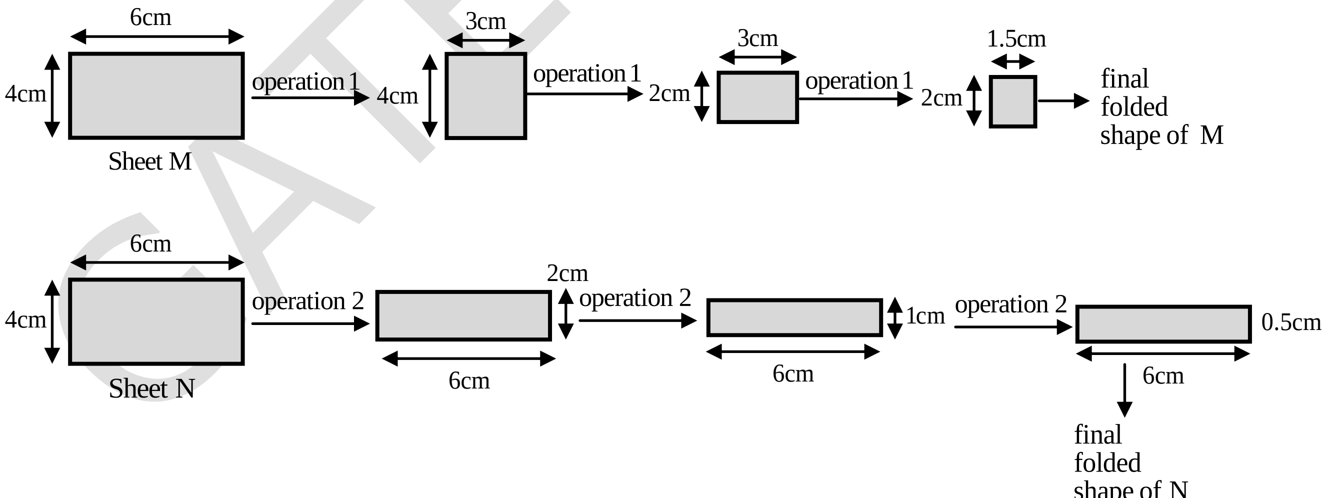
Folding operation 1 is carried out on Sheet M three times.

Folding operation 2 is carried out on Sheet N three times.

The ratio of perimeters of the final folded shape of Sheet N to the final folded shape of Sheet M is ______.

(A) 3:2 (B) 5:13 (C) 7:5 (D) 13:7

Key: (D)

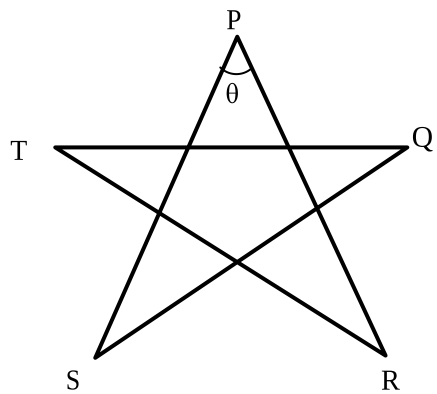


∴ Perimeter of final folded shape of N = 2(6 + 0.5) = 13

Perimeter of final folded shape of M = 2 (2 + 1.5) = 7

∴ Required ratio = 13:7

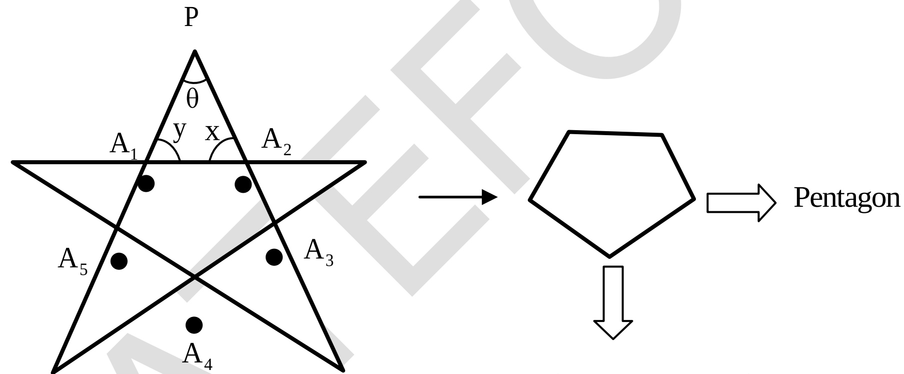
3. Five line segments of equal lengths, PR, PS, QS, QT and RT are used to form a star as shown in the figure below.



The value of θ, in degrees, is _______.

(A) 45 (B) 72 (C) 108 (D) 36

Key: (D)



$$\text{Sum of internal angles formed at pentagon} = (5-2)\times 180$$
$$= 3\times 180$$

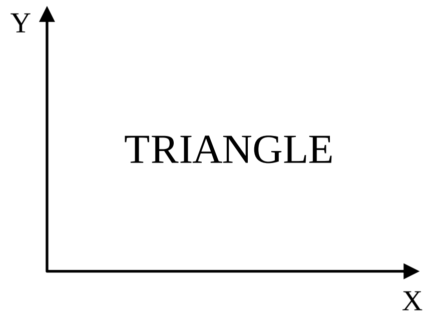
$$\Rightarrow \text{Each internal angle} = \frac{3\times 180}{5} = 108°$$

In $\Delta^{le}\, PA_1 A_2;\ \angle\theta = ?;\ \angle x = 180 - 108 = 72;\ \angle y = 180 - 108 = 72$

$\therefore \angle x + \angle y + \theta = 180$

$\Rightarrow \theta = 180 - 72 - 72 = 36°$

4.



(A) 

(B) 

(C) 

(D) 

Key: (D)

The mirror image of TRIANGLE about the X-axis is

[∵ Top and Bottom will interchange (or) symmetrical about X-axis]

5. Statement: Either P marries Q or X marries Y

Among the options below, the logical **NEGATION** of the above statement is:

(A) Neither P marries Q nor X marries Y.

(B) X does not marry Y and P marries Q

(C) P does not marry Q and X marries Y

(D) P marries Q and X marries Y

Key: (A)

Given statement: Either P marries Q or X marries Y.

The logical negation of the Either P marries Q or X marries Y

“above statement is Neither P marries Q nor X marries Y.”

6. A function, λ, is defined by

$$\lambda(p,q)=\begin{cases}(p-q)^2, & \text{if } p\ge q,\\ p+q, & \text{if } p<q.\end{cases}$$

The value of the expression $\dfrac{\lambda(-(-3+2),(-2+3))}{(-(-2+1))}$ is:

(A) 16 (B) 0 (C) $\dfrac{16}{3}$ (D) –1

Key: (B)

$$\frac{\lambda(-(-3+2),(-2+3))}{(-(-2+1))}=\frac{\lambda(-(-1),1)}{1}=\lambda(1,1)=(1-1)^2=0$$

$$\left[\because \lambda(p,q)=(p-q)^2 \text{ if } p=q\right]$$

7. For persons P, Q, R and S are to be seated in a row, all facing the same direction, but not necessarily in the same order. P and R cannot sit adjacent to each other. S should be seated to the right of Q. The number of distinct seating arrangements possible is:

(A) 2 (B) 6 (C) 4 (D) 8

Key: (B)

According to the given information,

$$\frac{Q}{}\times\frac{2}{(P,R)}\frac{S}{}\times\frac{1}{}=2\text{ ways} \qquad \text{OR}$$

$$\frac{2}{(P,R)}\frac{Q}{}\frac{1}{}\frac{S}{}=2\text{ ways} \qquad \text{OR}$$

$$\frac{2}{(P,R)}\times\frac{Q}{}\times\frac{S}{}\times\frac{1}{}=2\text{ ways}$$

$\Rightarrow$ Total number of ways $=2+2+2=6$

$\therefore$ The number of distinct seating arrangements possible is 6.

8. $\oplus$ and $\odot$ are two operators on numbers p and q such that

$$p \oplus q = \frac{p^2 + q^2}{pq} \text{ and } p \odot q = \frac{p^2}{q};$$

If $x \oplus y = 2 \odot 2$, then $x =$

(A) $\frac{3y}{2}$ (B) $2y$ (C) y (D) $\frac{y}{2}$

Key: (C)

$$x \oplus y = 2 \odot 2$$

$$\Rightarrow \frac{x^2 + y^2}{xy} = \frac{2^2}{2} \left[\because p \oplus q = \frac{p^2 + q^2}{pq} \text{ and } p \odot q = \frac{p^2}{q}\right]$$

$$\Rightarrow x^2 + y^2 = 2xy \Rightarrow x^2 + y^2 - 2xy = 0 \Rightarrow (x - y)^2 = 0 \Rightarrow x - y = 0 \Rightarrow \boxed{x = y}$$

9. Humans have the ability to construct worlds entirely in their minds, which don't exist in the physical world. So far as we know, no other species possesses this ability. This skill is so important that we have different words to refer to its different flavors, such as imagination, invention and innovation.

Based on the above passage, which one of the following is TRUE?

(A) We do not know of any species other than humans who possess the ability to construct mental worlds

(B) imagination, invention and innovation are unrelated to the ability to construct mental worlds

(C) No species possess the ability to construct worlds in their minds

(D) The terms imagination, invention and innovation refer to unrelated skills

Key: (A)

10. In a company, 35% of the employees drink coffee, 40% of the employees drink tea and 10% of the employees drink both tea and coffee. What % of employees drink neither tea nor coffee?

(A) 35 (B) 15 (C) 40 (D) 25

Key: (A)

$C \rightarrow$ Coffee $\rightarrow$ % of employees drink Coffee = 35%

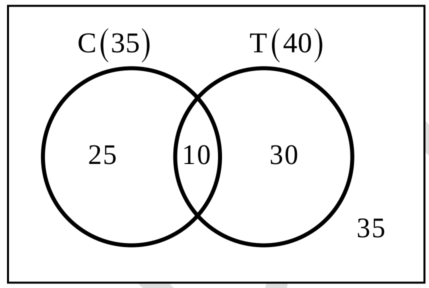
$T \rightarrow$ Tea $\rightarrow$ % of employees drink Tea = 40%

$\rightarrow$ % of employees drink both Tea and Coffee = 10%

% of employees drink neither Tea nor Coffee

$= 100\% - (25\% + 10\% + 30\%)$

$= 35\%$ $\quad (\because$ From the venn diagram$)$



CIVIL ENGINEERING

1. Vehicular arrival at an isolated intersection follows the Poisson distribution. The mean vehicular arrival rate is 2 vehicle per minute. The probability (round off to 2 decimal places) that at least 2 vehicles will arrive in any given 1-minute interval is _____________.

Key: (0.593)

Sol: The mean vehicular arrival rate, $(\lambda) = 2\text{veh/min}$

As per Poisson's distribution

$$P(x \ge n) = 1 - P(x < n)$$
$$P(x \ge 2) = 1 - P(x < 2)$$
$$= 1 - \{P(x=0) + P(x=1)\}$$
$$= 1 - \left(\left(\frac{\lambda^0 e^{-\lambda}}{0!}\right) + \left(\frac{\lambda^1 e^{-\lambda}}{1!}\right)\right)$$
$$= 1 - \left(e^{-2} + 2e^{-2}\right) = 1 - 3e^{-2} = 0.593$$

2. Spot speeds of vehicles observed at a point on a highway are 40, 55, 60, 65 and 85 km/h. The space mean speed (in km/h, round off to two decimal places) of the observed vehicle is _________.

Key: (56.99)

Sol: Space mean speed $(V_s) = \frac{n}{\Sigma \frac{1}{V}} = \frac{5}{\frac{1}{40} + \frac{1}{55} + \frac{1}{60} + \frac{1}{65} + \frac{1}{85}}$

Space mean speed = 56.99 kmph

3. Which one of the following is correct?

(A) The partially treated effluent from a food processing industry, containing high concentration of biodegradable organics, is being discharged into a flowing river at a point P. If the rate of degradation of the organics is higher than the rate of aeration, then dissolved oxygen of the river water will be lowest at point P.

(B) For an effluent sample of a sewage treatment plant, the ratio $BOD_{5 day 20^{o}C}$ upon ultimate BOD is more than 1.

(C) A young lake characterized by low nutrient content and low plant productivity is called eutrophic lake.

(D) The most important type of species involved in the degradation of organic matter in the case of activated sludge process basedwastewater treatment is chemoheterotrophs.

Key: (D)

4. Consider the limit:

$$\lim_{x\to1}\left(\frac{1}{\ell nx}-\frac{1}{x-1}\right)$$

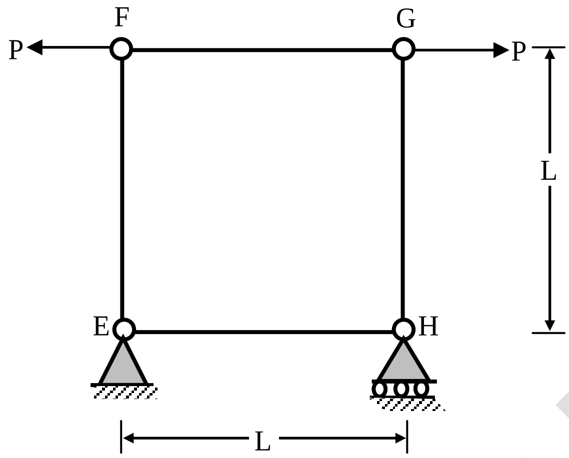
The limit (correct up to one decimal place) is ______________.

Key: (0.5)

$$\lim_{x\to1}\left(\frac{1}{\ell nx}-\frac{1}{x-1}\right)\to(\infty-\infty\text{ form})=\lim_{x\to1}\left(\frac{x-1-\ell nx}{(x-1)\ell nx}\right)\to\left(\frac{0}{0}\text{form}\right)$$

$$=\lim_{x\to1}\left(\frac{\frac{1}{x^2}}{(x-1)\left(-\frac{1}{x^2}\right)+\frac{1}{x}+\frac{1}{x}}\right)=\frac{1}{0+1+1}=\frac{1}{2}=0.5$$

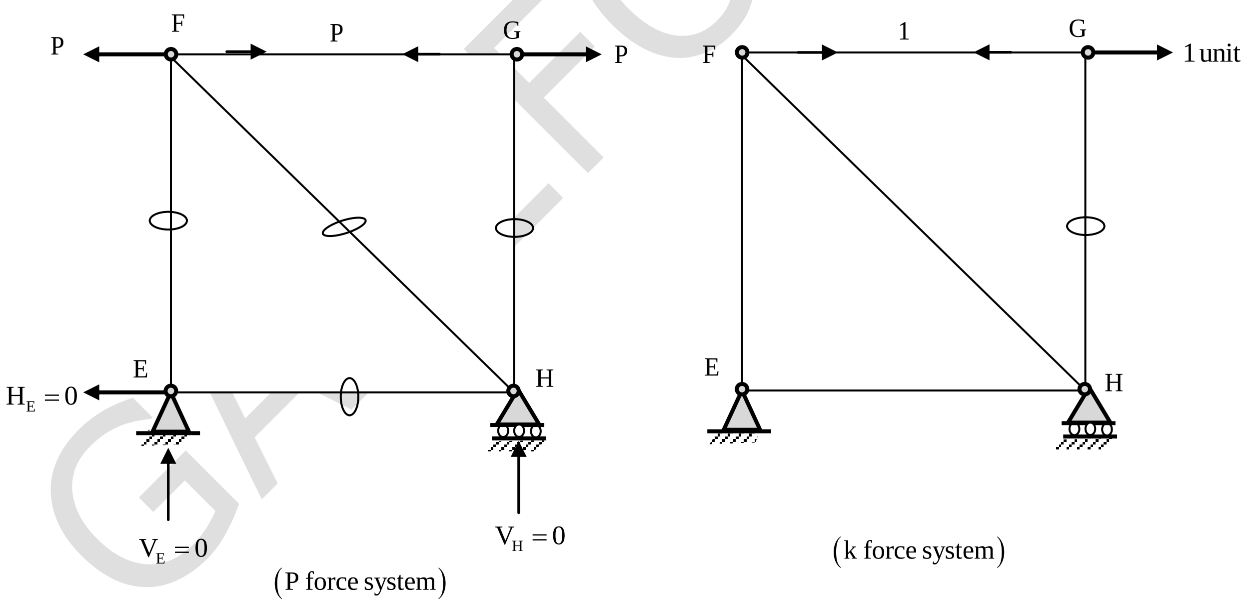
5. A truss EFGH is shown in the figure, in which all the members have the same axial rigidity R. In the figure, P is the magnitude of external horizontal forces acting at joints F and G.



If $R = 500 \times 10^3$ kN, $P = 150$kN and $L = 3$m, the magnitude of the horizontal displacement of joint G (in mm, round off to one decimal place) is ___________.

Key: (0.9)

Sol:



Note: No need to calculate 'k' force in all members because 'P' force is zero fore all members except FG

By unit load method

$$\Delta_{HG} = \sum_{i=1}^{n} \frac{P_i k_i L_i}{A_i E_i}$$

Δ_{HG} = Horizontal deflection at joint G

$$\therefore \Delta_{HG} = \underbrace{\frac{P \times 1 \times L}{AE}}_{FG-member} \times \underbrace{'O'}_{(\text{For all other members})}$$

$$\Delta_{HG} = \frac{PL}{AE} = \left(\frac{150 \times 3}{500 \times 10^3} \times 10^3\right) mm = 0.90\ mm$$

6. Which of the following is NOT a correct statement?

(A) The first reading from a level station is a 'Fore Sight'

(B) Contours of different elevations may intersect each other in case of an overhanging cliff

(C) Basic principle of surveying is to work from whole to parts

(D) Planimeter is used for measuring 'Area'.

Key: (A)

7. An unlined canal under regime conditions along with a silt factor of 1 has a width of flow 71.25m. Assuming the unlined canal as a wide channel, the corresponding average depth of flow (in m. round off to two decimal places) in the canal will be _________________.

Key: (2.938)

Sol: Silt factor (f) = 1, Width of flow (B) = 71.25m

As per Lacey's theory

Hydraulic mean radius $(R) = \frac{5}{2}\left(\frac{V^2}{f}\right)$

For a wide, channel R = y

Average depth of flow $(y) = \frac{5}{2}\left(\frac{V^2}{f}\right)$

Perimeter (P) = Width $(B) = 4.25\sqrt{Q}$

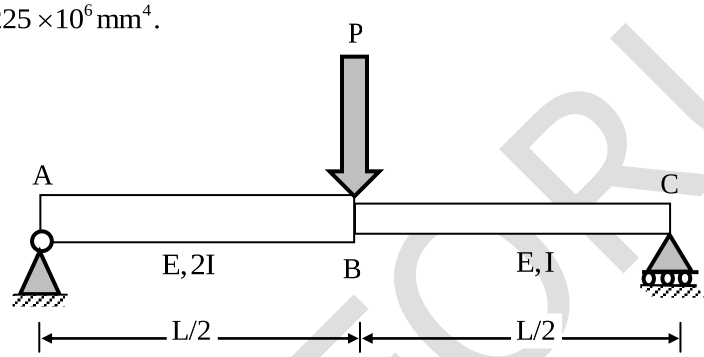
$$71.25 = 4.25\sqrt{Q}$$

$$Q = \left(\frac{71.25}{4.25}\right)^2 = 225\ m^3/sec$$

Mean velocity $(V)=\left(\frac{Qf^2}{140}\right)^{1/6}$

Average depth of flow $(y)=\frac{5}{2}\left(\frac{\left(\frac{Qf^2}{140}\right)^2}{f}\right)=\frac{5}{2}\frac{Q^2f^3}{140^2}=\frac{5}{2}\times\frac{225^2\times1^3}{140^2}=2.938\text{m}$

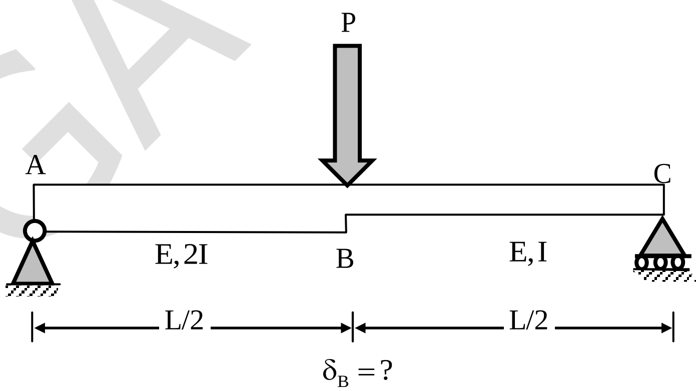
8. Employ stiffness matrix approach for the simply supported beam as shown in the figure to calculate unknown displacements rotations. Take length L-8m, modulus of elasticity, $E=3\times10^4\,\text{N/mm}^2$; Moment of inertia, $I=225\times10^6\,\text{mm}^4$.



The mid-span deflection of the beam (in mm, round off to integer) under $P=100\text{kN}$ in downward direction will be _________.

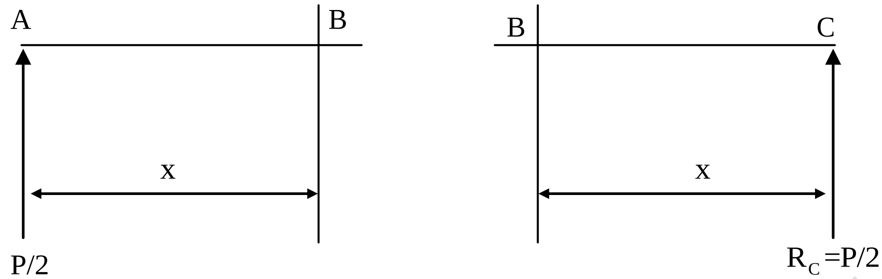
Key: (118.5)

Sol: Given P=100kN, $E=3\times10^4$, $I=225\times10^6\text{mm}^4$, L=8m



As deflection to be find out at mid span (point load location) strain energy method is the easiest to find.

$U_{AC}=U_{AB}+U_{BC}$



$$U_{AB} = \int_0^{L/2} \frac{\left(\frac{P}{2}x\right)^2}{4EI} dx, \quad U_{BC} = \int_0^{L/2} \frac{\left(\frac{P}{2}x\right)^2}{2EI} dx$$

$$U_{AC} = \frac{1}{16EI}\int_0^{L/2} (Px)^2 dx + \frac{1}{8EI}\int_0^{L/2} (Px)^2 dx = \frac{3}{16EI}\int_0^{L/2} (Px)^2 dx$$

$$= \delta_B = \frac{\partial U}{\partial p} = \frac{3}{16EI} = \int_0^{L/2} 2Px^2 dx = \frac{3P}{8EI}\left[\frac{(L/2)^3}{3}\right] = \frac{PL^3}{64EI}$$

$$\delta_B = \frac{100\times10^3\times(8000)^3}{64\times3\times10^4\times225\times10^6} = 118.5mm \simeq 119mm$$

9. The rank of matrix $\begin{vmatrix} 1 & 2 & 2 & 3 \\ 3 & 4 & 2 & 5 \\ 5 & 6 & 2 & 7 \\ 7 & 8 & 2 & 9 \end{vmatrix}$ is

(A) 2 (B) 3 (C) 4 (D) 1

Key: (A)

$$A = \begin{bmatrix} 1 & 2 & 2 & 3 \\ 3 & 4 & 2 & 5 \\ 5 & 6 & 2 & 7 \\ 7 & 8 & 2 & 9 \end{bmatrix}$$

$$\begin{matrix} R_2 - 3R_1 \\ R_3 - 5R_1 \\ R_4 - 7R_1 \end{matrix} \sim \begin{bmatrix} 1 & 2 & 2 & 3 \\ 0 & -2 & -4 & -4 \\ 0 & -4 & -8 & -8 \\ 0 & -6 & -12 & -12 \end{bmatrix}$$

$$\begin{matrix} R_3 - 2R_2 \\ R_4 - 3R_2 \end{matrix} \sim \begin{bmatrix} 1 & 2 & 2 & 3 \\ 0 & -2 & -4 & -4 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \text{ is row Echelon form}$$

$\therefore \text{rank}(A) = \text{number of non zero rows} = 2$

10. The shaper of the most commonly designed highway vertical curve is

(A) spiral

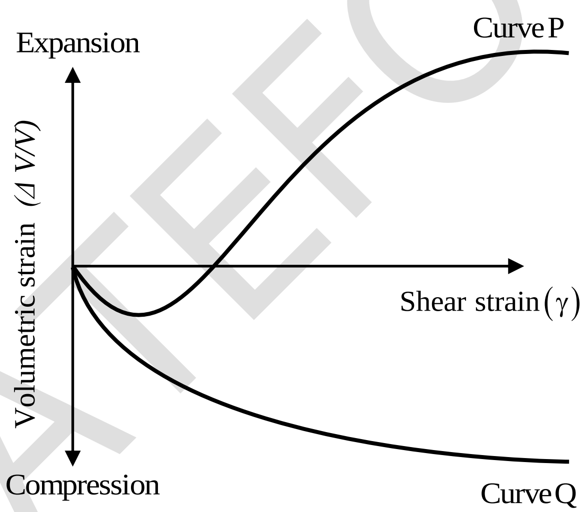
(B) circular (single radius)

(C) parabolic

(D) circular (multiple radii)

Key: (C)

11. Based on drained triaxial shear tests on sands and clays, the representative variations of volumetric strain $\left(\frac{\Delta V}{V}\right)$ with the shear strain (y) is shown in the figure.



Choose the CORRECT option regarding the representative behavior exhibited by Curve P and Curve Q.

(A) Curve P represents loose sand and normally consolidated clay, while Curve 'Q' represents dense sand and over consolidated clay

(B) Curve 'P' represents loose sand and over consolidated clay, while Curve 'Q' represents dense sand and normally consolidated clay

(C) Curve 'P' represents dense sand and over consolidated clay, while Curve 'Q' represents loose sand and normally consolidated clay

(D) Curve 'P' represents dense sand and normally consolidated clay, while Curve 'Q' represents loose sand and over consolidated clay

Key: (C)

12. A highway designed for 80 km/h speed has a horizontal curve section with radius 250m. If the design lateral friction is assumed to develop fully, the required super elevation is

(A) 0.07 (B) 0.05 (C) 0.02 (D) 0.09

Key: (B)

Sol: Design speed (v) = 80 kmph $80\times\frac{5}{18}=22.22\text{ m/s}$

Design lateral friction = 0.15

Radius (R) = 250 m

We know that

$$e+f=\frac{v^2}{gR}$$

$$e+0.15=\frac{(22.22)^2}{9.81\times 250}$$

$$e=\frac{(22.22)^2}{9.81\times 250}-0.15$$

$$e=0.201-0.15\Rightarrow e=0.0513$$

13. A small project has 12 activities – N. P. Q. R. S. T. U. V. W. X. Y and Z. The relationship among these activities and the duration of these activities are given in the Table.

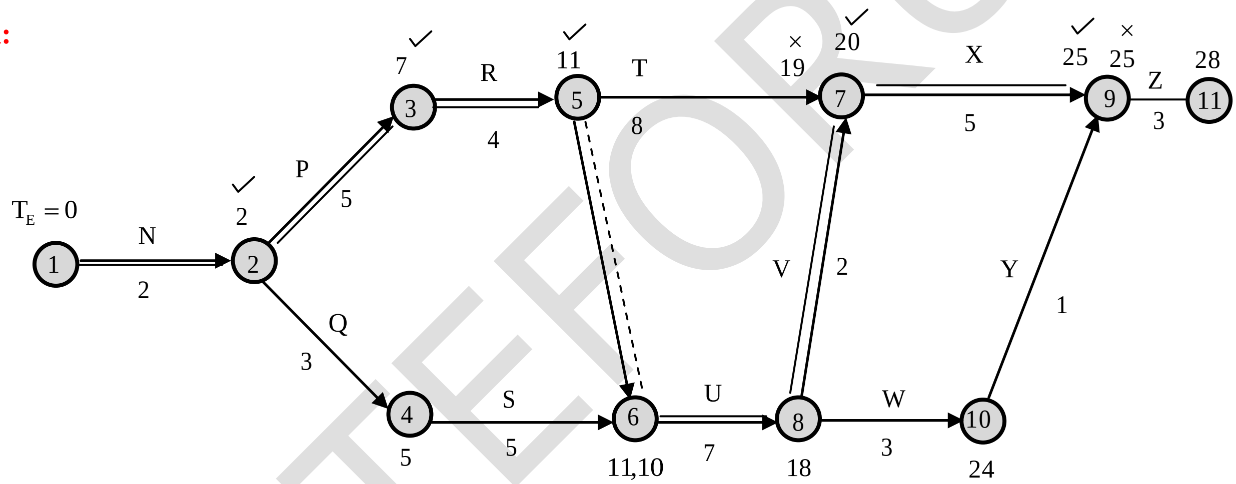
Activity	Duration (in weeks)	Depends upon
N	2	–
P	5	N
Q	3	N
R	4	P

S	5	Q
T	8	R
U	7	R, S
V	2	U
W	3	U
X	5	T, V
Y	1	W
Z	3	X, Y

The total float of the activity 'V' (in weeks, in integer) is ________________.

Key: (0)

Sol:



The critical path is

N – P – R – U – V – X – Z

And the total float on activity which is in critical path is zero.

14. A partially saturated soil sample has natural moisture content of 25% and bulk unit weight of 18.5 kN/m^3. The specific gravity of soil solids is 2.65 and unit weight of water is 9.81 kN/m^3. The unit weight of the soil sample on full saturation is

(A) 20.12 kN/m^3 (B) 18.50 kN/m^3 (C) 21.12 kN/m^3 (D) 19.03 kN/m^3

Key: (D)

Sol: Moisture content (w) = 25% = 0.25

Bulk unit weigh $(\gamma) = 18.5\ \text{kN/m}^3$

Specific gravity (G) = 2.65

Saturated unit weight $(\gamma_{sat}) = ?$

We know that at full saturation

$$eS = wG$$
$$e = wG = 0.25 \times 2.65 = 0.6625$$
$$\gamma_{sat} = \left(\frac{G_s + e}{1 + e}\right)\gamma_w$$

$$\gamma_{sat} = \left(\frac{G_s + wG}{1 + wG}\right)\gamma_w = \left(\frac{2.65 + 0.25 \times 2.65}{1 + 0.25 \times 2.65}\right) \times 9.81 = 19.54\ \text{kN/m}^3$$

15. A baghouse filter has to treat 12m^3/s of waste gas continuously. The baghouse is to be divided into 5 sections of equal cloth area such that one section can be shut down for cleaning and/ or repairing, while the other 4 sections continue to operate. An air-to-cloth ratio of 6.0m^3/min-m' cloth will provide sufficient treatment to the gas. The individual bags are of 32 cm in diameter and 5m in length. The total number of bags (in integer) required in the baghouse is ____________.

Key: (30)

Sol: Discharge (Q) $= 12\ \text{m}^3/\text{sec}$

Total area of filter required $= \dfrac{\text{Discharge}}{\text{velocity}} = \dfrac{12\ \text{m}^3/\text{sec}}{\frac{6}{60}\ \text{m/sec}} = \dfrac{720}{6} = 120\ \text{m}^2$

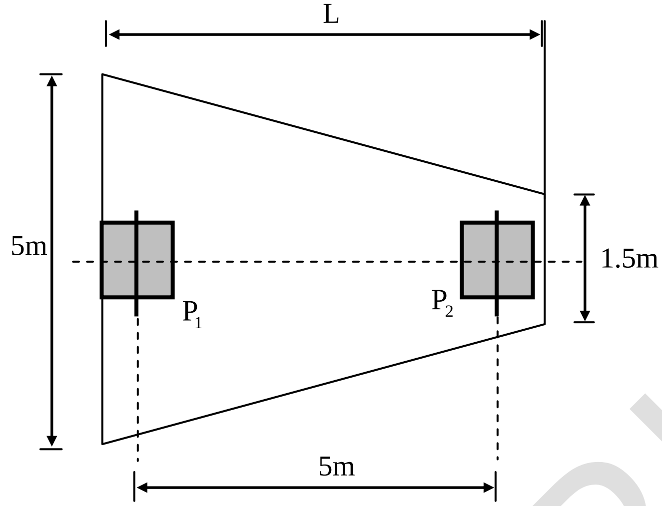
Surface area of each bag $= (\pi D)L = \pi \times 0.32 \times 65 = 5.626\ \text{m}^2$

Number of bags $= \dfrac{\text{Total are required}}{\text{Area of each bag}} = \dfrac{120}{5.626} = 23.81 = 24\ \text{bags}$

Number of bags per section $= \dfrac{24}{4} = 6$

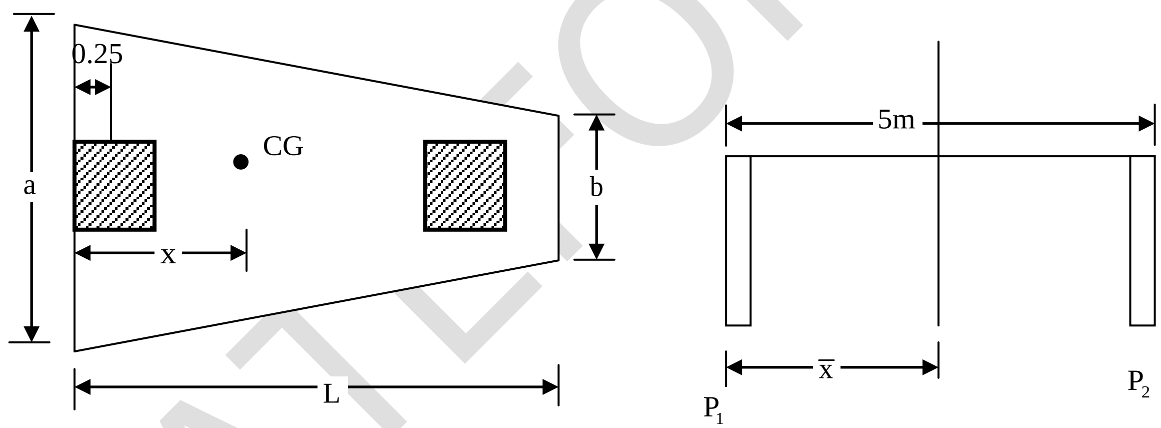
Number of bags for 5 sections = $6 \times 5 = 30$

16. A combined trapezoidal footing of length L supports two identical square columns (P_1 and P_2) of size 0.5m × 0.5m, as shown in the figure. The columns P_1 and P_2 carry loads of 2000 kN and 1500 kN respectively.



Key: (5.83)

Sol:



Taking moment about centre of column

$$\bar{x} = \frac{P_1 \times 0 + P_2 \times 5}{P_1 + P_2} = \frac{2000 \times 0 + 1500 \times 5}{2000 + 1500} = 2.143\text{m}$$

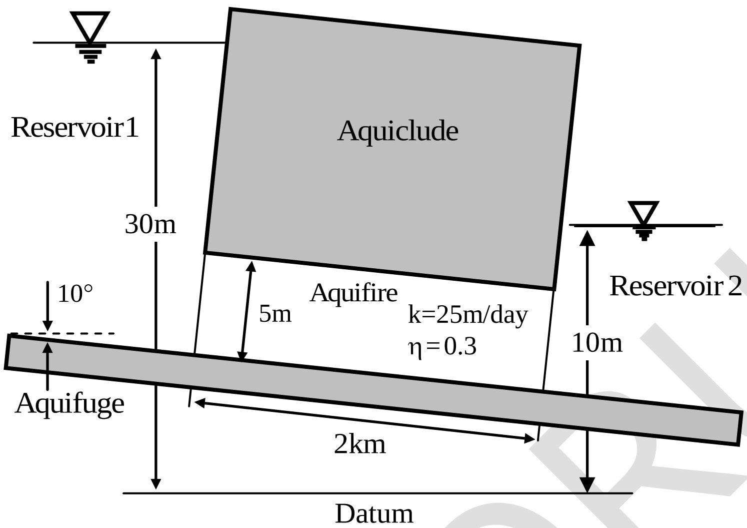
$$x = \left(\frac{a + 2b}{a + b}\right) \times \frac{L}{3} = \left(\frac{5 + 2 \times 1.5}{5 + 15}\right)\frac{L}{3}$$

$$x = \bar{x} + 0.25$$

$$\left(\frac{5 + 2 \times 1.5}{5 \times 1.5}\right)\frac{L}{3} = 2.143 + 0.25$$

$$L = 5.833\text{ m}$$

17. Two reservoirs are connected through a homogeneous and isotropic aquifer having hydraulic conductivity (K) of 25m/day and effective porosity (η) of 0.3 as shown in the figure (not to scale). Ground water is flowing in the aquifer at the steady state.



If water in Reservoir 1 is contaminated then the time (in days, round off to one decimal place) taken by the contaminated water to reach to Reservoir 2 will be ____________.

Key: (2400)

Sol: Hydraulic conductivity (k) = 25 m/day

Distance between reservoir (L) = 2km = 2000 m

Porosity (n) = 0.3

$$\text{Hydraulic gradient (i)} = \frac{\Delta h}{L} = \frac{(30-10)\text{m}}{2000\text{m}} = \frac{20}{2000} = 0.01$$

$$\text{Discharge velocity(v)} = ki = 25\,\text{m/day} \times 0.01 = 0.25\,\text{m/day}$$

$$\text{Actual velocity} = \frac{V}{n} = \frac{0.25}{0.3} = 0.8333\,\text{m/day}$$

$$\text{Velocity} = \frac{\text{distance}}{\text{time}}$$

$$\text{time} = \frac{2000\text{m}}{\left(\frac{0.25}{0.3}\right)\text{m/day}} = 2400\text{ days}$$

18. The values of abscissa (x) and ordinate (y) of a curve are as follows:

x	y
2.0	5.00
2.5	7.25
3.0	10.00
3.5	13.25
4.0	17.00

By Simpson's 1/3rd rule, the area under the curve (round off to two decimal places) is ________.

Key: (20.66)

Sol: $h = 0.5,\ y_0 = 5,\ y_1 = 7.25;\ y_2 = 10,\ y_3 = 13.25,\ y_4 = 17$

$\therefore$ By Simpson's $\frac{1}{3}$rd rule

The area is $\int_2^4 y\,dx = \frac{h}{3}\left[\left(y_0 + y_4\right) + 4\left(y_1 + y_3\right) + 2\left(y_2\right)\right]$

$$= \frac{0.5}{3}\left[(5+17) + 4(7.25+13.25) + 2(10)\right]$$

$$= \frac{0.5}{3}\left[22+82+20\right] = \frac{124}{6} = 20.66$$

19. A tube well of 20 cm diameter fully penetrates a horizontal, homogeneous and isotropic confined aquifer of infinite horizontal extent. The aquifer is of 30m uniform thickness. a steady pumping at the rate of 40 litres/s from the well for a longtime result in a steady drawdown of 4m at the well face. the subsurface flow to the well due to pumping is steady, horizontal and Darcian and the radius of influence of the well is 245m. The hydraulic conductivity of the aquifer (in m/day, round off to integer) is ___________.

Key: (35.76)

Sol: For unconfined aquifer

$$Q = \frac{2\pi T S_w}{\ell n\left(\frac{R}{r_w}\right)}$$

$Q = 40\ \text{lit/sec} = \dfrac{40\times10^{-3}}{\dfrac{1}{24\times60\times60}} = 3456$

$1\ \text{day} = 24\times60\times60\ \text{sec}$

$1\ \text{sec} = \left(\dfrac{1}{24\times60\times60}\right)\text{day}$

$Q = 3456\ \text{m}^3/\text{day}$

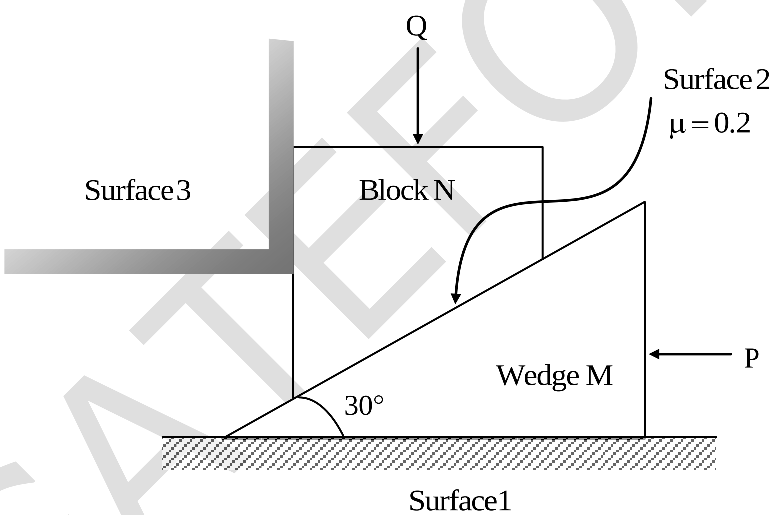
$$Q = \frac{2\pi TS_w}{\ell n\left(\dfrac{R}{r_w}\right)}$$

$$3456\ \text{m}^3/\text{day} = \frac{2\times\pi\times T\times4}{\ell n\left(\dfrac{245\text{m}}{0.1\text{m}}\right)}$$

$T = 1073.11\ \text{m}^2/\text{day}$

$\text{Transmissibility}, (T) = kB = k = \dfrac{T}{B} = \dfrac{1073.11}{30} = 35.76\ \text{m/day}$

20. A wedge M and a block N are subjected to forces P and Q as shown in the figure.



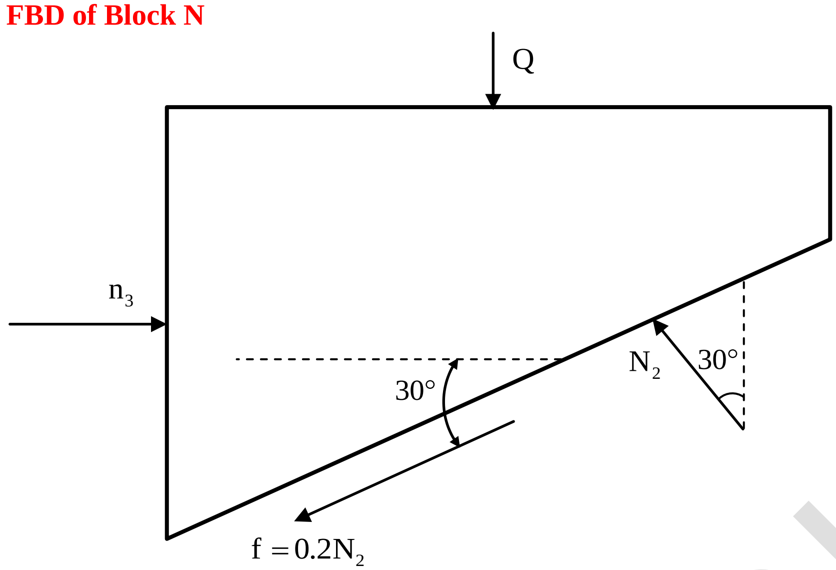
If force P is sufficiently large, then the block N can be raised. The weights of the wedge and the block are negligible compared to the forces P and Q. The coefficient of friction (μ) along the inclined surface between the wedge and the block is 0.2. All other surfaces are frictionless. The wedge angle is 30°.

The limiting force P, in terms of Q, required for impending motion of block N to just move it in the upward direction is given as $P = \alpha Q$. The value of the coefficient 'α' (rounded off to one decimal place)is

(A) 2.0 (B) 0.5 (C) 0.6 (D) 0.9

Key: (D)

Sol: FBD of Block N

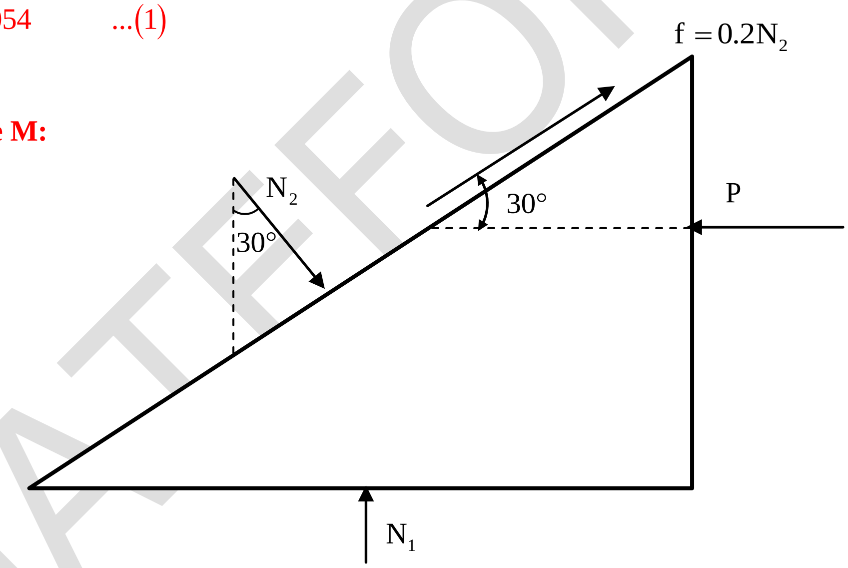


$\Sigma F_y = 0$

$N_2 \cos 30 = Q + 0.2N_2 \times \sin 30$

$\therefore N_2 = Q \times 1.3054 \qquad ...(1)$

FBD of Wedge M:



$\Sigma F_y = 0$

$P = N_2 \sin 30 + 0.2N_2 \cos 30$

$P = N_2 \times 0.6732$

From equation (1)

$P = Q \times 1.3054 \times 0.6732$

$P = 0.8788 \times Q = \alpha \times Q$

$\alpha \simeq 0.9$

21. A secondary clarifier handles a total flow of 9600 m^3/d from the aeration tank of a conventionalactivated-sludge treatment system. The concentration of solids in the flow from the aeration tank is3000 mg/L. The clarifier is required to thicken the solids 12000mgL and hence it is to be designed for a solid flux of 3.2 $kg/m^2.h$. The surface area of the designed clarifier for thickening (in m^2, in integer) is __________.

Key: (375)

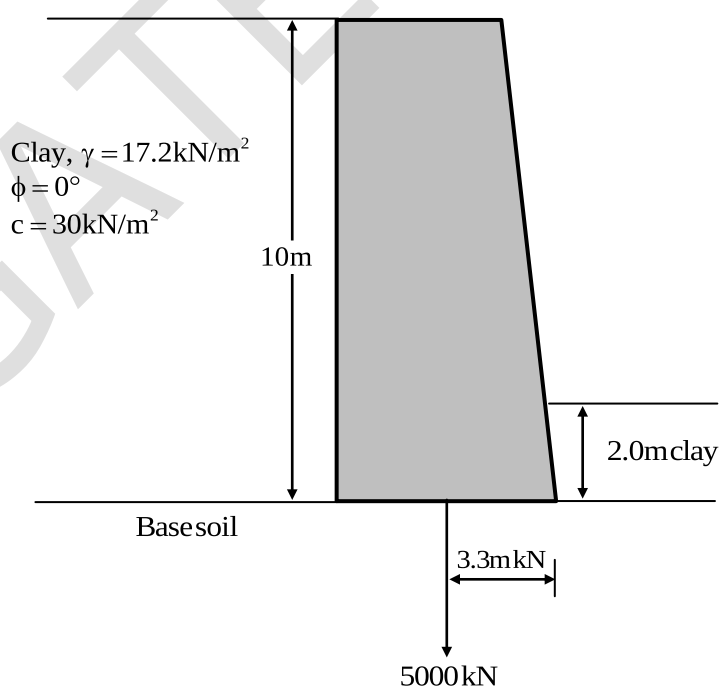
Sol: Total flow $(Q) = 9600\ m^3/day$

Concentration of solids $= 3000\ mg/L$

Solid flux = $3.2\ kg/m^2.h$

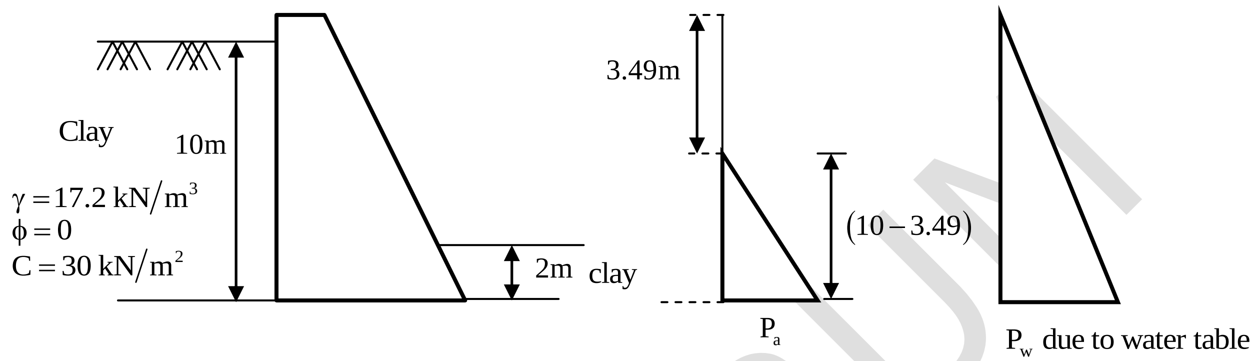
$$\text{Surface area} = \frac{\text{Total solids}}{\text{Solid flux rate}} = \frac{MLSS \times Q}{\text{Solid flux rate}} = \frac{9600\left(m^3/day\right)Q}{3.2\ kg/m^2.hr} = \frac{9600 \times \frac{3}{24}}{3.2} = 375m^2$$

22. A retaining wall of height 10m with clay backfill is shown in the figure (not to scale). Weight of the retaining wall is 5000kN per m acting at 3.3 m from the top of the retaining wall. The interface friction angle between base of the retaining wall and the base soil is 20.The depth of clay in front of the retaining wall is 2.0 m.The properties of the clay backfill, and the clay placed in front of the retaining wall are the same. Assume that the tension crack is filled with water. UseRankine's earth pressure theory. Take unit weight of water, $\gamma_w = 9.81kN/m^3$.



The factor of safety (Rounded off to two decimal places) against sliding failure of the retaining wall after ignoring the passive earth pressure will be _________.

Key: (4.29)



As the soil clay

Critical depth $(z_z) = \dfrac{2c}{\gamma\sqrt{k_a}}$

For $\phi = 0$ $\quad k_a = \dfrac{1-\sin 0}{1+\sin 0} = 1$

$$z_c = \frac{2\times 30}{17.2\sqrt{1}} = 3.49\ m$$

$$P_a = k_a.\gamma_{sub}.z - 2c\sqrt{k_a} = 1\times(17.2-9.81)\times 10 - 2\times 30\sqrt{1}$$

$$P_a = 13.9\ kN/m^2$$

$$P_w = k_a.\gamma_w z = 1\times 9.81\times 10 = 98.1\ kN/m^2$$

Total active thrust

$$= K_a.\frac{1}{2}\gamma H^2 - 2C\sqrt{K_a}H + \frac{2C^2}{\gamma} + \frac{\gamma_w.z_C{}^2}{2}$$

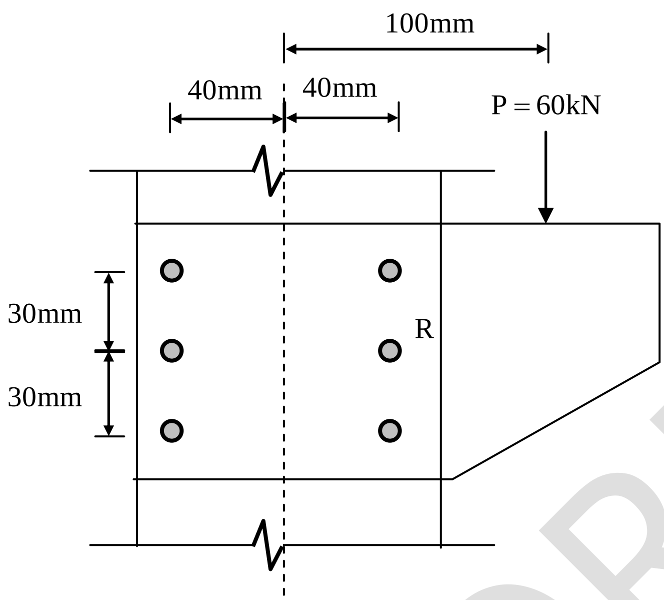
$$= 1\times\frac{1}{2}\times 17.2\times 10^2 - 2\times 30\sqrt{1}\times 10 + \frac{2\times 30^2}{17.2} + \frac{9.81\times 3.488^2}{2}$$

$$F_a = 424.326 kN$$

Frictional force = $N\tan\delta = w\tan\delta = 5000\tan 20 = 1819.85\ kN$

$$F.O.S = \frac{\text{frictional force}}{\text{Active thurst}} = \frac{1819.851}{424.326} = 4.29$$

23. A column is subjected to a total load (P) of 60kN supported through a bracket connection, as shown in the figure (not to scale).



The result force in bolt R (in kN, round off to one decimal place) is ___________.

Key: (28.18)

Resultant force $(R) = P_1 + P_2$

Shear force $(P_1) = \frac{P}{n} = \frac{60kN}{6} = 10\ kN$

Torsional force $(P_2) = \frac{Pe.r}{\Sigma r^2}$

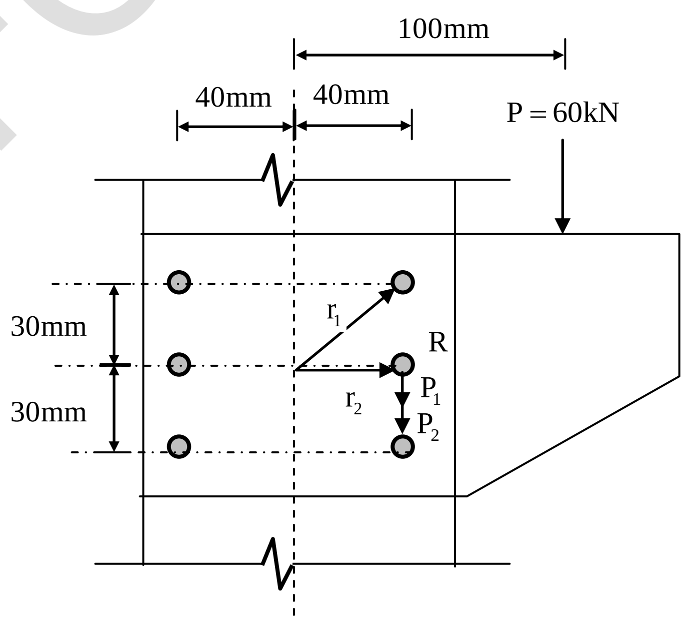
$$= \frac{60 \times 100 \times 40}{\left(4 \times 50^2 + 2 \times 40^2\right)}$$

$P_2 = 18.18\ kN$

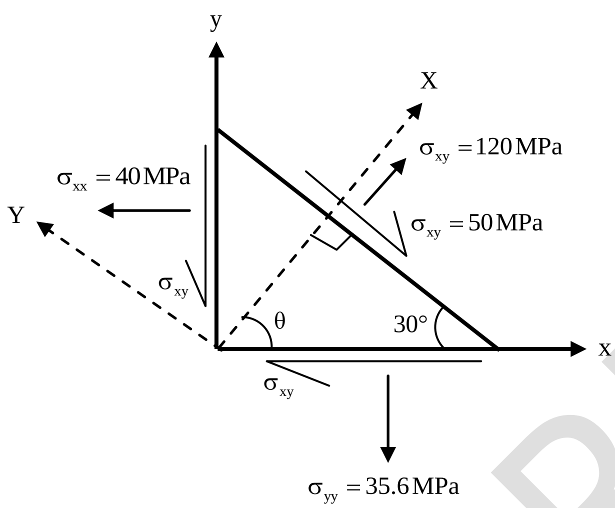
Resultant force $(R) = P_1 + P_2$

$= 10 + 18.18$

$= 18.18kN$



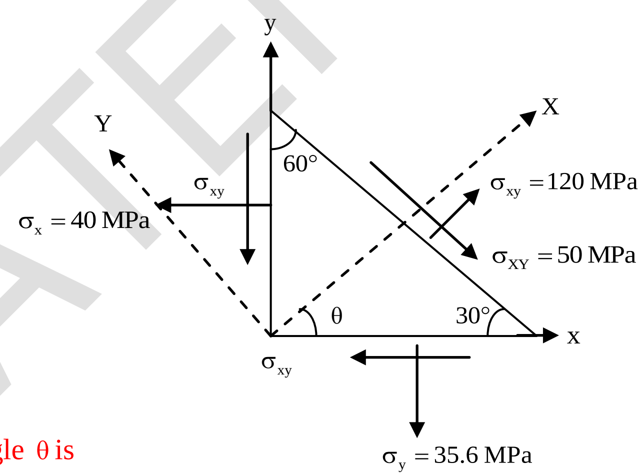
24. The state of stress in a deformable body is shown in the figure. Consider transformation of the stress from the x-y coordinate system to the X-Y coordinate system. The angle, θ, locating the X-axis is assumed to be positive when measured from the x-axis in counter-clockwise direction



The absolute magnitude of the shear stress component σ_{xy} (in MPa, rounded off to one decimal place) in x-y coordinate system is ________.

Key: (96.18)

Sol:



Resultant stress at angle θ is

$$\sigma_\theta = \left(\frac{\sigma_x + \sigma_y}{2}\right) + \left(\frac{\sigma_x - \sigma_y}{2}\right)\cos 2\theta + \tau_{xy}.\sin 2\theta$$

$$120 = \left(\frac{40 + 35.6}{2}\right) + \left(\frac{40 - 35.6}{2}\right)\cos(2\times 30) + \tau_{xy}.\sin(2\times 30)$$

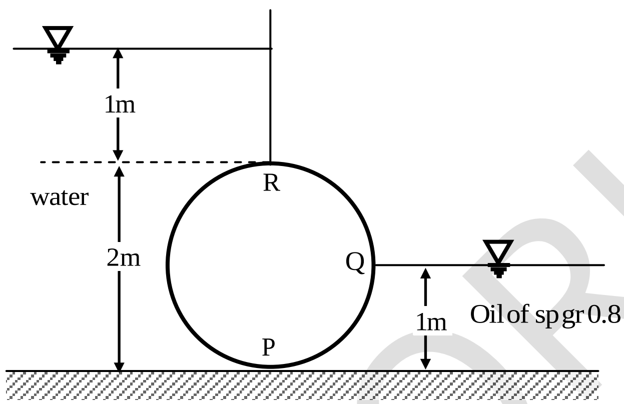
$$\tau_{xy} = 96.18\text{ MPa}$$

25. The shape of the cumulative distribution function of Gaussian distribution is

(A) Straight line at 45 degree angle
(B) Bell-shaped
(C) S-shaped
(D) Horizontal line

Key: (C)

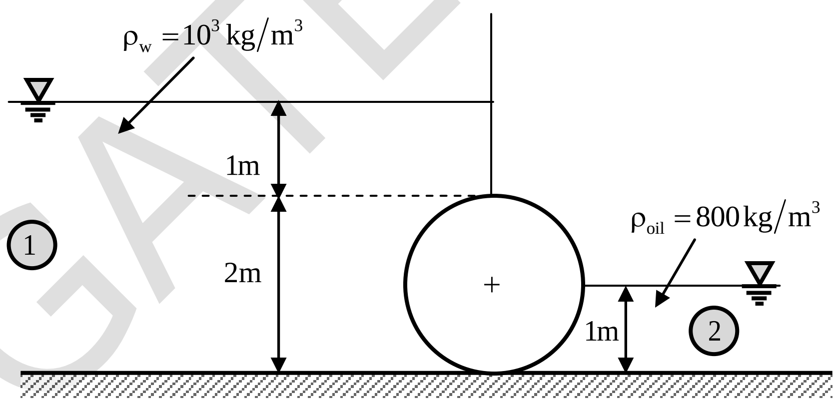
26. A cylinder (2.0m diameter, 3.0m long and 25kN weight) is acted upon by water on one side and oil (specific gravity = 0.8) on other side as shown in the figure.



The absolute ratio of the net magnitude of vertical forces to the net magnitude of horizontal forces (rounded off to two decimal places) is ______.

Key: (0.38)

Sol:



1. $\vec{F}_{H_{NET}} = \vec{F}_{H_{Water}} = \vec{F}_{H_{Oil}}$

$$F_{H_{Net}} = \rho_{water}.g.\bar{h}_{water}.A_{\text{projected cylinder}} - \rho_{oil}.g.\bar{h}_{oil}.A_{\text{projected half cylinder}}$$

$$F_{H_{net}} = 1000\times 9.81\times\left(1+\frac{2}{2}(2\times 3)\right) - 800\times 9.81\times\left(\frac{1}{2}\right)(1\times 3)$$

$$F_{Net} = 117720 - 11772$$

$$\left|F_{H_{Net}}\right| = 105948\,N = 105.948\,kN \qquad ...(1)$$

2. $F_V \uparrow = F_{V_{Water}}^{\uparrow} + F_{V_{Oil}}$

$$= \begin{bmatrix} \text{Weight of water} \\ \text{displayed} \\ \text{by cylinder} \end{bmatrix} + \begin{bmatrix} \text{Weight of oil} \\ \text{displayed} \\ \text{by cylinder} \end{bmatrix}$$

$$F_{V_{liquids}} = W_{Water} \uparrow + W_{Oil} \uparrow$$

$$F_{V_{liquids}} = \rho.g.V_{Water} + \rho_{Oil} g.V_{Oil}$$

$$= \rho_w.g.\frac{\pi R^2.L}{2} + \rho_{oil}.g.\frac{\pi R^2.L}{4}$$

$$F_{V_{liquids}} = 100 \times 9.81 \times \frac{\pi(1)^2(3)}{2} + 800 \times 9.81 \times \frac{\pi(1)^2}{4} \times 3$$

$$= 46228.536 + 18491.414$$

$$F_{V_{liquids}} = 64719.95N \cong 64.72kN \uparrow \sqrt{a^2 + b^2}$$

$$\left|F_{V_{Net}}\right|_{liquids} = (F_V)_{liquids} \uparrow - W_{cylinder} \downarrow$$

$$\left|F_{V_{liquids}}\right| = 64.72 \uparrow - 25 \downarrow$$

$$\therefore \left|F_{V_{NET}}\right| = 39.72\ kN \uparrow \qquad ...(2)$$

$$\frac{F_{V_{Net}}}{F_{H_{Net}}} = \frac{39.720(kN)}{108.948(kN)} = 0.3749 \cong 0.375 = 0.38$$

27. A water sample is analyzed for coliform organisms by the multiple tube fermentation method. The results of confirmed test are as follows:

Sample size(mL)	Number of positiveResults out of 5 tubes	Number of negativeResults out of5 tubes
0.01	5	0
0.001	3	2
0.0001	1	4

The most probable number (MPN) of coliform organisms for the above results is to be obtained using the following MPN index.

The MPN of coliform organisms per 100 mL is

MPN Index for Various Combinations of Positive Results when Five Tubes used per Dilution of 10.0 mL, 1.0 mL and 0.1mL	
Combination of Positive tubes	**MPN index per 100 mL**
0-2-4	11
1-3-5	19
4-2-0	22
5-3-1	110

(A) 110000 (B) 1100000 (C) 1100 (D) 110

Key: (A)

Sol: MPN for 10.0 – 1–0.1 mL = 110

$$\text{MPN per 100 mL} = 110\times\frac{10\text{mL}}{0.01} = 110\times1000 = 110000$$

28. If water is flowing at the same depth in most hydraulically efficient triangular and rectangular channel sections then the ratio of hydraulic radius of triangular section to that of rectangular section is

(A) $\frac{1}{\sqrt{2}}$ (B) 1 (C) 3 (D) $\sqrt{2}$

Key: (A)

Sol: For most hydraulic efficient triangular channel

$$R_1 = \frac{y}{2\sqrt{2}}$$

For most hydraulic efficient rectangular channel

$$R_2 = \frac{y}{2}$$

$$\frac{R_1}{R_2} = \frac{\frac{y}{2\sqrt{2}}}{y/2} = \frac{1}{\sqrt{2}}$$

29. Ammonia nitrogen is present in a given wastewater sample as the ammonium ion $\left(NH_4^+\right)$ and ammonia $\left(NH_3\right)$ .If pH is the only deciding factor for the proportion of these two constituents, which of the following is a correct statement?

(A) At pH 7.0, $\left(NH_4^+\right)$ and NH_3 will be found in equal measures

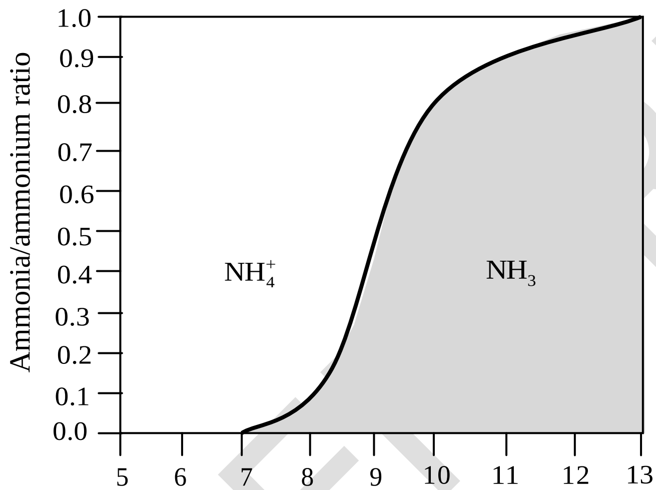
(B) At pH below 9.25 NH_3 will be predominant

(C) At pH 7.0 $\left(NH_4^+\right)$ will be predominant

(D) at pH above 9.25, only $\left(NH_4^+\right)$ will be present

Key: (C)

Sol:



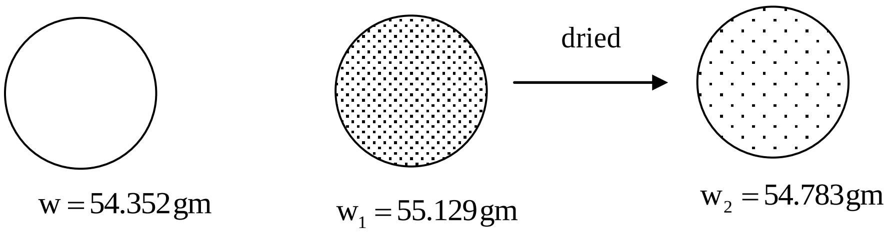
From the above curve, it is evident that at pH 7.0, NH_4^+ will be predominant.

30. A 50 mL sample of industrial wastewater is taken into a silica crucible. The empty weight of the crucible is 54.352g. The crucible with the sample is dried in a hot air over at 104°C till a constant weight of 55.129g. Thereafter, the crucible with the dried sample is fired at 600°C for 1h in a muffle furnace, and the weight of the crucible along with residue is determined as 54.783g. The concentration of total volatile solids is ____________.

(A) 1700 mg/L (B) 8620mg/L (C) 6920mg/L (D) 15540mg/L

Key: (C)

Sol: Volume of sample (V) = 50mL



$$\text{Total volatile solids } = \frac{W_1 - W_2}{V}$$
$$= \frac{55.129 - 54.783}{50}\,gm/mL$$
$$= \left(\frac{55.129 - 54.783}{50}\right) \times \frac{10^3}{10^{-3}}\,mg/L$$
$$= 6920\ mg/L$$

31. The direct and indirect costs estimated by a contractor for bidding a project is ₹ 160000 and ₹ 20000 respectively, If the mark up applied is 10% of the bid price, the quoted price (in ₹.) of the contactor is

(A) 182000 (B) 196000 (C) 198000 (D) 200000

Key: (D)

Sol: Direct cost = 160000

Indirect cost = 20000

Total cost = 1,60,000 + 20,000 = 1,80,000

Mark up = 10%

Mark up cost = 0.10 × 1,80,000 = 18,000

Bid price = 1, 80, 000 + 18,000 = 1,98,000

$$\text{Quoted price } = \frac{1,80,000}{0.9} = 2,00,000$$

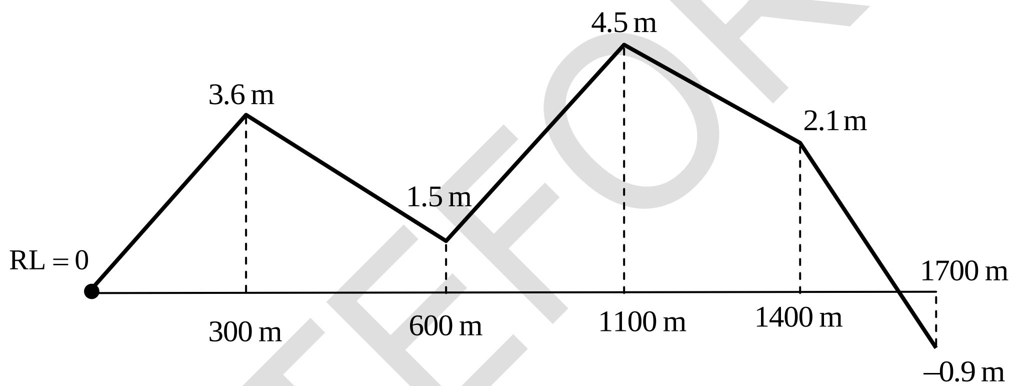
32. The longitudinal section of a runway provides the following data:

End to-end runway (m)	Gradient %
0 to 300	+1.2
300 to 600	–0.7
600 to 1100	+0.6
1100 to 1400	–0.8
1400 to 1700	–1.0

The effective gradient of the runway (in % round off to two decimal places) is ________.

Key: (0.32)

Sol: Assuming RL of start of runway as datum i.e., RL = 0m

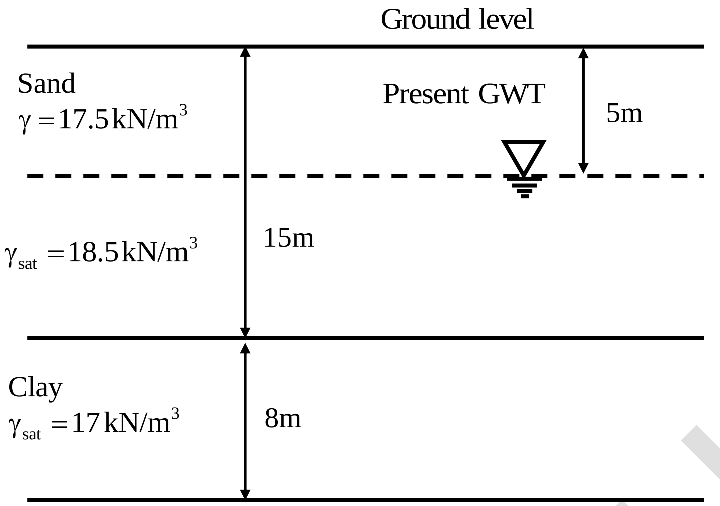


$$\text{Effective gradient} = \left[\frac{\text{Maximum difference in reduced level}}{\text{Total runway length}}\right]$$

$$= \left[\frac{4.5-(-0.9)}{1700}\times 100\right]\%$$

$$= 0.3176\% \simeq 0.32\%$$

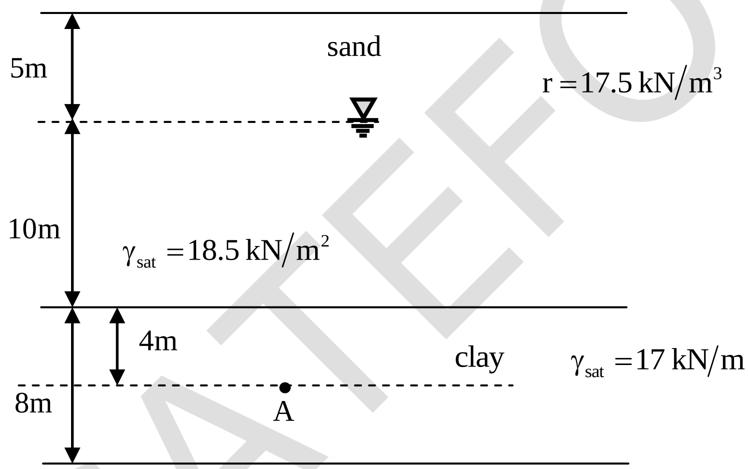
33. The soil profile at a construction site is shown in the figure (not to scale). Ground water table (GWT) is at 5m below the ground level at present. An old well data shows that the ground water table was as low as 10m below the ground level in the past. Take unit weight of water, $\gamma_w = 9.81\text{kN/m}$.



The over consolidation ratio (OCR) (rounded off to two decimal places) at the mid-point of the clay layer is ___________.

Key: (1.22)

Sol:



$$\text{Over consolidation ratio (OCR)} = \frac{\text{Pre consolidation stress}\left(\bar{\sigma}_x\right)}{\text{Present stress}\left(\bar{\sigma}_A\right)}$$

When water table at 10m depth from the ground

Effective stress at A = 10 × 17.5 + 5 × (18.5–9.81) + 4 (17–9.81) = 247.21 kN/m^2

$$\left(\bar{\sigma}\ \right) = 247.21 kN/m^2$$

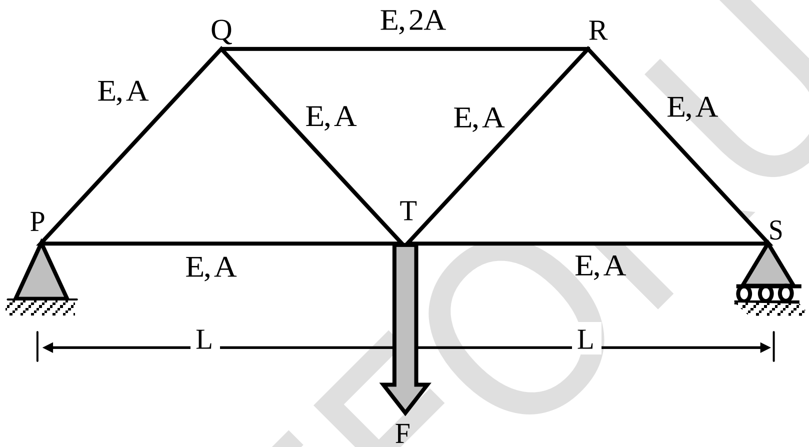
Presently water table at a depth of 5m from the ground level

Effective stress at A = 5 × 17.5 + 10 (18.5–9.81) + 4(17-9.81)

$\left(\overline{\sigma}\right) = 203.16\ \text{kN/m}$

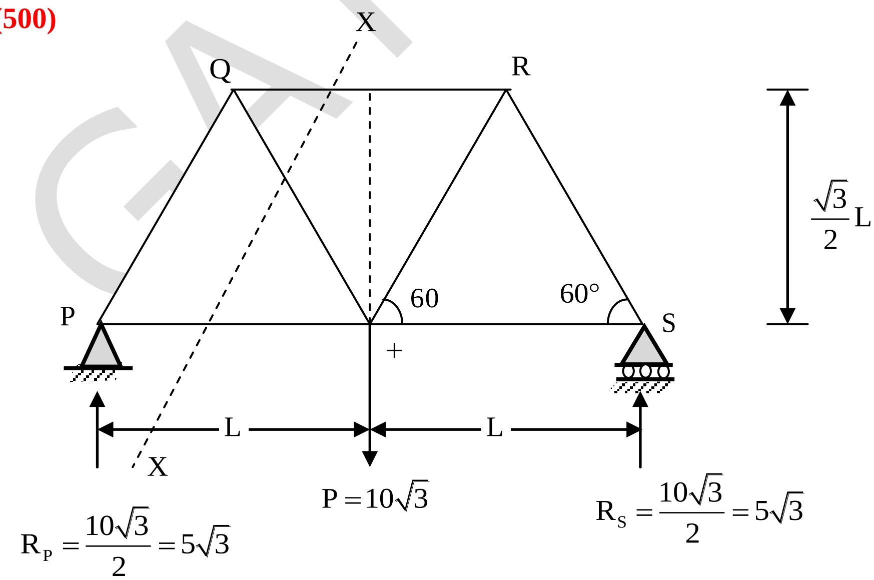
$\text{OCR} = \dfrac{247.21}{203.16} = 1.22$

34. Refer the truss as shown in the figure (not to scale).



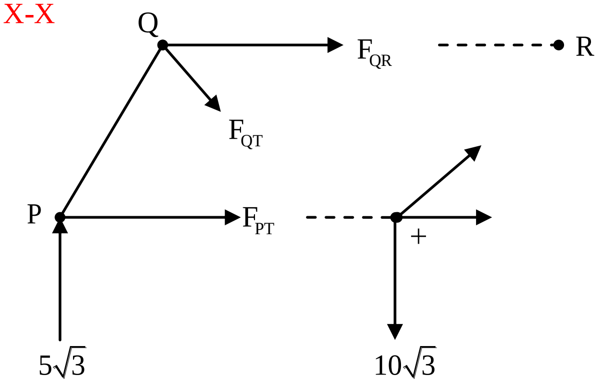
If load, $F = 10\sqrt{3}\text{kN}$, moment of inertia, $I = 8.33\times10^{6}\ \text{mm}^4$, area of cross-section, $A = 10^4\,\text{mm}^2$, and length, L =2m for all the members of the truss, the compressive stress (in kN/m^2, in integer) carried by the member Q-R is ______________.

Key: (500)



As per method of section

Cutting section X-X



Taking moment about T = 0

$$F_{QR}\times\frac{\sqrt{3}}{2}L+5\sqrt{3}\times L=0$$

$$F_{QR}\frac{\sqrt{3}}{2}L=-5\sqrt{3}L$$

$$F_{QR}=-10\text{kN}\qquad(\text{i.e., compressive force})$$

$$\text{Compressive stress }=\frac{\text{Force}}{\text{Area}}=\frac{10\text{kN}}{2\text{A}}=\frac{10\text{kN}}{2\times10^{4}\text{mm}^{2}}=5\times10^{-4}\,\text{kN/mm}^{2}$$

$$=5\times10^{-4}\times10^{6}\,\text{kN/m}^{2}=500\,\text{kN/m}^{2}$$

35. The cohesion (c), angle of internal friction (ϕ) and unit weight (γ) of a soil are 15 kPa, $20°$ and 17.5kN/m^3, respectively. The maximum depth of unsupported excavation in the soil (in m,rounded off to two decimal places) is ________________.

Key: (4.897)

Sol: Cohesion $(c)=15\text{ kPa}=15\text{ kN/m}^2$

Angle of internal friction $(\phi)=20°$

Unit weight of soil $(\gamma)=17.5\text{ kN/m}^3$

Maximum depth of unsupported excavation $=2\times\text{critical depth}=2\times\frac{2c}{\gamma\sqrt{k_a}}=\frac{4c}{\gamma\sqrt{k_a}}$

$$k_a=\frac{1-\sin\phi}{1+\sin\phi}=\frac{1-\sin 20}{1+\sin 20}=0.49$$

$$z=\frac{4c}{\gamma\sqrt{k_a}}=\frac{4\times15}{17.5\sqrt{0.49}}=4.897\text{ m}$$

36. In an Oedometer apparatus, a specimen of fully saturated clay has been consolidated under a vertical pressure of 50 kN/m^2 and is presently at equilibrium. The effective stress and pore water pressure immediately on increasing the vertical stress to 150kN/m^2, respectively are

(A) 0 and 150kN/m^2

(B) 100 kN/m^2 and 50kN/m^2

(C) 150 kN/m^2 and 0

(D) 50kN/m^2 and 100kN/m^2

Key: (D)

Sol: Increase in vertical stress $(\Delta\sigma) = 150 - 50 = 100\ kN/m^2$

Clay soil is saturated and no shearing, so

$\Delta\sigma =$ Pore water pressure increase
$\Delta P = 100\ kN/m^2$

The soil is in equilibrium at 50 kN/m^2,

The initial pore water pressure = 0

Final pore water pressure = 100 + 0 = 100 kN/m^2

Effective stress = Total stress – Pore water pressure = 150 – 100 = 50 kN/m^2

37. The volume determined from $\iiint^{v} 8xyz\,dV$ for $V = [2, 3] \times [1, 2] \times [0, 1]$ (in integer) is__________.

Key: (15)

x limits : 2 to 3 ; y limits : 1 to 2 and z limits: 0 to 1

$$\therefore \text{Volume} = \int_{x=2}^{3}\int_{y=1}^{2}\int_{z=0}^{1} 8xyz\,dx\,dy\,dz$$

$$= 8\left(\int_{x=2}^{3} x\,dx\right)\left(\int_{y=1}^{2} y\,dy\right)\left(\int_{z=0}^{1} z\,dz\right)$$

$$= 8\left(\frac{x^2}{2}\right)_2^3 \times \left(\frac{y^2}{2}\right)_1^2 \times \left(\frac{z^2}{2}\right)_0^1 = 5\times3\times1 = 15$$

38. A signalized intersection operates in two phases. The lost time is 3 seconds per phases. The maximum ratios of approach flow to saturation flow for the two phases are 0.37 and 0.40. The optimum cycle length using the Webster's method (in seconds rounded off to one decimal places) is __________.

Key: (60.869)

Sol: Number of phases (n) = 2

Lost time per phase = 3 seconds

Total lost time = 2 × 3 = 6 seconds

Critical ratios $y_1 = 0.37, y_2 = 0.40$

$y = y_1 + y_2 = 0.37 + 0.4 = 0.77$

As per Webster method

Optimum cycle length $(C_o) = \frac{1.5L+5}{1-y} = \frac{1.5\times6+5}{1-0.77} = 60.869\ \text{seconds}$

39. Which of the following is/are correct statement(s) ?

(A) If the whole circle bearing of a line is 270°, its reduced bearing is 90° NW.

(B) The boundary of water of a calm water pond will represent contour line

(C) In the case of fixed hair stadia tachometry, the staff intercept will be larger, when the staff is held nearer to the observation point.

(D) Back bearing of a line is equal to Fore bearing $\pm180°$

Key: (A,B,D)

40. Contractor X is developing his biding strategy against Contactor Y. The ratio of Y's bid price to X's cost of the 30 previous bids in which contractor X has completed against Contractor Y is given in the table:

Ratio of Y's bid price to X's cost	Number of bids
1.02	6
1.04	12
1.06	3
1.10	6
1.12	3

Based on the bidding behavior of the Contractor Y, the probability of winning against Contractor Y at a mark up of 8% for the next project is

(A) more than 50% but less than 100%

(B) 0%

(C) more than 0% but less than 50%

(D) 100%

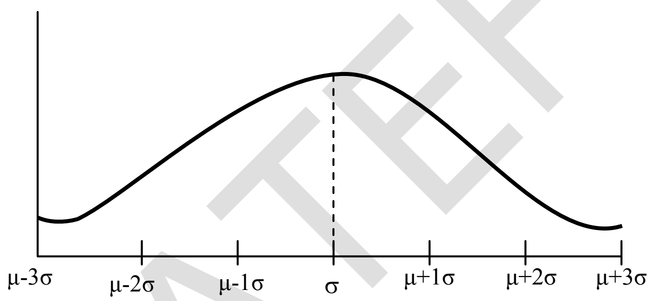
Key: (C)

Ratio of Y's bid price to X's Cost	Number of bids
1.02	6
1.04	12
1.06	3
1.10	6
1.12	3

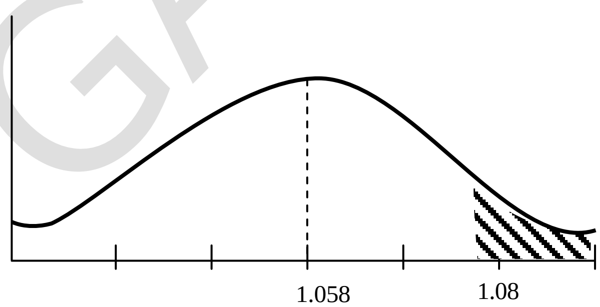
$$\text{Mean} = \frac{1.02\times 6+1.04\times 12+1.06\times 3+1.10\times 6+1.12\times 3}{30} = 1.058$$

Mean $=1.058$

Normal distribution of y's bidding



with markup of 8% i.e., = 1.08



Shaded portion is probability of X contractor winning contract over y which is less than 50%.

41. The solution of the second-order differential equation $\frac{d^2y}{dx^2}+2\frac{dy}{dx}+y=0$ with boundary conditions $y(0)=1$ and $y(1)=3$ is

(A) $e^{-x}-\left[3e\sin\left(\frac{\pi x}{2}\right)-1\right]xe^{-x}$

(B) $e^{-x}+(3e-1)xe^{-x}$

(C) $e^{-x}-(3e-1)xe^{-x}$

(D) $e^{-x}+\left[3e\sin\left(\frac{\pi x}{2}\right)-1\right]xe^{-x}$

Key: (B)

A. E is $m^2+2m+1=0\Rightarrow(m+1)(m+1)=0\Rightarrow m=-1,-1$

(two equal real roots), since R.H.S is 0

$\therefore$ D.E is homogenous equation

$\therefore$ Solution is y = C.F

$\Rightarrow y=(c_1+c_2x)e^{-x}\quad ...(1)$

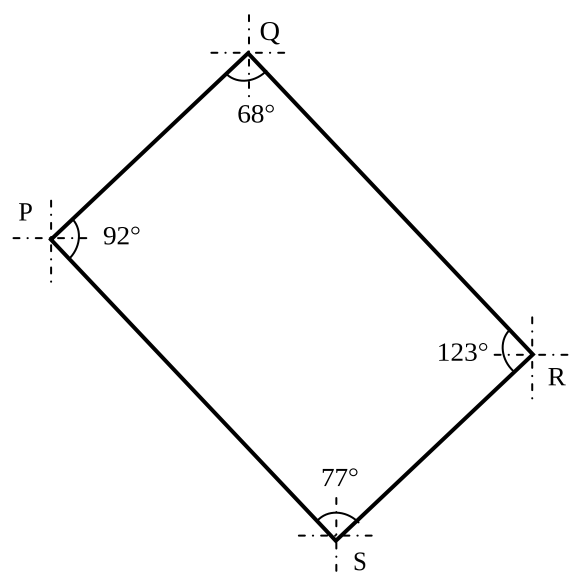
Using y(0) =1 (i.e., y = 1, x = 0) and y (1) = 3 (i.e., y = 3, x = 1), equation(1) gives

$1=c_1\ \&\ 3=(c_1+c_2)e^{-1}$

$\Rightarrow 3e=1+c_2\Rightarrow c_2=3e-1$

$\therefore y=(1+(3e-1)x)e^{-x}$

42. Traversing is carried out for a closed traverse PQRS. The internal angles at vertices P, Q, R and S are measured as 92°, 68°. 123°. And 77° respectively. If fore bearing of line PQ is 27°, fore bearing of line RS (in degrees, in integer) is ____________.



Key: (196)

Sol: Back bearing

$QR=BB_{PQ}-\angle Q=(27+180)-68°=139°$

$\text{Back bearing RS}=\text{Back bearing of QR}-\angle R$

$=(139+180)-123$

$FB_{RS}=196^{o}$

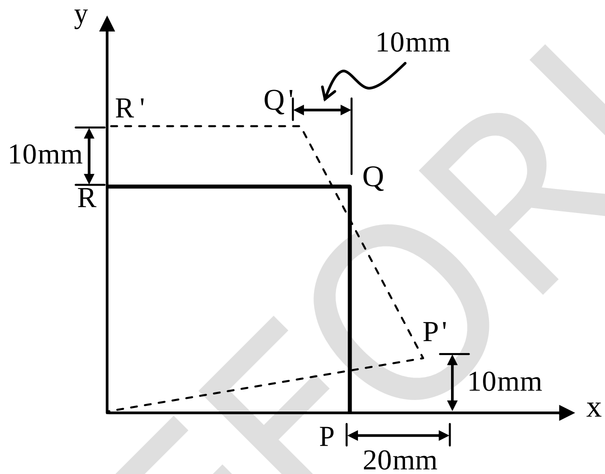
43. Gypsum is typically added in cement to

(A) increase workability (B) prevent quick setting

(C) enhance hardening (D) decrease heat of hydration

Key: (B)

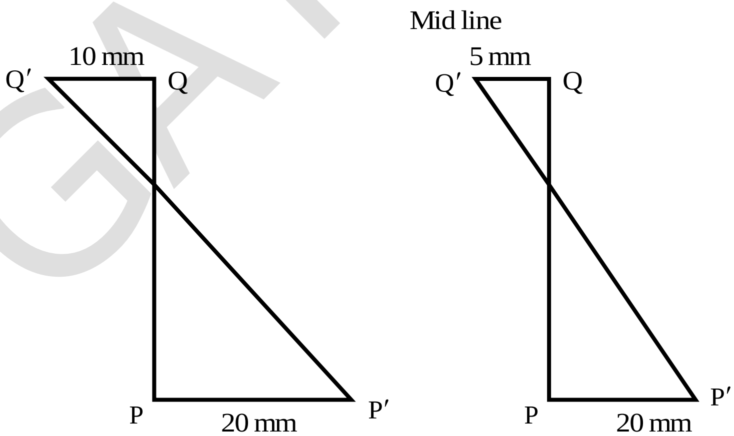
44. A square plate O-P-Q-R of a linear elastic material with sides 1.0m is loaded in a state of plane stress. Under a given stress condition, the plate deforms to a new configuration O-P'-Q-R' as shown in the figure (not to scale). Under the given deformation, the edges of the plate remain straight.



The horizontal displacement of the option (0.5m, 0.5m) in the plate O-P-Q-R (in mm, rounded off to one decimal places) is __________.

Key: (2.5)

Sol:



So horizontal displacement of the point (0.5m, 0.5m) = –2.5 mm + 5 mm = 2.5 mm

45. On a road, the speed –density relationship of a traffic stream is given by $u = 70 - 0.7k$ (where speed, u, is in km/h and density, k, is in veh/km). At the capacity condition, the average time headway will be

(A) 2.1s (B) 0.5s (C) 1.6s (D) 1.0s

Key: (A)

Sol: Method-1

Given speed density relationship.

$u = 70 - 0.7k$

$q = ku = k(70 - 0.7k)$

$q = 70k - 0.7k^2$

For maximum flow $\frac{dq}{dk} = 0$

$\frac{d}{dk}(70k - 0.7k^2) = 0$

$70 - 2 \times 0.7k = 0$

$k = \frac{70}{1.4} = 50$

Maximum flow $(q) = 70 \times 50 - 0.7 \times 50^2 = 3500 - 1750 = 1750$ veh/hr

Average time headway $= \frac{3600}{q_{max}} = \frac{3600}{1750} = 2.05$ seconds

Method-2:

$U = 70 - 0.7k$

Maximum flow $(q) = \frac{V_F k_J}{4}$

At $k_J = U_0$

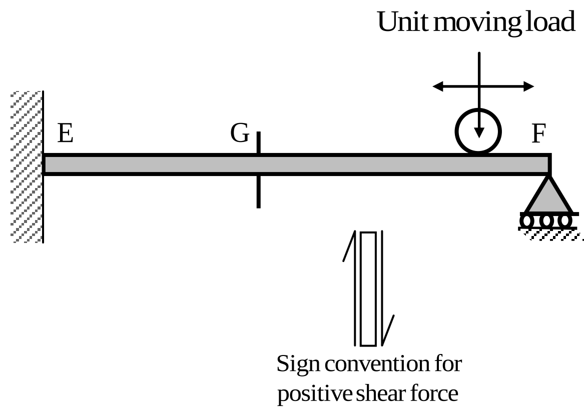
$k_J = \frac{70}{0.7} = 100$ veh/km

at $k = 0, U = V_F = 70$ km/hr

Maximum flow $(q) = \frac{100 \times 70}{4} = 25 \times 70 = 1750$ veh/hr

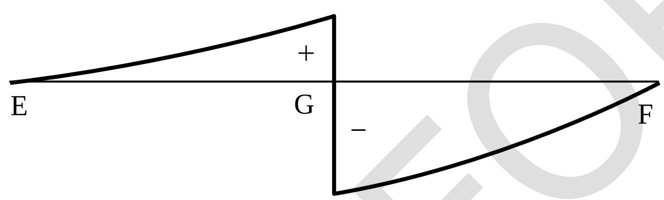
Time headway $= \frac{3600}{q} = \frac{3600}{1750} = 2.05$ seconds

46. A propped cantilever beam EF is subjected to a unit moving load as shown in the figure (not to scale). The sign convention for positive shear force at the left and right sides of my section is also shown:

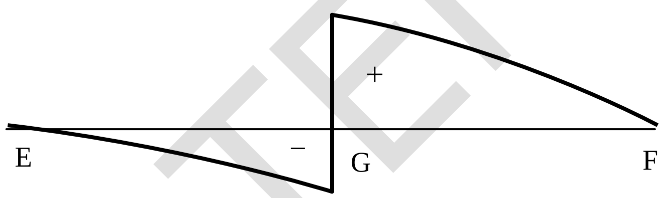


The CORRECT qualitative nature of the influence line diagram for shear force at G

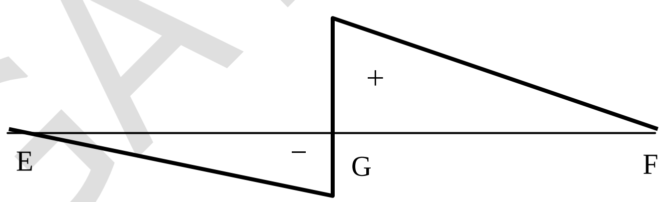
(A)



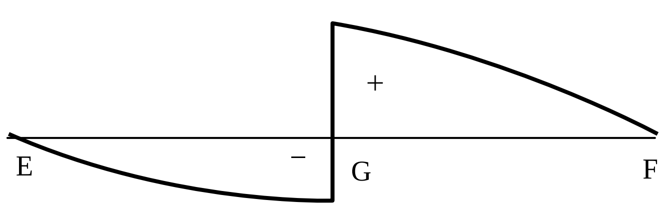
(B)



(C)

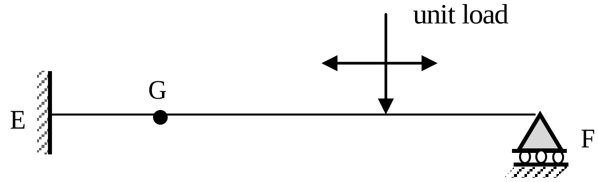


(D)

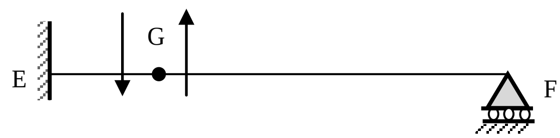


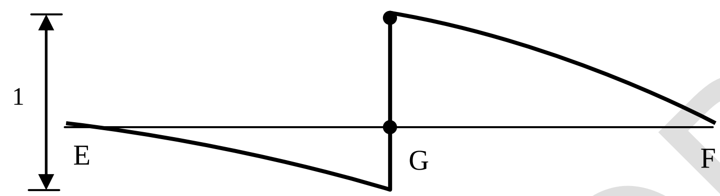
Key: (B)

Sol:



As per Mullers breslauce principle





47. A fluid flowing steadily in a circular pipe of radius R has a velocity that is everywhere parallel to the axis (centerline) of the pipe. The velocity distribution along the radial direction is $V_r = U\left(1-\frac{r^2}{R^2}\right)$, where r is the radial distance as measured from the pipe axis and U is the maximum velocity at r =0. The average velocity of the fluid in the pipe is

(A) $\frac{U}{4}$ (B) $\frac{U}{2}$ (C) $\frac{U}{3}$ (D) $\left(\frac{5}{6}\right)U$

Key: (B)

Given, $V_r = U\left(1-\frac{r^2}{R^2}\right)$

$$Q = \int V_r.dA = \int_0^R U\left(1-\frac{r^2}{R^2}\right)2\pi r dr$$

$$Q = \frac{2\pi U}{R^2}\left(\frac{R^2r^2}{2}-\frac{r^4}{4}\right)\Bigg|_0^R = \frac{\pi}{2}UR^2$$

$$\bar{V} = \frac{Q}{A} = \frac{\frac{\pi}{2}UR^2}{\pi R^2} = \frac{U}{2}$$

48. The liquid forms of particulate air pollutants are

(A) fly ash and fumes
(B) dust and mist
(C) mist and spray
(D) smoke and spray

Key: (C)

Sol: The liquid forms of particulate air pollutants are mist and spray.

Note: Mist is a cloud made of very small drops of water in the air just above the ground which reduces the visibility.

49. The value $\int_0^1 \left(e^x dx\right)$ using the trapezoidal rule with four equal subintervals is

(A) 2.192
(B) 718
(C) 1.727
(D) 2.718

Key: (C)

$$f(x) = e^x, a = 0, b = 1, n = 4 \Rightarrow h = \frac{b-a}{n} = 0.25$$
$$y_0 = f(a) = e^0 = 1; y_1 = f(a+h) = e^{0.25} = 1.284$$
$$y_2 = f(a+2h) = e^{0.5} = 1.648; y_3 = f(a+3h) = e^{0.75} = 2.117$$
$$y_4(a+4h) = e^1 = 2.718$$

$$\therefore \text{By Trapezoidal rule, } \int_0^1 e^x dx = \frac{h}{2}\left[\left(y_0 + y_4\right) + 2\left(y_1 + y_2 + y_3\right)\right]$$
$$= \frac{1}{8}\left[(1 + 2.718) + 2(1.284 + 1.648 + 2.117)\right] \simeq 1.727$$

50. Which one of the following statements is correct?

(A) Combustion is an exothermic process, which takes place in the absence of oxygen

(B) Pyrolysis is an exothermic process, which takes place in the absence of oxygen

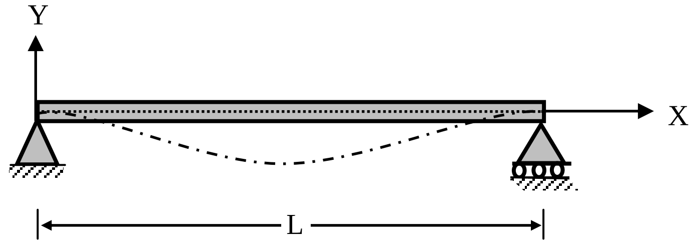
(C) Combustion is an endothermic process, which takes place in the abundance of oxygen

(D) Pyrolysis is an endothermic process, which takes place in the absence of oxygen.

Key: (D)

Sol: Pyrolysis is an exothermic process as there is a substantial heat ???? to raise the biomass to the reaction temperature.

51. The equation of deformation is derived to be $y = x^2 - xL$ for a beam shown in the figure.



The curvature of the beam at the mid-span (in units in integer) will be ________.

Key: (2)

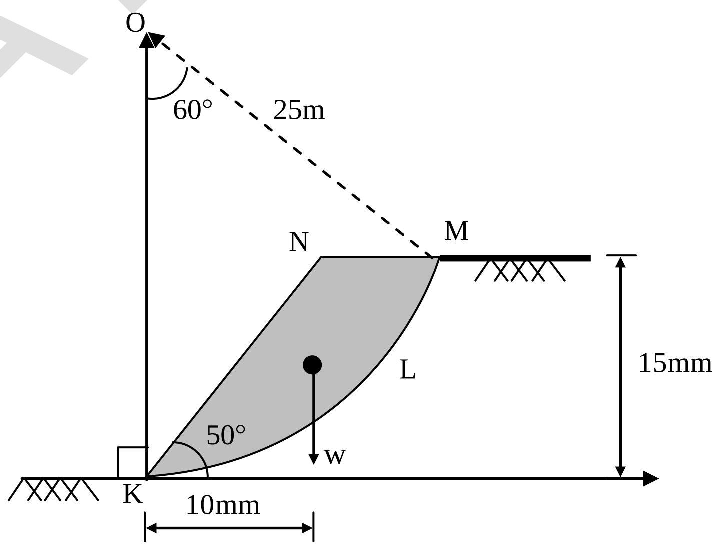
Sol: Curvature is $\frac{d^2y}{dx^2}$

Given equation

$$y = x^2 - xL$$
$$\frac{dy}{dx} = 2x - L$$
$$\boxed{\frac{d^2y}{dx^2} = 2}$$

The beam is having constant curvature throughout the beam.

52. An unsupported slope of height 15m is shown in the figure (not to scale), in which the slope face makes an angle 50° with the horizontal.



The slope material comprises purely cohesive soil having undrained cohesion 75kPa. A trial slip circle KLM, with a radius 25m, passes through the crest and toe of the slope and it subtends an angle 60° at its center O. The weight of the active soil mass (W, bounded by KLMN) is 2500 kN/m, which is acting at a horizontal distance of 10m from the toe of the slope. Consider the water table to be present at a very large depth from the ground surface.

Considering the trial slip circle KLM, the factor of safety against the failure of slope under undrained condition (rounded off to two decimal places) is _________.

Key: (1.96)

Sol: $FOS = \dfrac{\text{Resisting moment}}{\text{Actuating moment}}$

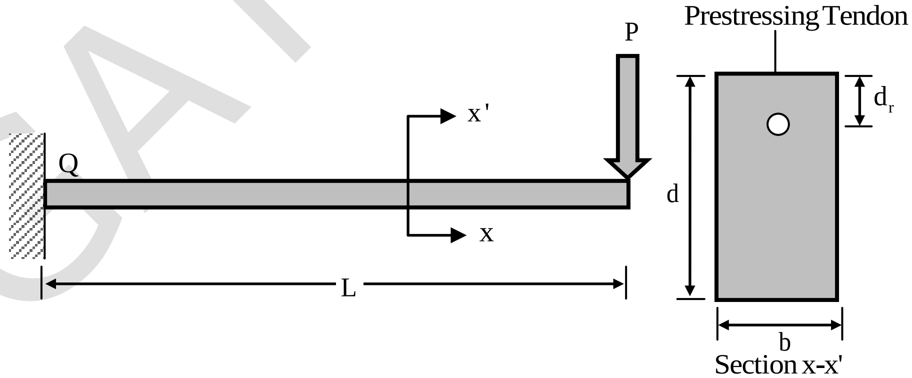
$FOS = \dfrac{C_u IR}{w\bar{x}}$

$\ell = \text{length of ac KLM}$

$\bar{x} = \text{Distance of 'w' from toe}$

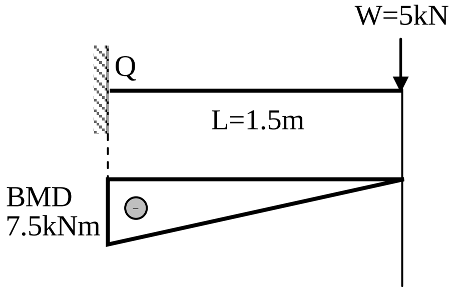
$$\Rightarrow FOS = \frac{75 \times 2\pi \times 25 \times \frac{60}{36} \times 25}{2500 \times 100} \Rightarrow FOS = 1.96$$

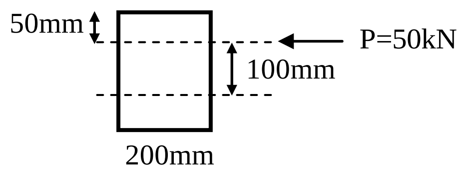
53. A prismatic cantilever prestressed concrete beam of span length, L=1.5m has one straight tendon place in the cross-section as shown in the figure (not to scale). The total prestressing force of 50kN in the tendon is applied at $d_c = 50\text{mm}$ for the top in the cross-section of width, b=200mm and depth, d = 300mm.



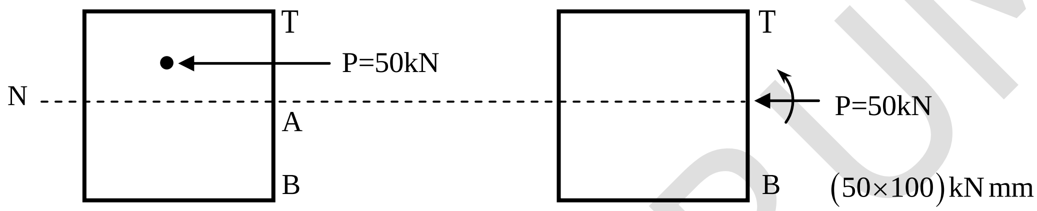
If the concentrated load, P= 5kN, the resultant stress (in MPa, in integer) experienced at point 'Q' will be _________.

Key: (0)





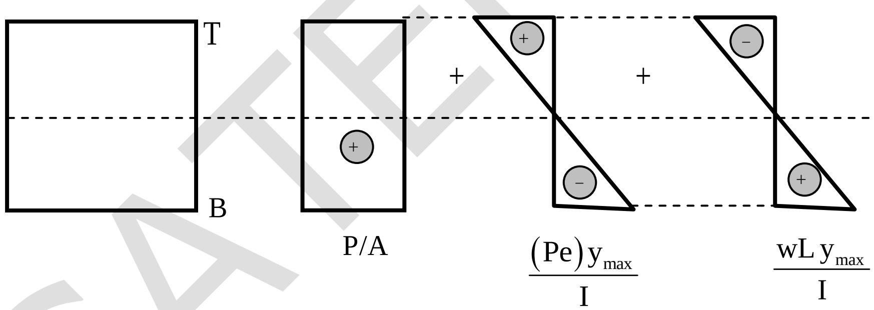
Let, T = top and B = Bottom



Assuming, Compression +

Tension −

Consider a cross section element at Q



MOI of C/S (1) $= \frac{1}{12}BD^3 = \frac{1}{12} \times 200 \times 300^3$

$= 450 \times 10^6 \, mm^4$

Section modulus (Z) $= \frac{1}{y} = \frac{BD^2}{12 \times \frac{D}{2}} = \frac{BD^2}{6}$

$= \frac{450 \times 10^6 \, mm^4}{150} = 3 \times 10^6 \, mm^4$

Note: For rectangular cross-section

$$\text{Section Modulus(Z)} = \frac{BD^2}{6} = \frac{200 \times 300^2}{6} = 3\times10^6\,\text{mm}^4$$

'Q' is the top point.

Stress at top, (σ_T)

$$(\sigma_T) = \frac{50\times10^3\,\text{N}}{200\times300} + \frac{(50\times10^3)\times100}{3\times10^6} - \frac{(5\times10^3)\times(1.5\times10^3)}{3\times10^6}$$

$$= 0.833 + 1.667 - 2.5$$

$$= 3\times10^{-3}\,\text{N/mm}^2$$

Resultant stress at 'Q' rounded of in integer = 0.

54. If $P = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$ and $Q = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$ then $Q^T P^T$

(A) $\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$ (B) $\begin{bmatrix} 1 & 3 \\ 2 & 4 \end{bmatrix}$ (C) $\begin{bmatrix} 2 & 1 \\ 4 & 3 \end{bmatrix}$ (D) $\begin{bmatrix} 2 & 4 \\ 1 & 3 \end{bmatrix}$

Key: (D)

$$Q^T = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix};\ P^T = \begin{bmatrix} 1 & 3 \\ 2 & 4 \end{bmatrix}$$

$$Q^T P^T = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}\begin{bmatrix} 1 & 3 \\ 2 & 4 \end{bmatrix} = \begin{bmatrix} 2 & 4 \\ 1 & 3 \end{bmatrix}$$

55. 'Kinematic viscosity' is dimensionally represented as

(A) $\frac{M}{LT}$ (B) $\frac{T^2}{L}$ (C) $\frac{M}{L^2T}$ (D) $\frac{L^2}{T}$

Key: (D)