GATE 2021

CIVIL ENGINEERING

Questions & Detailed Solutions

Exam held on 06/02/2021
Forenoon Session

If you find any discrepency in question or solution, kindly write us at : **info@madeeasy.in** mentioning stream, date of exam and session.

SECTION A : GENERAL APTITUDE

Q.1 Four 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) 4

(c) 6 (d) 8

Ans. (c)

Following cases can be

PQSR, RQSP, QPSR, QRSP, RQPS and PQRS

End of Solution

Q.2 Statement: Either P marries Q or X marries Y

Among the option 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 marries Q and X marries Y

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

Ans. (a)

End of Solution

Q.3 Consider two rectangular sheets, Sheet M and Sheet N of dimensions 6 cm × 4 cm 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 perimeter of the final folded shape of Sheet N to the final folded shape of Sheet M is _______.

(a) 5 : 13 (b) 7 : 5

(c) 13 : 7 (d) 3 : 2

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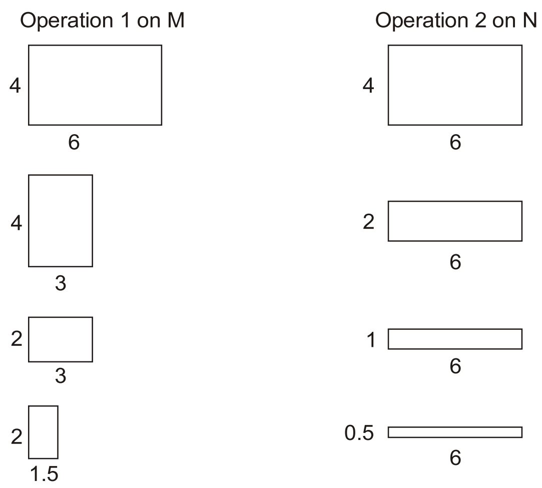
Ans. (c)



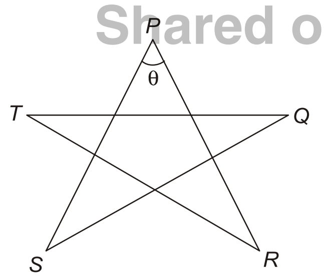
$(\text{Perimeter})_M = 2(2 + 1.5) = 7$

$(\text{Perimeter})_N = 2(0.5 + 6) = 13$

$$\text{Required ratio} = \frac{13}{7}$$

End of Solution

Q.4

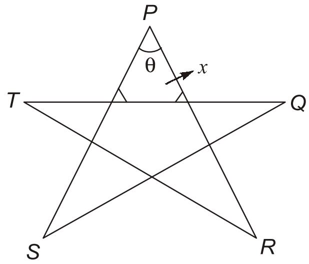


Five line segments of equal lengths, PR, PS, QS, QT and RT are used to form a star as shown in the figure above.

The value of θ, in degree, is_______

(a) 72
(b) 36
(c) 108
(d) 45

Ans. (b)



Sum of angle formed at the pentagon = 540°

Each angle of pentagon = $\frac{540}{5} = 108°$

$\angle x = 180 - 108 = 72°$

Sum of angle of triangle = 180°

$72° + 72° + \theta = 180°$

$\theta = 36°$

End of Solution

Q.5 A function, λ, is defined by

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

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

(a) $\frac{16}{3}$
(b) –1
(c) 0
(d) 16

Ans. (c)

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

So, 1st definition will be applicable as $p = q$.

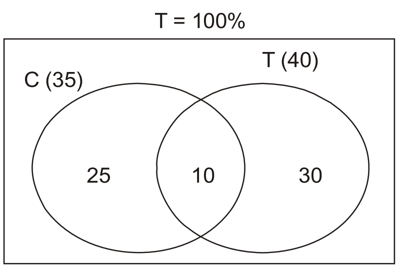
Hence, $\lambda(1, 1) = (1 - 1)^2 = 0$

End of Solution

Q.6 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) 15
(b) 35
(c) 25
(d) 40

Ans. (b)



Percent of employees drink neither tea nor coffee = 100 – 25 – 10 – 30 = 35

End of Solution

Q.7 Human 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 worlds 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 posses the ability to construct mental worlds.

(b) Imagination, invention and innovation are unrelated to the ability to construct mental worlds.

(c) No spices posses the ability to construct worlds in their minds.

(d) The terms imagination, invention and innovation refer to unrelated skill.

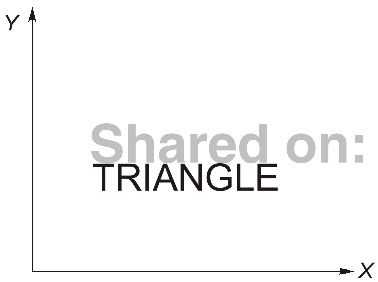
Ans. (a)

Option (b) and (d) are weekend by the word 'UNRELATED SKILLS'. Option (c) is weekend by the expression, no species posses the ability.

Hence answer is option (a) which reflects the information given in the passage.

End of Solution

Q.8



The mirror image of the above text about the x-axis is

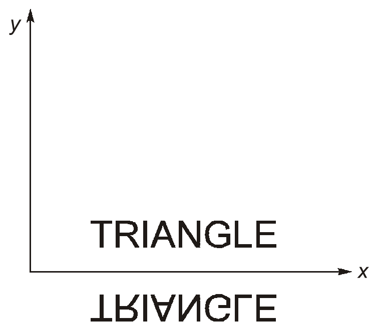
(a) 

(b) 

(c) 

(d) 

Ans. (d)



End of Solution

Q.9 Getting to the top is ________ than staying on top.

(a) more easy
(b) easier
(c) much easy
(d) easiest

Ans. (b)

When the comparison is between two things we use the second degree of the adjective. The degree form of easy are: (easy - easier - easiest).

End of Solution

Q.10 $\oplus$ 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) y
(b) $\frac{3y}{2}$
(c) $2y$
(d) $\frac{y}{2}$

Ans. (a)

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

$$\frac{x^2 + y^2}{xy} = \frac{2^2}{2}$$

$$x^2 + y^2 = 2xy$$

$$(x - y)^2 = 0$$

$$x = y$$

End of Solution

■■■■

SECTION B : TECHNICAL

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

(a) 4
(b) 2
(c) 1
(d) 3

Ans. (b)

Using $R_2 \to R_2 \to 3R_1$, $R_3 \to R_3 - 5R_1$, $R_4 \to R_4 - 7R_1$

$$A = \begin{bmatrix} 1 & 2 & 2 & 3 \\ 0 & -2 & -4 & -4 \\ 0 & -4 & -8 & -8 \\ 0 & -6 & -12 & -12 \end{bmatrix}$$

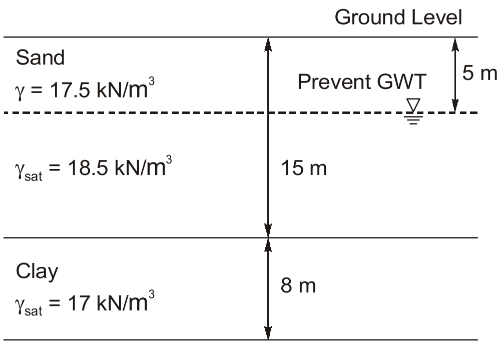
Using $R_3 \to R_3 - 2R_2$, $R_4 \to R_4 - 3R_2$

$$A = \begin{bmatrix} 1 & 2 & 2 & 3 \\ 0 & -2 & -4 & -4 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

So, $\rho(A)$ = No. of non-zero rows = 2.

End of Solution

Q.2 The soil profile at a construction site is shown in the figure (not to scale). Ground water table (GWT) is at 5 m below the ground level at present. An old well data shows that the ground water table was as low as 10 m below the ground level in the past. Take unit weight of water. γ_w = 9.81 kN/m^3.



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

Ans. (1.22)

$$\text{OCR} = \frac{\bar{\sigma}_c}{\bar{\sigma}_0}$$

$\bar{\sigma}_c$ = Preconsolidation stress

$\bar{\sigma}_0$ = Present effective stress

$$\bar{\sigma}_c = 17.5 \times 10 + (18.5 - 9.81) \times 5 + (17 - 9.81) \times 4$$
$$= 247.21 \text{ kN/m}^2$$
$$\bar{\sigma}_0 = 17.5 \times 5 + (18.5 - 9.81) \times 10 + (17 - 9.81) \times 4$$
$$= 203.16 \text{ kN/m}^2$$
$$\text{OCR} = \frac{247.21}{203.16} = 1.22$$

End of Solution

Q.3 'Kinematic viscosity' is dimensionally represented as

(a) $\frac{M}{L^2T}$
(b) $\frac{L^2}{T}$
(c) $\frac{M}{LT}$
(d) $\frac{T^2}{L}$

Ans. (b)

End of Solution

Q.4 Spot speeds of vehicles observed at a point on a highway are 40, 55, 60, 65 and 80 km/h. The space-mean speed (in km/h, round off to two decimal places) of the observed vehicles is ________.

Ans. (56.99)

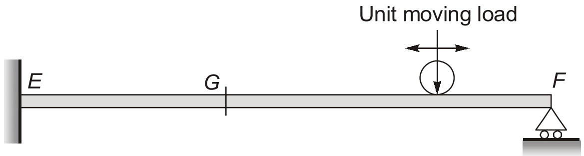
$V_1 = 40,\ V_2 = 55,\ V_3 = 60,\ V_4 = 65,\ V_5 = 80$

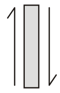
$$V_S = \left(\frac{n}{\frac{1}{V_1} + \frac{1}{V_2} + \ldots + \frac{1}{V_n}}\right) = \frac{5}{\frac{1}{40} + \frac{1}{55} + \frac{1}{60} + \frac{1}{65} + \frac{1}{80}}$$

$$= 56.99 \text{ kmph}$$

End of Solution

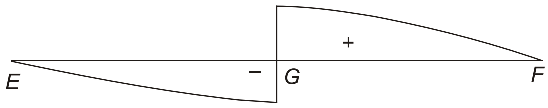
Q.5 A propped cantilever beam EF is subjected to a unit moving load as shown in the figure (not to scale). The sign convention for positive shear force at the left and right sides of any section is also shown.

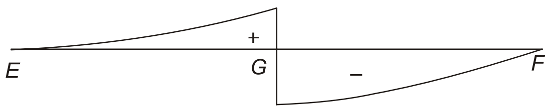


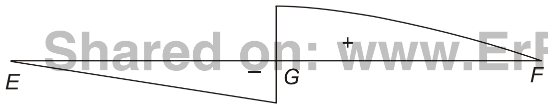


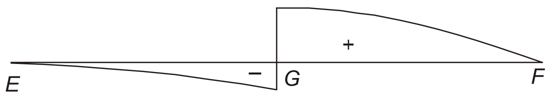
Sign convention for positive shear force

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

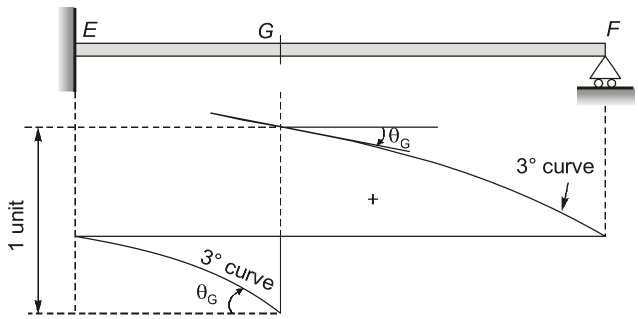
(a)


(b)


(c)


(d)


Ans. (d)



As per Muller Breslau principle ILD for stress function (shear -V_G) will be a combination of curves (3° curves).

End of Solution

Q.6 The direct and indirect costs estimated by a contractor for bidding a project is Rs. 160000 and Rs. 20000 respectively. If the mark up applied is 10% of the bid price, the quoted price (in Rs.) of the contractor is

(a) 198000 (b) 196000

(c) 200000 (d) 182000

Ans. (c)

Total cost estimated = Rs. 160000 + Rs. 20000 = Rs. 180000

Mark up = 10%

0.9 × Quoted price = Total cost estimated

$$\text{Quoted price} = \frac{180000}{0.9} = \text{Rs. } 200000$$

End of Solution

Q.7 The volume determined from $\iiint_V 8xyz dV$ for $V=[2,3]\times[1,2]\times[0,1]$ will be (in integer) ______

Ans. (15)

Given, $V = [2, 3,] \times [1, 2] \times [0, 1]$ i.e.,

$2 < x < 3,\ 1 < y < 2,\ 0 < z < 1$

So, $I = \iiint_V 8xyz dV = 8\iiint_V xyz\, dx\, dy\, dz$

$$= 8\int_{x=2}^{3} x dx \times \int_{y=1}^{2} y dy \times \int_{z=0}^{1} z dz$$

$$= 8\left[\frac{x^2}{2}\right]_2^3 \left[\frac{y^2}{2}\right]_1^2 \left[\frac{z^2}{2}\right]_0^1$$

$$= (9-4)(4-1)(1-0)$$

$$= 5 \times 3 \times 1$$

$$= 15$$

End of Solution

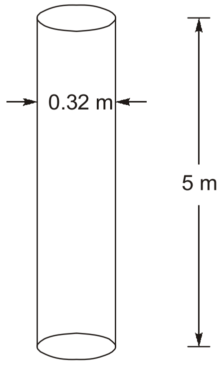
Q.8 A baghouse filter has to treat 12 m^3/s of waste gas continuously. The baghouse is to be divided into 5 sections of equal cloth area such that one section can be shut down for cleaning and/or repairing, while the other 4 sections continue to operate. An air-to-cloth ratio of 6.0 $m^3/min\text{-}m^2$ cloth will provide sufficient treatment to the gas. The individual bags are of 32 cm in diameter and 5 m in length. The total number of bags (in integer) required in the baghouse is ______.

Ans. (30)

Given, discharge to be passed = 12 m^3/s

Out of 5 sections, 4 will operate at a time.

Each bag is



Thus, surface area of each bag = $\pi \times 0.32 \times 5$ m^2 = 5.0265 m^2

Total surface area required wr.t. given discharge

$$= \frac{12 \text{ m}^3/\text{s}}{6 \text{ m}^3/\text{min-m}^2} = \frac{12 \text{ m}^3/\text{s}}{\frac{6}{60} \text{ m}^3/\text{s-m}^2} = 120 \text{ m}^2$$

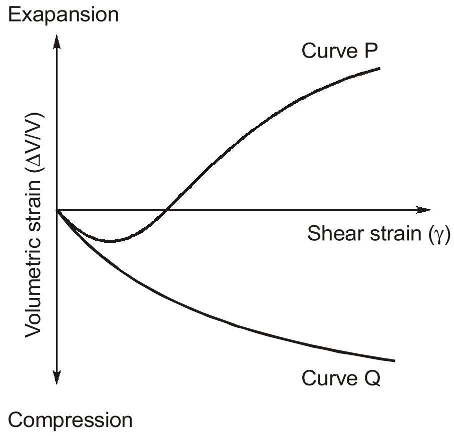
$\therefore$ Working bag filters required = $\dfrac{120 \text{ m}^2}{5.0265 \text{ m}^2} = 23.87$ or 24 bag filters

But, since it is asked total (which includes a standby set also), then,

Total no. of bag filters = $24 \times \dfrac{5}{4} = 30$

End of Solution

Q.9 Based on drained triaxial shear tests on sands and clays, the representative variations of volumetric strain ($\Delta V/V$) with the shear strain (γ) is shown in the figure.



Choose the correct option regarding the representative behaviour exhibited by Curve P and Curve Q.

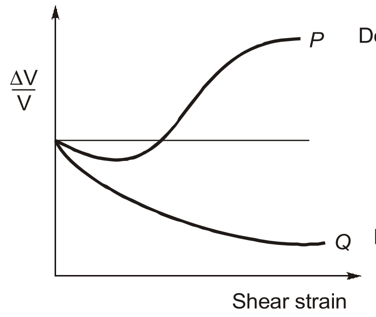
(a) Curve P represents loose sand and normally consolidated clay, while Curve Q represents dense sand and overc onsolidated clay.

(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.

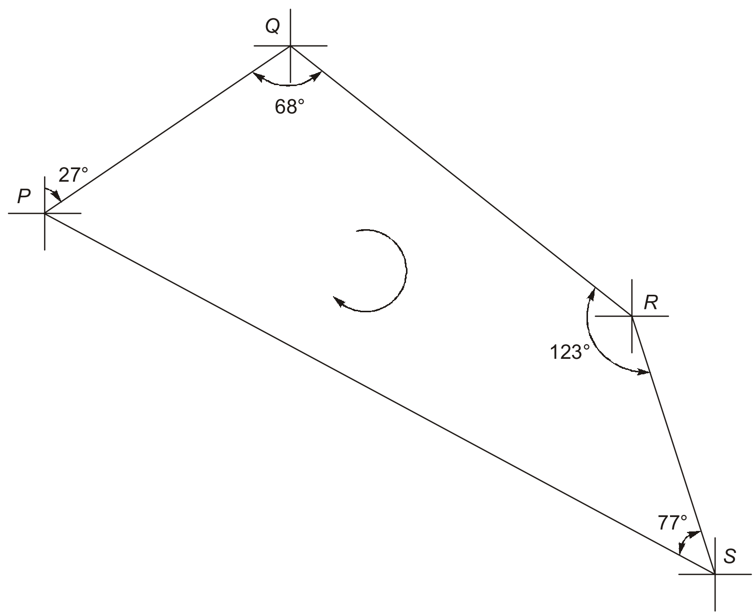
Ans. (c)



End of Solution

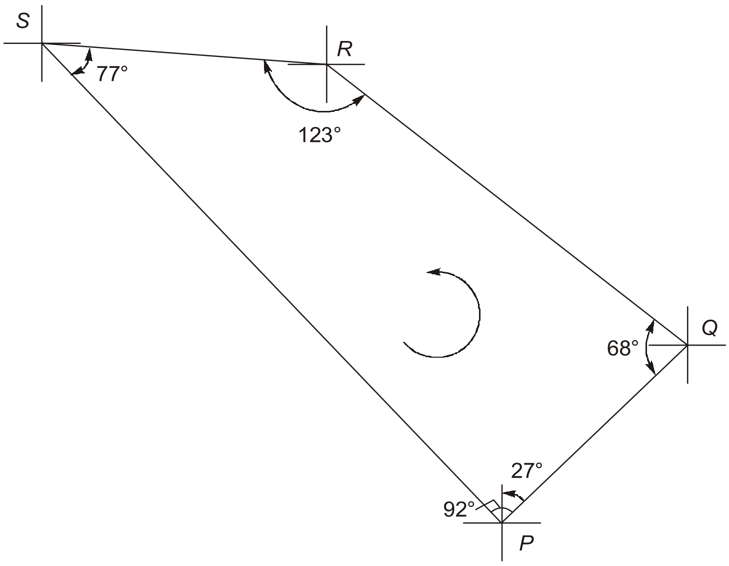
Q.10 Traversing is carried out for a closed traverse PQRS. The internal angles at vertices P, Q, R and S are measured a 92°, 68°, 123° and 77°, respectively. If fore bearing of line PQ is 27°, fore bearing of line Rs (in degrees, in integer) is ________.

Ans. (196, 218)



$$Q = \begin{cases} BB \text{ of } PQ = 27° + 180° = 207° \\ FB \text{ of } QR = 207° - 68° = 139° \end{cases}$$

$$R = \begin{cases} BB \text{ of } QR = 139° + 180° = 319° \\ FB \text{ of } RS = 319° - 123° = 196° \end{cases}$$

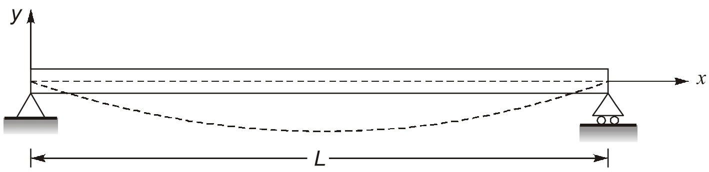


$$Q = \begin{cases} BB \text{ of } PQ = 27° + 180° = 207° \\ FB \text{ of } QR = 207° + 68° = 275° \end{cases}$$

$$R = \begin{cases} BB \text{ of } QR = 275° - 180° = 95° \\ FB \text{ of } RS = 95° + 123° = 218° \end{cases}$$

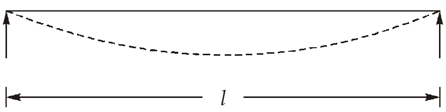
End of Solution

Q.11 The equation of deformation is derived to be $y = x^3 - xL$ for a beam shown in the figure.



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

Ans. (2)



Given, $y = x^2 - xl$

Curvature at mid section is $\frac{1}{R} = \frac{d^2y}{dx^2}$

$$\frac{dy}{dx} = 2x - l$$

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

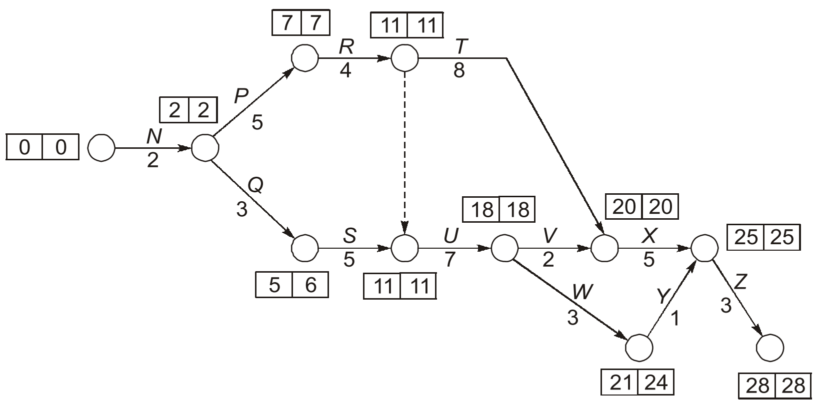
End of Solution

Q.12 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 ________.

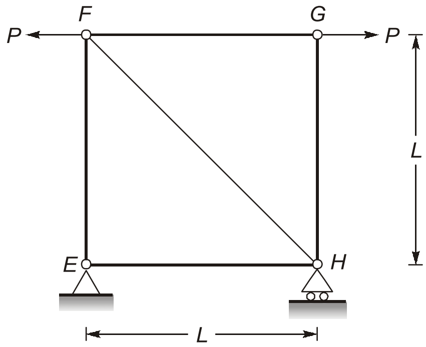
Ans. (0)



$$F_{T_V} = T_{L_j} - T_{E_i} - t_{ij}$$
$$= 20 - 18 - 2$$
$$= 0$$

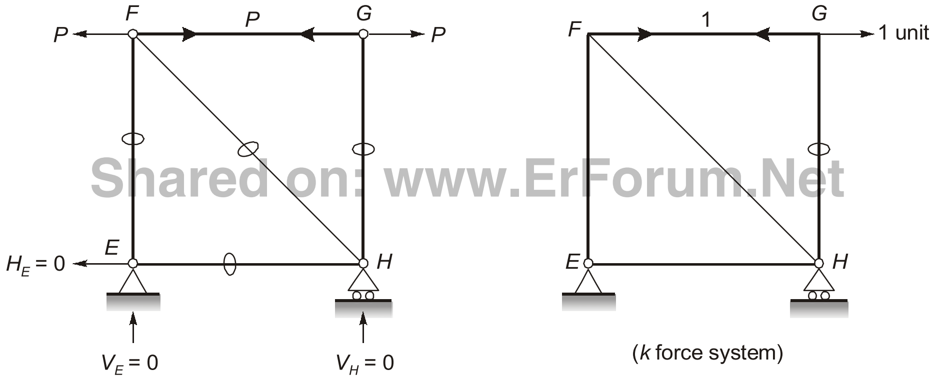
End of Solution

Q.13 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 ______

Ans. (0.90)



(*P* force system) (*k* force system)

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

By unit load method

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

Δ_{HG} = Horizontal deflection at joint G

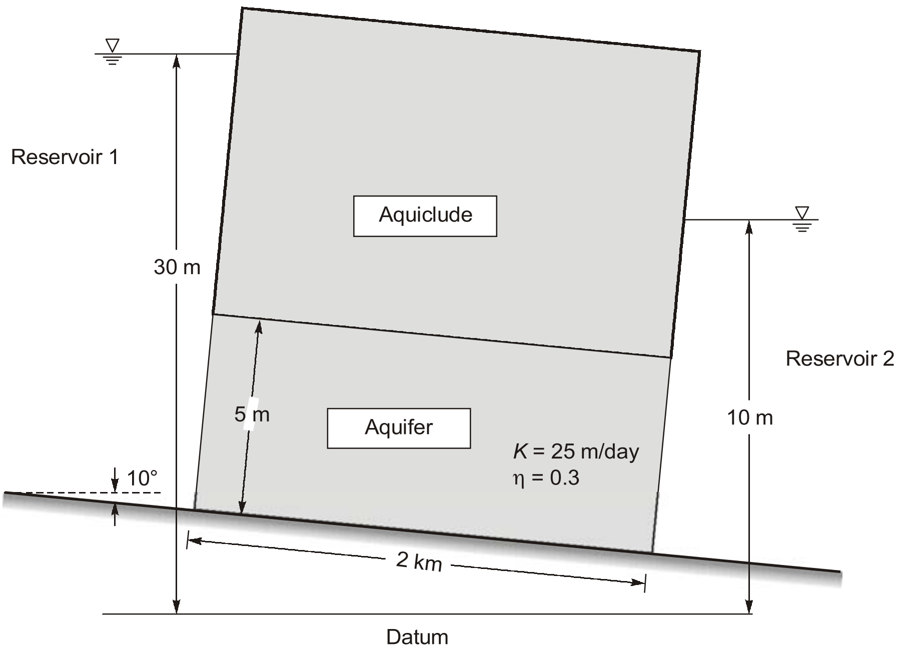
$\therefore \quad \Delta_{HG} = \underbrace{\frac{P \times 1 \times L}{AE}}_{\text{FG-member}} + \underbrace{'O'}_{\text{(For all other members)}}$

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

$$= 0.90 \text{ mm}$$

End of Solution

Q.14 Two reservoirs are connected through a homogeneous and isotropic aquifer having hydraulic conductivity (k) of 25 m/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 is 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 ________

Ans. (2400)

$$k = 25 \text{ m/d}$$

$$n = 0.3$$

$$i = \frac{20 \text{ m}}{2000 \text{ m}} = 0.01$$

$$V = ki$$

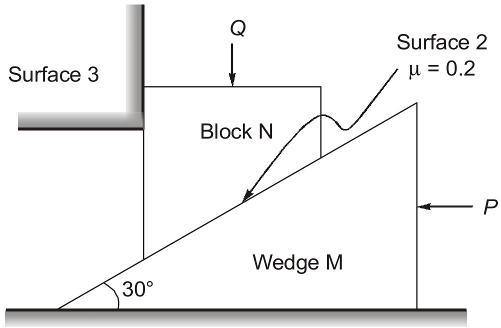
$$V_s = \frac{V}{n}$$

$$t = \frac{l}{V_s}$$

$$t = 2400 \text{ days}$$

End of Solution

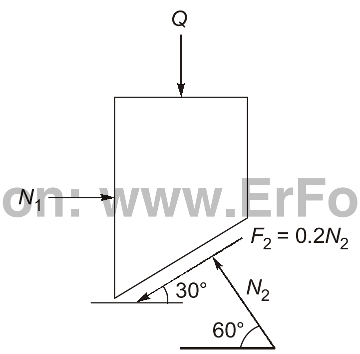
Q.15 A wedge M and a block N are subjected to force P and Q as shown in the figure. If force P is sufficiently large, then the block N can be raised. The weights of the wedge and the block are negligible compared to the forces P and Q. The coefficient of friction (μ) along the inclined surface between 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 = αQ. The value of the coefficient 'α' (round off to one decimal place) is

(a) 0.5
(b) 0.9
(c) 2.0
(d) 0.6

Ans. (b)

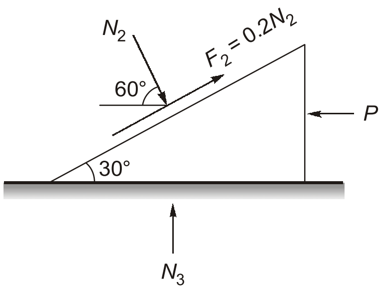


$$\Sigma Y = 0 \Rightarrow$$

$$N_2 \sin 60° - 0.2\, N_2 \sin 30° - Q = 0$$

$$Q = 0.766\, N_2 \quad \text{...(i)}$$

F.B.D. of wedge



$$\Sigma X = 0$$

$$\Rightarrow \quad 0.2N_2 \cos 30° + N_2 \cos 60° - P = 0$$

$$P = 0.67\, N_2$$

$$\Rightarrow \quad P = 0.67 \times \frac{Q}{0.766}$$

$$\Rightarrow \qquad P = 0.875Q \simeq 0.9Q$$

$$P = \alpha\, Q$$

$$\Rightarrow \qquad \alpha = 0.9$$

End of Solution

Q.16 The liquid forms of particulate air pollutants are

(a) fly ash and fumes
(b) smoke and spray
(c) dust and mist
(d) mist and spray

Ans. (d)

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

End of Solution

Q.17 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) Pyrolysis is an endothermic process, which takes place in the absence of oxygen.
(d) Combustion is an endothermic process, which takes place in the abundance of oxygen.

Ans. (c)

Pyrolysis is an endothermic process as there is a substantial heat input required to raise the biomass to the reaction temperature.

End of Solution

Q.18 A water sample is analysed for coliform organisms by the multiple-tube fermentation method. The results of confirmed test are as follows:

Sample Size (m*l*)	Number of positive result out of 5 tubes	Number of negative results out of 5 tubes
0.01	5	0
0.001	3	2
0.001	1	4

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

MPN Index for various Combination of Positive Results when Five Tubes used per dilution of 10.0 m*l*, 1.0 m*l* and 0.1 m*l*

Combination of positive tubes	MPN index per 100 m*l*
0-2-4	11
1-3-5	19
4-2-0	22
5-3-1	110

The MPN of coliform organisms per 100 ml is

(a) 110 (b) 1100
(c) 1100000 (d) 110000

Ans. (d)

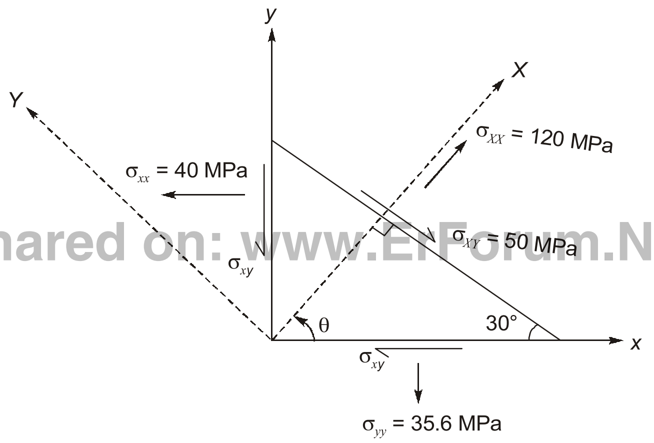
The sample size is 0.01 ml, 0.001 m*l* and 0.0001 m*l* which is 1000 times lesser than the standard of 10 m*l*, 1 m*l* and 0.1 m*l*.

The positive set is 5-3-1 and w.r.t. the positive combination,

MPN/100 m*l* will be 110 × 1000 = 110000

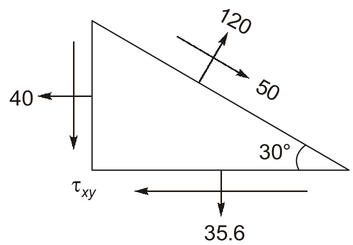
End of Solution

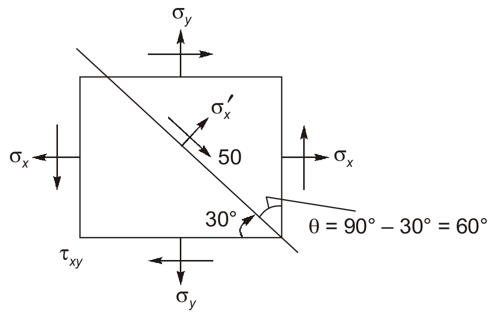
Q.19 The state of stress in a deformable body is shown in the figure. Consider transformation of the stress from the x-y coordinates system to the X-Y coordinates system The angle θ, locating the X-axis, is assumed to be positive when measured from the x-axis is counter-clockwise direction.



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

Ans. (96.2)





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

Here $\theta = 60°$

$$\sigma_x = 40 \text{ MPa},\ \sigma_y = 35.6,\ \sigma_x' = 120,\ \tau_{x'y'} = -50$$

Substituting the values in above equation, we get

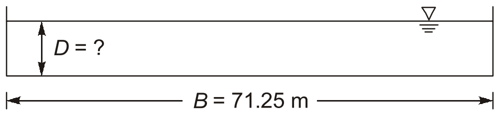
$$\tau_{xy} = 96.186 \text{ MPa}$$

End of Solution

Q.20 An unlined canal under regime conditions along with a silt factor of 1 has a width of flow 71.25 m. 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 ________.

Ans. (2.94)

$$f = 1$$



$R = D$ (for wide rectangular channel)

$$Af^2 = 140\left(\frac{2}{5}fR\right)^{5/2}$$

$$(BD)\ f^2 = 140\left(\frac{2}{5}f \times D\right)^{5/2}$$

$$(71.25 \times D) \times 1 = 140\left(\frac{2}{5} \times 1 \times D\right)^{5/2}$$

$$D \times 0.5089 = \left(\frac{2}{5}\right)^{5/2} \times (D)^{5/2}$$

$$D^{3/2} = 5.029$$

or $$D = 2.94 \text{ m}$$

End of Solution

Q.21 Which one of the following is correct?

(a) The most important type of species involved in the degradation of organic mater in the case of activated sludge process based wastewater treatment is *chemoheterotrophs*.

(b) For an effluent sample of a sewage treatment plant, the ratio $BOD_{5\text{-day-}20°C}$ upon ultimate BOD is more than 1.

(c) The partially treated effluent from a food processing industry, containing high concentration of biodegradable organism is being discharge 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.

(d) A young lake characterised by low nutrient content and low plant productivity is called *eutrophic* lake.

Ans. (a)

Chemoheterotrophs are the organisms which generate energy with the help of chemical reactions by consuming organic matter during their metabolism. These are the species which help to degrade the organic matter in ASP.

End of Solution

Q.22 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 two decimal places) that at least 2 vehicles will arrive in any given 1-minute interval is _______

Ans. (0.59)

$$\lambda = 2 \text{ mean} = 2 \text{ veh/min}$$

Probability that at least 2 vehicle will arrive in any given 1 minute

$$= P(x \geq 2) = 1 - [P(x = 0) + P(x = 1)]$$

$$\because \quad P(x = 0) + P(x = 1) = \frac{e^{-2}(2)^0}{0!} + \frac{e^{-2}(2)^1}{1!} = 0.406$$

Hence required probability $= 1 - 0.406$

$= 0.593 \simeq 0.59$

End of Solution

Q.23 On a road, the speed-density relationship of a traffic stream is given by u = 70 – 0.7 k (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) 1.0 s (b) 2.1 s

(c) 0.5 s (d) 1.6 s

Ans. (b)

$$u = 70 - 0.07k$$

$$u = 70\left[1 - \frac{k}{\frac{70}{0.7}}\right]$$

$$V_f = 70 \text{ kmph}$$

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

$$q_{max} = \frac{1}{4}V_f k_j = \left(\frac{1}{4}\times 70\times 100\right) = 1750 \text{ veh/hr}$$

$$q_{max} = \frac{3600}{h_i}$$

$$1750 = \frac{300}{h_i}$$

Average time headway

$$h_i = \frac{3600}{1750} = 2.057 = 2.1 \text{ sec}$$

End of Solution

Q.24 Which of the following is NOT a correct statement?

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

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

(c) Planimeter is used for measuring 'area'.

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

Ans. (d)

First reading from level station is called BS.

End of Solution

Q.25 A highway designed for 80 km/h speed has a horizontal curve section with radius 250 m. If the design lateral friction is assumed to develop fully, the required superelevation is

(a) 0.02 (b) 0.05

(c) 0.07 (d) 0.09

Ans. (b)

$$V = 80 \text{ kmph}, \; R = 250 \text{ m}$$

$$e + f = \frac{V^2}{127R}$$

$$e + 0.15 = \frac{80^2}{127\times 250}$$

$$e = 0.051$$

End of Solution

Q.26 The cohesion (c), angle of internal friction (ϕ) and unit weight (γ) of a soil are 15 kPa. 20° and 17.5 kN/m^3, respectively. The maximum depth of unsupported excavation in the soil (in m, round off to two decimal places) is _______

Ans. (4.9)

Maximum depth of unsupported excavation,

$$H = \frac{4C}{\gamma_t \sqrt{k_a}}$$

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

$$\Rightarrow \quad H = \frac{4 \times 15}{17.5\sqrt{0.49}} = 4.9 \text{ m}$$

End of Solution

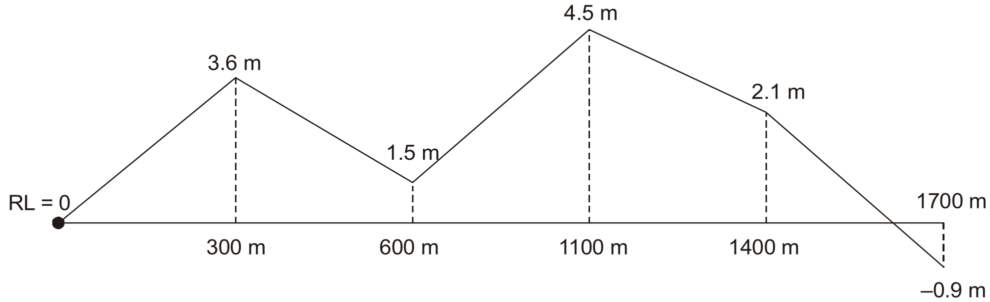
Q.27 The longitudinal section of a runway provides the following data:

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 ________

Ans. (0.32)

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



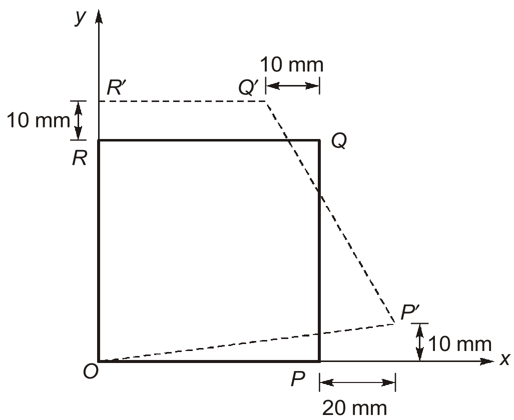
$$\text{Effective gradient} = \left[\frac{\text{Maximum difference in reduced level}}{\text{Total runway length}}\right]$$

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

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

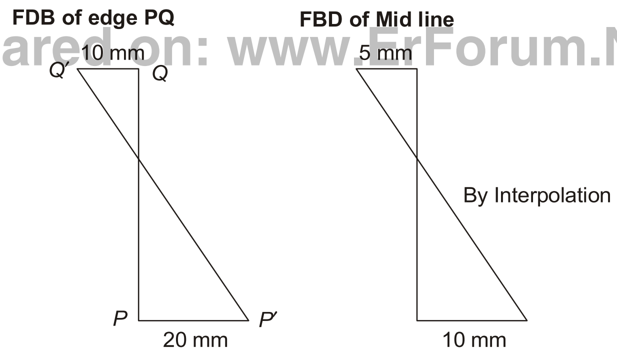
End of Solution

Q.28 A square plate O-P-Q-R of a linear elastic material with sides 1.0 m 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 point (0.5 m, 0.5 m) in the plate O-P-Q-R (in mm, round off to one decimal place) is ____

Ans. (2.5)



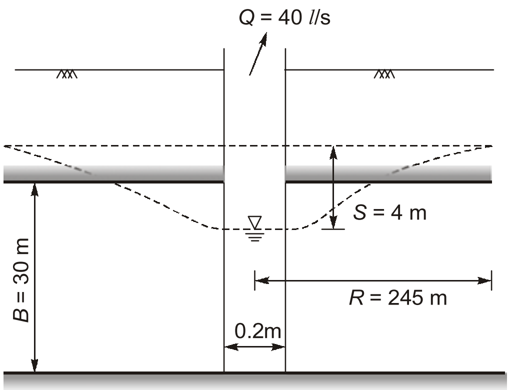
So horizontal displacement of the point (0.5 m, 0.5 m)

$$= -2.5 \text{ mm} + 5 \text{ mm} = 2.5 \text{ mm}$$

End of Solution

Q.29 A tube-well of 20 cm of diameter fully penetrate a horizontal, homogeneous and isotropic confined aquifer of infinite horizontal extent. The aquifer is of 30 m uniform thickness. A steady pumping at the rate of 40 litres/s from the well for a long time results in a steady drawdown of 4 m 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 245 m. The hydraulic conductivity of the aquifer (in m/day, round off to integer) is ________.

Ans. (36)



$$40 \times 10^{-3} \text{ m}^3/\text{s} = \frac{2\pi k \times 30 \text{ m} \times 4 \text{ m}}{\ln\left(\frac{245}{0.1}\right)}$$

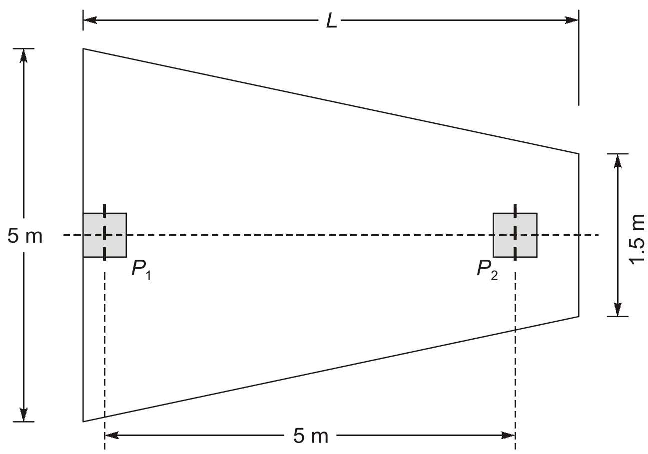
$$k = 4.14 \times 10^{-4} \text{ m/s}$$

or, $k = 35.77$ m/d

≈ 36 m/d (round off to nearest integer)

End of Solution

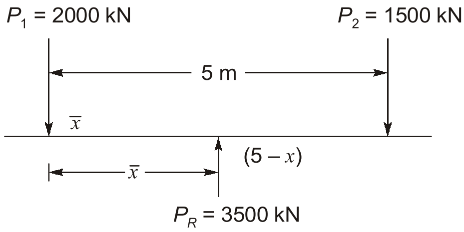
Q.30 A combined trapezoidal footing of length L supports two identical square columns (P_1 and P_2) of size 0.5 m × 0.5 m, as shown in the figure. The columns P_1 and P_2 carry loads of 2000 kN and 1500 kN, respectively.



If the stress beneath the footing is uniform, the length of the combined footing L (in m, round off to two decimal places) is ______.

Ans. (5.83)

C.G. of load from P_1

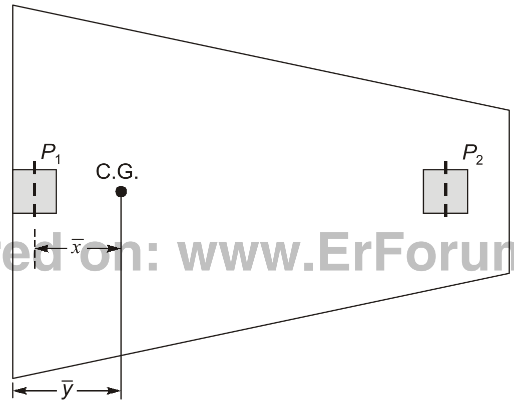


$$P_R\bar{x} = P_1 \times 0 + P_2 \times 5$$

$$\bar{x} = \frac{1500 \times 5}{3500} = 2.143 \text{ m}$$

Distance of C.G. of footing from face of P_1

$$\bar{y} = \bar{x} + 0.25 = 2.393 \text{ m}$$



C.G. of footing $\bar{y} = \left(\frac{B_1 + 2B_2}{B_1 + B_2}\right) \times \frac{L}{3}$

$$2.393 = \left(\frac{5 + 2 \times 1.5}{5 + 1.5}\right) \times \frac{L}{3}$$

$$L = 5.833 \text{ m say } 5.83 \text{ m}$$

End of Solution

Q.31 The shape of the cumulative distribution function of Gaussian distribution is

(a) Bell-shaped
(b) S-shaped
(c) Horizontal line
(d) Straight line at 45 degree angle

Ans. (b)

End of Solution

Q.32 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 _______.

Ans. (20.67)

$d = 0.5$ unit

$y_1 = 5$
$y_2 = 7.25$
$y_3 = 10$
$y_4 = 13.25$
$y_5 = 17$

$$A = \frac{d}{3}\left[(y_1 + y_5) + 4(y_2 + y_4) + 2y_3\right]$$

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

$$= 20.67 \text{ unit}^2$$

End of Solution

Q.33 A secondary clarifier handles a total flow of 9600 m^3/d from the aeration tank of a conventional activated-sludge treatment system. The concentration of solids in the flow from the aeration tank is 3000 mg/l. The clarifier is required to thicken the solids to 12000 mg/l, 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 _______.

Ans. (375)

$$Q = 9600 \text{ m}^3/\text{d}$$

$$X = 3000 \text{ mg}/l$$

$$X_u = 12000 \text{ mg}/l$$

Solids loading rate or solid flux = 3.2 kg/m^2-h

Surface area, $$A = \frac{\text{Total quantity of solids entering}}{\text{Solid flux}}$$

$$A = \frac{9600 \text{ m}^3/\text{d} \times 3000 \text{ mg}/l}{3.2\times 10^6 \text{mg/m}^2\text{-h}}$$

$$= \frac{9600\times 10^3\ l/d \times 3000 \text{ mg}/l}{3.2\times 10^6 \text{ mg/m}^2\text{-h}\times 24\ h/d}$$

$$= 375 \text{ m}^2$$

End of Solution

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Q.34 In an Oedometer apparatus, a specimen of fully saturated clay has been consolidated under a vertical pressure of 50 kN/m^3 and is presently at equilibrium. The effective stress and pore water pressure immediately on increasing the vertical stress to 150 kN/m^2, respectively are

(a) 50 kN/m^2 and 100 kN/m^2
(b) 100 kN/m^2 and 50 kN/m^2
(c) 150 kN/m^2 and 0
(d) 0 and 150 kN/m^2

Ans. (a)

Stress is increased suddenly, hence entire change will be taken by water

$\Delta\bar{\sigma} = \Delta U = 100 \text{ kPa}$.

There will be no change in effective stress

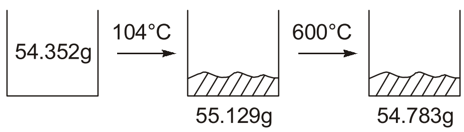
$\therefore \quad \bar{\sigma} = 50 \text{ kPa}$

End of Solution

Q.35 A 50 ml sample of industrial wastewater is taken into a silica crucible. The empty weight of the crucible is 54.352 g. The crucible with the sample is dried in a hot air oven at 104°C till a constant weight of 55.129 g. Thereafter, the crucible with the dried sample is fired at 600°C for 1 h in a muffle furnace, and the weight of the crucible along with residue is determined as 54.783 g. The concentration of total volatile solids is ______.

(a) 15540 mg/l
(b) 8620 mg/l
(c) 6920 mg/l
(d) 1700 mg/l

Ans. (c)

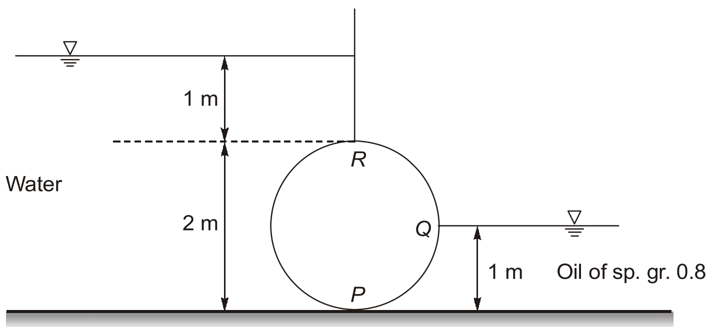


Volatile solids weight = 55.129 – 54.783 = 0.346 gm (in 50 ml)

So, in one litre = $\dfrac{346}{0.05} = 6920$ mg/litre

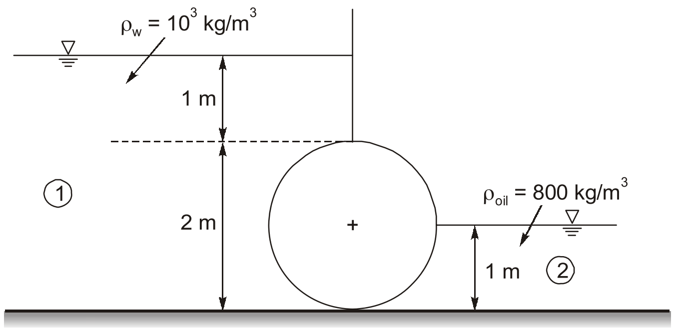
End of Solution

Q.36 A cylinder (2.0 m diameter, 3.0 m long and 25 kN 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 (round off to two decimal places) is ________

Ans. (0.37)



Net horizontal force (F_H) due to liquids

$$F_H = F_{H1} - F_{H2}$$

$$= \rho_w g \bar{h}_1 A_{V_1} - \rho_{oil} g \bar{h}_2 A_{V_2}$$

$$= (10^3)(9.81)\left(1+\frac{2}{2}\right)(2\times3) - (800)(9.81)\left(\frac{1}{2}\right)(1\times3)$$

$$F_H = 105.948 \text{ kN } (\rightarrow)$$

Net vertical force (F_V) due to liquids

$$F_V = F_{V_1} + F_{V_2} - W$$

$$= \rho_w g \forall_1 + \rho_{oil} g \forall_2 - 25\times10^3$$

$$= (10^3)(9.81)\left(\frac{\pi(1)^2\times3}{2}\right) + (800)(9.81)\left(\frac{\pi}{4}(1)^2\times3\right) - 25\times10^3$$

$$= 39.719 \text{ kN } (\uparrow)$$

$$\frac{F_V}{F_H} = \frac{39.719}{105.948} = 0.374$$

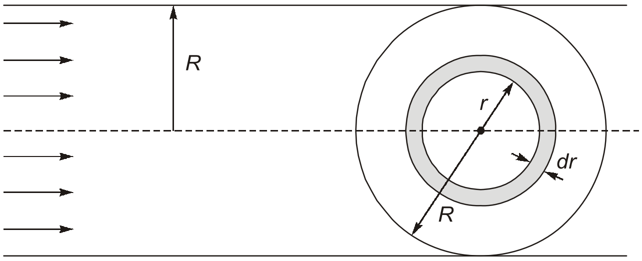
End of Solution

Q.37 A fluid flowing steadily in a circular pipe of radius R has a velocity that is everywhere parallel to the axis (centreline) on 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) $\left(\frac{5}{6}\right)U$ (b) $\frac{U}{4}$

(c) $\frac{U}{2}$ (d) $\frac{U}{3}$

Ans. (c)



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

$$\dot{m} = \int_0^R \rho(2\pi r dr)u = 2\pi\rho U\int_0^R\left(1-\frac{r^2}{R^2}\right)rdr$$

$$\rho\left(\pi R^2\right)\bar{u} = 2\pi\rho U\left[\frac{R^2}{2}-\frac{R^4}{R^2\times 4}\right]$$

$$\bar{u} = \frac{U}{2}$$

$\bar{u}$ = Mean velocity

U = Max velocity

End of Solution

Q.38 A signalized intersection operates in two phases. The lost time is 3 seconds per phase. 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, round off to one decimal place) is ________.

Ans. (60.9)

$$n = 2,\ L = 3\times 2 = 6 \text{ sec}$$

$$y_1 = 0.37,\ y_2 = 0.40$$

$$Y = y_1 + y_2$$

$$= 0.37 + 0.40$$

$$= 0.77$$

$$C_0 = \left(\frac{1.5L+5}{1-Y}\right) = \frac{1.5\times 6+5}{1-0.77}$$

$$= 60.87 \text{ sec} \simeq 60.9 \text{ sec}$$

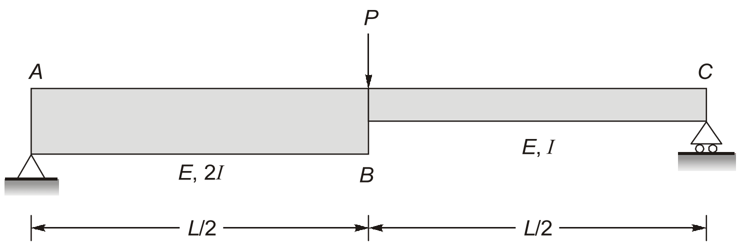
End of Solution

Q.39 The shape of the most commonly designed highway vertical curve is
(a) circular (multiple radii) (b) circular (single radius)
(c) parabolic (d) spiral

Ans. (c)

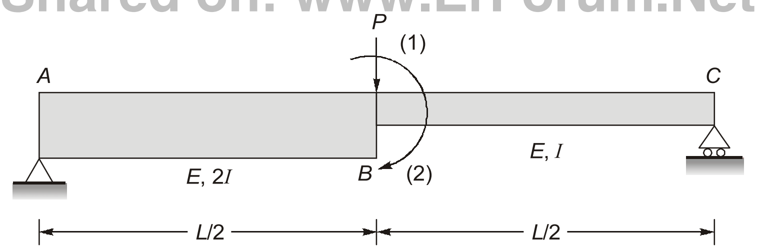
End of Solution

Q.40 Employ stiffness matrix approach for the simply supported beam as shown in the figure to calculate unknown displacements/rotations. Take length, $L = 8$ m; modulus of elasticity, $E = 3 \times 10^4$ N/mm^2; moment of inertia, $I = 225 \times 10^6$ mm^4.



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

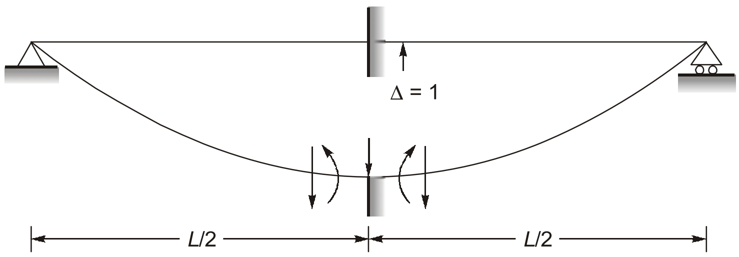
Ans. (119)



By stiffness matrix method

Step-1: Generation of stiffness matrix

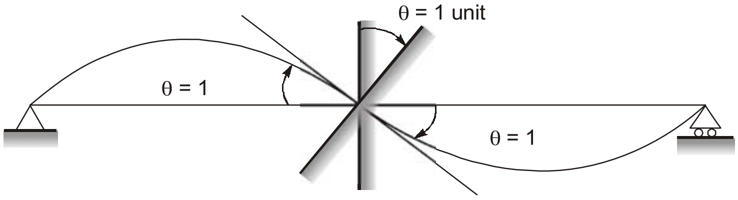
Column-1



$$k_{11} = \frac{3E(2I)}{(L/2)^3} + \frac{3E(I)}{(L/2)^3} = \frac{72EI}{L^3}$$

$$k_{21} = -\frac{3E(2I)}{(L/2)^2} + \frac{3E(I)}{(L/2)^2} = -\frac{12EI}{L^2}$$

Column-2



$$k_{22} = \frac{3E(2I)}{(L/2)} + \frac{3E(I)}{(L/2)} = 18\frac{EI}{L}$$

$$\text{Stiffness matrix } [k] = \begin{bmatrix} 72\frac{EI}{L^3} & -\frac{12EI}{L^2} \\ -\frac{12EI}{L^2} & \frac{18EI}{L} \end{bmatrix}$$

Step-2: Calculation of unknown Nodal displacements (Δ_B, θ_B)

Using $[P] = [k]\,[\Delta]$

$$\Rightarrow \quad \begin{bmatrix} P \\ O \end{bmatrix} = \begin{bmatrix} \frac{72EI}{L^2} & -\frac{12EI}{L^2} \\ -\frac{12EI}{L^2} & \frac{18EI}{L} \end{bmatrix} \begin{bmatrix} \Delta_B \\ \theta_B \end{bmatrix}$$

On solving

$$\Delta_B = \frac{PL^3}{64EI}(\downarrow)$$

$$\theta_B = \frac{PL^2}{96EI}(\text{CW})$$

$$\therefore \quad \Delta_B = \frac{(100\times10^3)\times(8000)^3}{64\times3\times10^4\times225\times10^6}$$

$$= 118.519 \text{ mm} \simeq 119 \text{ mm}$$

End of Solution

Q.41 Consider the limit:

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

The limit (correct up to one decimal place) is _______

Ans. (0.5)

$$\lim_{x\to1}\left[\frac{1}{\ln x}-\frac{1}{x-1}\right] = \lim_{x\to1}\left[\frac{(x-1)-\ln x}{\ln x(x-1)}\right]\left(\frac{0}{0}\text{ form}\right)$$

So using L-Hospital's rule twices

$$= \lim_{x\to1}\left[\frac{1-\frac{1}{x}}{\log x+(x-1)\left(\frac{1}{x}\right)}\right] = \lim_{x\to1}\left(\frac{1}{2+\log x}\right) = 0.5$$

End of Solution

Q.42 If $P=\begin{bmatrix}1 & 2\\ 3 & 4\end{bmatrix}$ and $Q=\begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix}$ then Q^TP^T is

(a) $\begin{bmatrix}1 & 2\\ 3 & 4\end{bmatrix}$
(b) $\begin{bmatrix}1 & 3\\ 2 & 4\end{bmatrix}$
(c) $\begin{bmatrix}2 & 4\\ 1 & 3\end{bmatrix}$
(d) $\begin{bmatrix}2 & 1\\ 4 & 3\end{bmatrix}$

Ans. (c)

$$PQ = \begin{bmatrix}1 & 3\\ 2 & 4\end{bmatrix}\begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix} = \begin{bmatrix}2 & 4\\ 1 & 3\end{bmatrix}$$

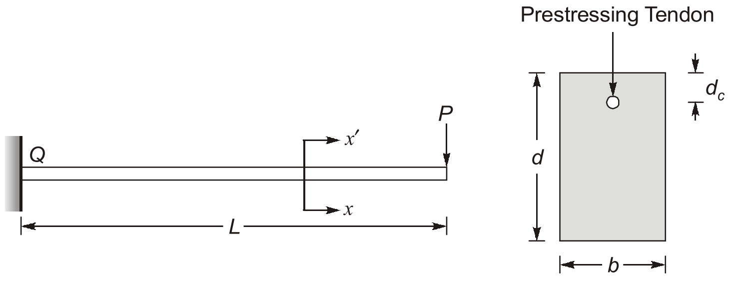
$$(PQ)^T = \begin{bmatrix}2 & 4\\ 1 & 3\end{bmatrix}$$

Now using Reversal law

$$Q^TP^T = (PQ)T = \begin{bmatrix}2 & 4\\ 1 & 3\end{bmatrix}$$

End of Solution

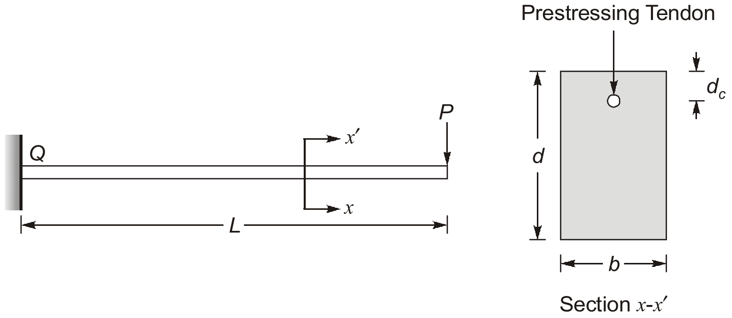
Q.43 A prismatic cantilever prestressed concrete beam of span length, L = 1.5 m has one straight tendon placed in the cross-section as shown in the following figure (not to scale). The total prestressed force of 50 kN in the tendon is applied at d_c = 50 mm from the top in the cross-section of width, b = 200 mm and depth, d = 300 mm.



Section x-x'

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

Ans. (0)



$$e = \frac{D}{2} - 50 = \frac{300}{2} - 50 = 100 \text{ mm}$$

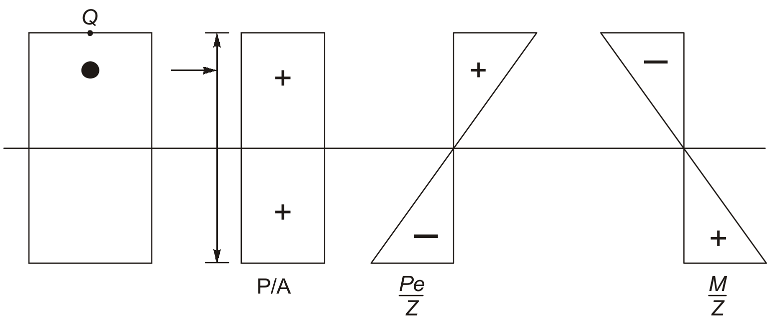
$$DL = 0.2 \times 0.3 \times 1.0 \times 25 = 1.50 \text{ kN/m}$$

$$P = 50 \text{ kN} = 50000 \text{ N}$$

$$W = 5 \text{ kN}$$

$$\text{Maximum BM} = \frac{wL^2}{2} + WL$$

$$= \frac{1.5 \times 1.5^2}{2} + 5 \times 1.50 = 9.1875 \text{ kNm}$$



$$\frac{P}{A} = \frac{50000}{200 \times 300} = 0.833 \text{ N/mm}^2$$

$$\frac{Pe}{Z} = \frac{50000 \times 100}{200 \times \frac{300^2}{6}} = 1.67 \text{ N/mm}^2$$

$$\frac{M}{Z} = \frac{9.1875 \times 10^6}{200 \times \frac{300^2}{6}} = 3.0625 \text{ N/mm}^2$$

Stress at Q,

$$\text{Stress at } Q = \frac{P}{A} + \frac{Pe}{Z} - \frac{M}{Z}$$
$$= 0.833 + 1.67 - 3.0625$$
$$= -0.56 \text{ N/mm}^2 \text{ (Tensile)}$$

End of Solution

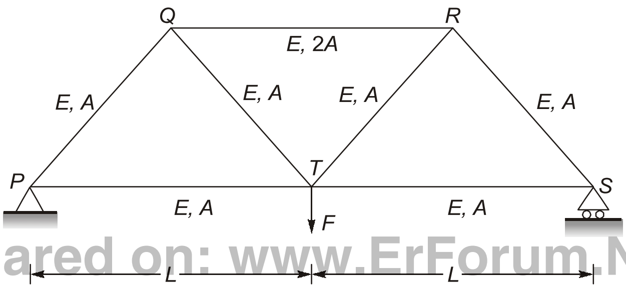
Q.44 Gypsum is typically added in cement to

(a) increase workability
(b) decrease heat of hydration
(c) prevent quick setting
(d) enhance hardening

Ans. (c)

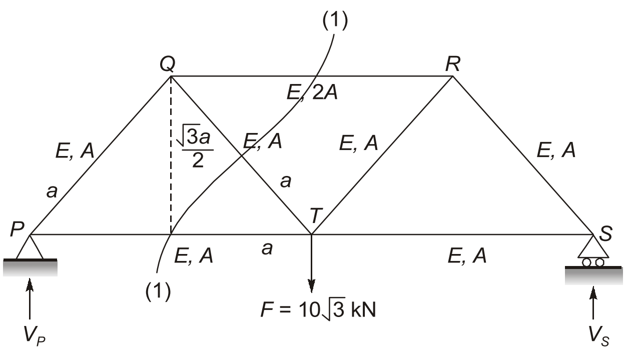
End of Solution

Q.45 Refer the truss as shown in the figure (not to scale)



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

Ans. (500)



$$V_P = V_S = 5\sqrt{3} \text{ kN}$$

Considering equilibrium of LHS of section (1)-(1)

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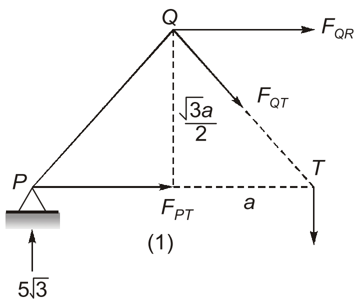


Taking moment about 'T'

$$\Sigma M_T (\circlearrowright) = 0$$

$$\left(5\sqrt{3} \times a\right) + F_{QR}\left(\frac{\sqrt{3}a}{2}\right) = 0$$

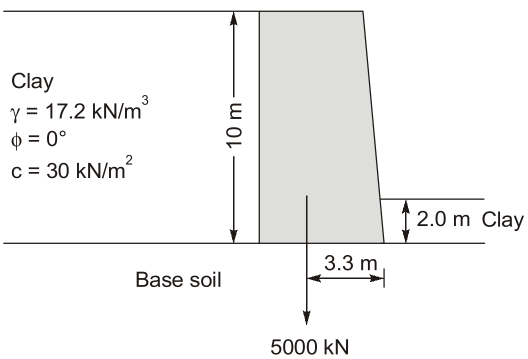
$\Rightarrow$ $F_{QR} = -10$ kN or 10 kN (C)

Compressive stress in member QR (σ_C)

$$\sigma_C = \frac{F_{QR}}{2A} = \frac{10 \text{ kN}}{2 \times \left(10^4 \times 10^{-6}\right)\text{m}^2} = 500 \text{ kN/m}^2$$

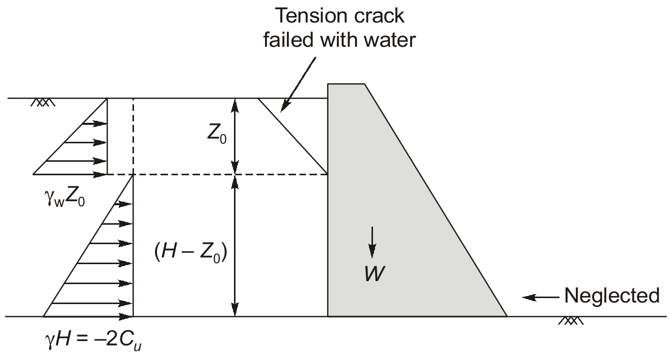
End of Solution

Q.46 A retaining wall of height 10 m with clay backfill is shown in the figure (not to scale). Weight of the retaining wall is 5000 kN per m acting at 3.3 from the toe 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. Use Rankine's earth pressure theory. Take unit weight of water. γ_w = 9.81 kN/m^3.



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

Ans. (4.289)



$$k_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 0}{1+\sin 0} = 1$$

Depth of tension crack is 'Z_0'

$$\Rightarrow \qquad Z_0 = \frac{2C_u}{\gamma\sqrt{k_a}} = \frac{2\times 30}{17.2\sqrt{1}} = 3.488 \text{ m}$$

Total active thrust due to soil and water

$$= \frac{1}{2}(\gamma H - 2C_u)\times(H - Z_0)\times 1 + \frac{1}{2}\gamma_w Z_0 \times Z_0 \times 1$$

$$= \frac{1}{2}(17.2\times 10 - 2\times 30)\times(10 - 3.488)\times 1 + \frac{1}{2}\times 9.81\times 3.488\times 3.488 \text{ kNm}$$

$$= 424.347 \text{ kN/m} \qquad \text{(acting horizontally)}$$

Frictional resistance

$$= N\tan\delta = W\tan\delta$$

$$= 5000 \times \tan 20°$$

$$= 1819.851$$

$$\text{FOS} = \frac{\text{Resisting force}}{\text{Actuating force}} = \frac{1819.581}{424.347} = 4.289$$

End of Solution

Q.47 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.

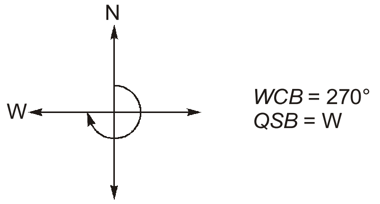
(b) Back bearing of a line is equal to Fore bearing ± 180°.

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

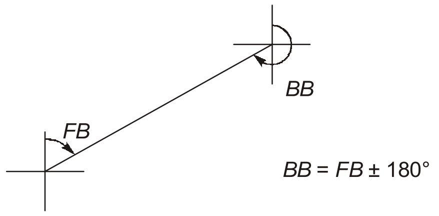
(d) In the case of fixed hair stadia tacheometry, the staff intercept will be larger, when the staff is held nearer to the observation point.

Ans. (a, b, c)

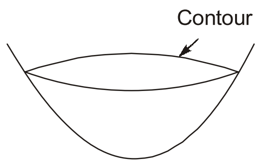
(a)



(b)



(c)



End of Solution

Q.48 Contractor X is developing his bidding strategy against Contractor Y. The ratio of Y's bid price to X's cost for the 30 previous bids in which Contractor X has competed 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 behaviour of the Contractor Y, the probability of winning against Contractor Y at a mark up of 8% for the next project is

(a) 0%
(b) more than 50% but less than 100%
(c) more than 0% but less than 50%
(d) 100%

Ans. (c)

End of Solution

Q.49 The value of $\int_0^1 e^x dx$ using the trapezoidal rule with four equal subintervals is

(a) 1.718
(b) 2.192
(c) 1.727
(d) 2.718

Ans. (c)

Given, $n = 4,\ a = 0,\ b = 1,$

then $h = \dfrac{b-a}{n} = 0.25$

$\therefore$ $y = f(n) = e^x$

So

$x =$	0	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	1
$y =$	1	$e^{1/4}$	$e^{1/2}$	$e^{3/4}$	e^1
	y_0	y_1	y_2	y_3	y_4

Using T-rule

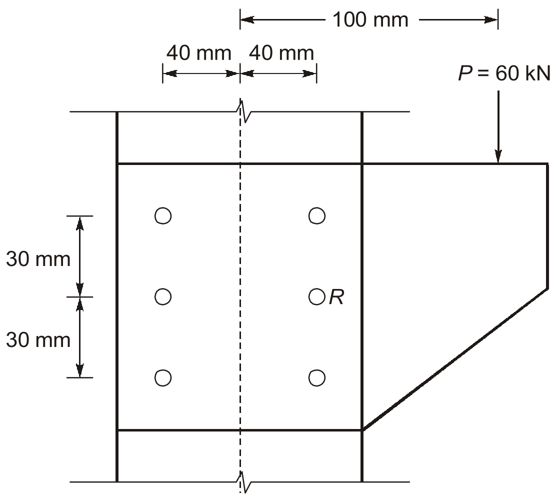
$$I = \int_0^1 e^n dx = \frac{h}{2}\left[y_0 + y_4 + 2(y_1 + y_2 + y_3)\right]$$

$$= \frac{0.25}{2}\left[1 + e + 2\left(e^{1/4} + e^{1/2} + e^{3/4}\right)\right]$$

$$= 1.727$$

End of Solution

Q.50 A column is subjected to total load (P) of 60 kN supported through a bracket connection, as shown in the figure (not to scale).



The resultant force in bolt R (in kN, round off to one decimal place) is ________

Ans. (28.2)

$$F_1 = \frac{P}{n} = \frac{60}{6} = 10 \text{ kN}$$

$$F_2 = \frac{P \cdot e}{\Sigma r_i^2} \times r_R = \frac{60 \times 100 \text{ mm}}{4 \times 50^2 + 2 \times 40^2} \times 40$$

$$F_2 = \frac{60 \times 100 \times 40}{10000 + 3200} = \frac{60 \times 100 \times 40}{13200} = \frac{200}{11} \text{ kN}$$

$$F_R = F_1 + F_2$$

$$= 10 + \frac{200}{11} = \frac{310}{11} = 28.2 \text{ kN}$$

End of Solution

Q.51 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) 21.12 kN/m^3
(b) 20.12 kN/m^3
(c) 18.50 kN/m^3
(d) 19.03 kN/m^3

Ans. (d)

$$w = 0.25, \; \gamma_t = 18.5 \text{ kN/m}^3$$

$$G_s = 2.65, \; \gamma_w = 9.81$$

$$\gamma_t = \frac{G_s \gamma_w (1 + w)}{1 + e}$$

$$\Rightarrow \quad e = \frac{2.65 \times 9.81 \times 1.25}{18.5} - 1$$

$$\Rightarrow \quad e = 0.756$$

At full saturation, $S = 1$

$$\Rightarrow \quad \gamma_{sat} = \frac{(G_s + e)\gamma_w}{1 + e}$$

$$\gamma_{sat} = \frac{(2.65 + 0.756) \times 9.81}{1.756}$$

$$= 19.03 \text{ kN/m}^3$$

End of Solution

Q.52 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) $e^{-x} + (3e - 1)xe^{-x}$
(b) $e^{-x} + \left[3e\sin\left(\frac{\pi x}{2}\right) - 1\right]xe^{-x}$
(c) $e^{-x} - (3e - 1)xe^{-x}$
(d) $e^{-x} - \left[3e\sin\left(\frac{\pi x}{2}\right) - 1\right]xe^{-x}$

Ans. (a)

Given $(D^2 + 2D + 1)\, y = 0$

$$y(0) = 1$$
$$y(1) = 3$$

Auxiliary equation in $m^2 + 2m + 1 = 0$

$\Rightarrow$ $m = -1, -1$

$$CF = (C_1 + C_2 x)e^{-x}$$

And $PI = 0$

C_1 solution is $uy = CF + PI$

$$y = (C_1 + C_2 x)e^{-x} \quad \text{...(i)}$$

Using y(0) = 1, $C_1 = 1$

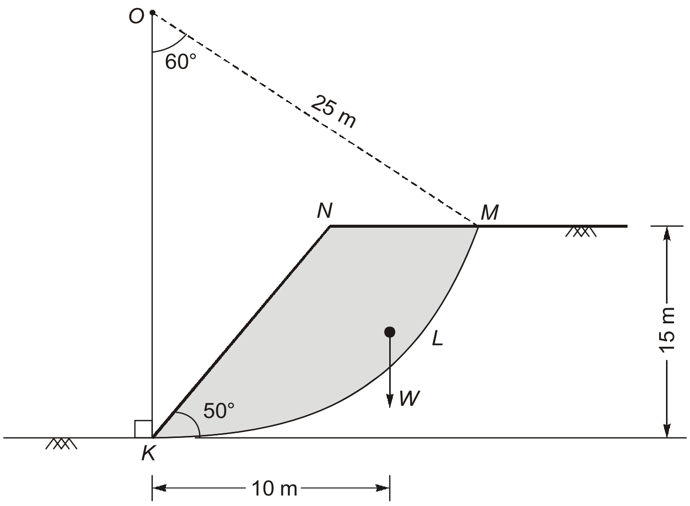
Using y(1) = 3, $C_2 = 3e - 1$

Hence by eq. (i), $y = [1 + (3e - 1)x]\, e^{-x}$

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

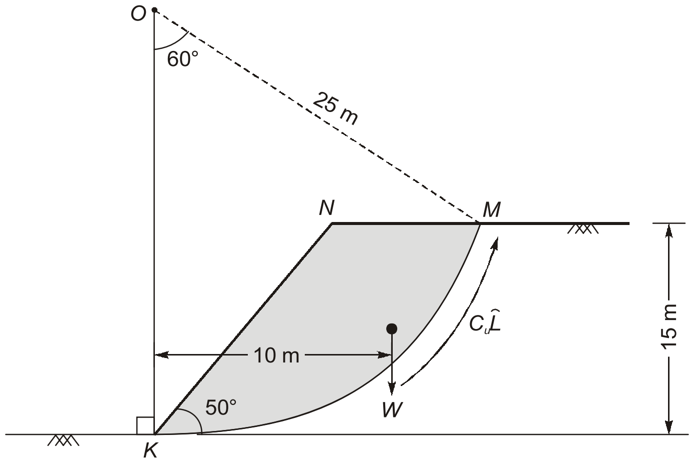
End of Solution

Q.53 An unsupported slope of height 15 m 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 75 kPa. A trial slip circle KLM with a radius 25 m, passes through the crest and toe of the slope and it subtends an angle 60° at its centre O. The weight of the active soil mass (W, bounded by KLMN) is 2500 kN/m, which is acting at a horizontal distance of 10 m from 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 (round off to two decimal places) is ____________

Ans. (1.96)



$$\text{FOS} = \frac{\text{Resisting moment}}{\text{Actuating moment}}$$

$$\text{FOS} = \frac{C_u l R}{w\bar{x}}$$

l = Length of ac KLM

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

$$\Rightarrow \quad \text{FOS} = \frac{75 \times 2\pi \times 25 \times \frac{60}{360} \times 25}{2500 \times 10}$$

$$\Rightarrow \quad \text{FOS} = 1.96$$

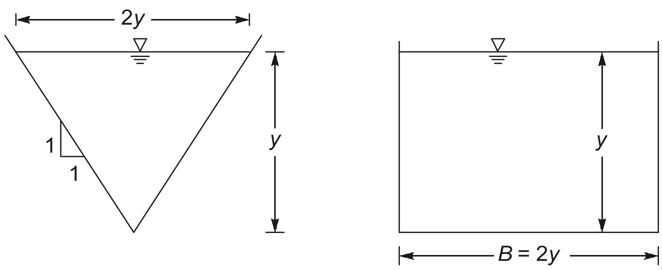
End of Solution

Q.54 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) 2
(b) $\sqrt{2}$
(c) 1
(d) $\frac{1}{\sqrt{2}}$

Ans. (d)

Efficient channel section



$$A = y^2 \qquad A = 2y^2$$

$$P = 2\sqrt{2}\,y \qquad P = 4y$$

$$R_I = \frac{y}{2\sqrt{2}} \qquad R_{II} = \frac{y}{2}$$

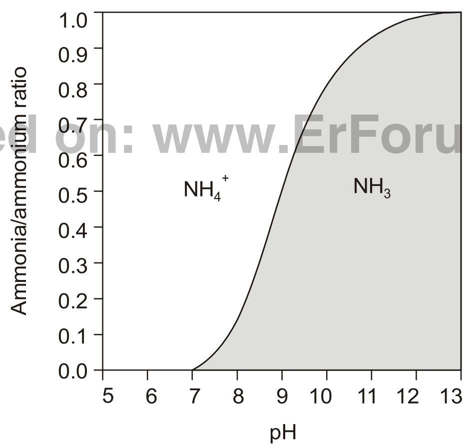
$$\therefore \quad \frac{R_I}{R_{II}} = \frac{1}{\sqrt{2}}$$

End of Solution

Q.55 Ammonia nitrogen is present in a given wastewater sample as the ammonium ion (NH_4^+) and ammonia (NH_3). 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, NH_4^+ 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, NH_4^+ will be predominant.
(d) At pH above 9.25, only NH_4^+ will be present

Ans. (c)



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

End of Solution

■■■■