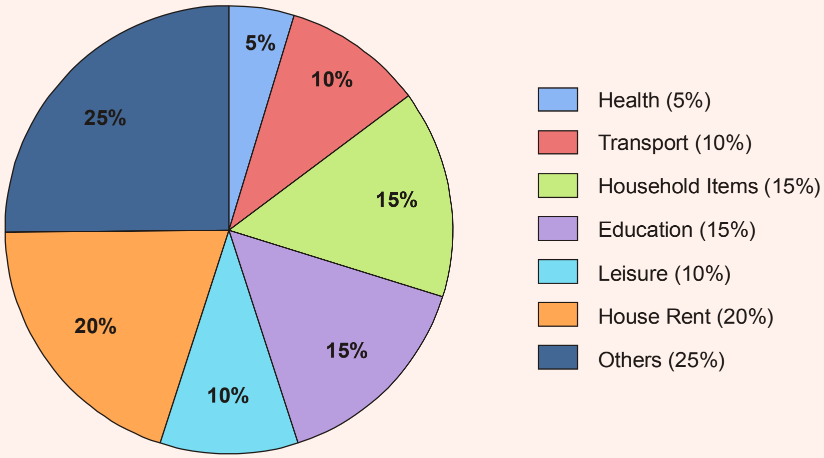
GATE 2020

Civil Engineering

Solved Papers

Q.1 The total expenditure of a family, on different activities in a month, is shown in the pie-chart. the extra money spent on education as compared to transport (in percent) is ____.



(a) 33.3 (b) 50

(c) 100 (d) 5

Ans. (b)

Let total monhly earining = Rs. 100

$$\text{Monthly spent on education} = \frac{15}{100}\times 100 = \text{Rs.}15$$

$$\text{Monthly spent on transport} = \frac{10}{100}\times 10 = \text{Rs. }10$$

% money extra spent on education as compard to transportation

$$= \frac{15-10}{10}\times 100 = 50\%$$

End of Solution

Q.2 The unit's place in 26591749^{110016} is ________.

(a) 6 (b) 1

(c) 3 (d) 9

Ans. (b)

$$\simeq 26591749^{(110016)}$$

$$\simeq \text{Unit place of } 9^{\text{even}} = 1$$

$\therefore$ Cyclicity of 9 is (9, 1) (9, 1), (9, 1)

So answer will be 1.

End of Solution

Q.3 The sum of two positive numebrs is 100. After subtracting 5 from each number, the product of the resulting numbers is 0. One of the original numbers is ______.

(a) 95 (b) 90

(c) 85 (d) 80

Ans. (a)

If the product of two positive numbers should be zero, one of the number must be zero. After subtracting 5 if a positive number should become zero, that number should be 5. If one number is 5 and the sum is 100 then the other number must be 95.

Let the two positive numbers be x and y.

$$\therefore \quad x + y = 100 \quad \text{...(i)}$$

$$(x - 5)(y - 5) = 0 \quad \text{...(ii)}$$

$\Rightarrow x = 5$ or $y = 5$

If $x = 5$ then $y = 95$

If $y = 5$ then $x = 95$

$\therefore$ One of the number is 95 since 5 is not in any of the options.

End of Solution

Q.4 Five friends P, Q, R, S and T went camping. At night, they had to sleep in a row inside the tent. P, Q and T refused to sleep next to R since he snored loudly. P and S wanted to avoid Q as he usually hugged people in sleep.

Assuming everyone was satisfied with the sleeping arrangements, what is the order in which they slept?

(a) RSPTQ
(b) QRSPT
(c) QTSPR
(d) SPRTQ

Ans. (a)

Option (a) satisfies the given conditions in the paragraph.

End of Solution

Q.5 The american psychologist Howard Gardner expounds that human intelligence can be sub-categorised into multiple kinds, in such a vway that individuals differ with respect to their relative competence in each kind. Based on this theory, modern educationists insist on prescribing multi-dimensional curriculum and evluation parameters that enable development and assessment of multiple intelligences.

Which of the following statements can be inferred from the given text?

(a) Modern educationists want to develop and asses the theory of multiple intelligences.
(b) Modern educationists insist that the teaching curriculum and evaluation needs to be multi-dimensional.
(c) Howard Gardner wants to develop and assess the theory of multiple intelligences.
(d) Howard Gardner insits that the teaching curriculum and evaluation needs to be multi-dimensional.

Ans. (b)

End of Solution

Q.6 Insert seven numbers between 2 and 34, such that the resulting sequence including 2 abnd 34 is an arithmetic progression. The sum of these inserted seven numbers is ________.

(a) 124 (b) 120

(c) 126 (d) 130

Ans. (c)

2, a, $(a + d)$, $(a + 2d)$, ... $(a + 6d)$, 34

$\therefore$ Total number of terms of $AP(n) = 9$

Let sum of seven inserted numbers = S

$$\therefore \quad S = \frac{7}{2}[a+(a+6d)] = 7[a+3d]$$

$$T_n = 34$$

Also, $a - 2 = (a + d - a)$

$\Rightarrow$ $a - d = 2$

Similarly $a - 2 = 34 - (a + 6d)$

$\Rightarrow$ $a - 2 = 34 - a - 6d$

$\Rightarrow$ $2a = 36 - 6d = 36 - 6(a - 2)$

$\Rightarrow$ $2a = 36 - 6a + 12$

$\Rightarrow$ $8a = 48$

$\Rightarrow$ $a = 6$

$\therefore$ $d = a - 2 = 6 - 2 = 4$

$\therefore$ $S = 7(a + 3d) = 7(6 + 3 \times 4) = 126$

End of Solution

Q.7 It is a common criticism that most of the academicians live in their _____, so, they are not aware of the real life challenges.

(a) glas palaces (b) big flats

(c) ivory towers (d) homes

Ans. (c)

End of Solution

Q.8 Select the work that fits the analogy:

Fuse : Fusion :: Use : ______

(a) Usage (b) Uses

(c) Usion (d) User

Ans. (a)

End of Solution

Q.9 His number for reading is insatiable. He reads indiscriminately. He is most certainly a/an ________ reader.

(a) all-round (b) voracious

(c) precocious (d) wise

Ans. (b)

End of Solution

Q.10 If 0, 1, 2, ..., 7, 8, 9 are coded as O, P, Q, ..., V, W, X, then 45 will be coded as ________.

(a) ST (b) SS

(c) SU (d) TS

Ans. (a)

$$\begin{array}{cccccccccc} 0, & 1, & 2, & 3, & 4, & 5, & 6, & 7, & 8, & 9 \\ \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\ O & P & Q & R & S & T & U & V & W & X \end{array}$$

$\therefore$ 45 is coded as 'ST'.

End of Solution

■■■■

Q.1 The data for an agricultural field for a specific month are given below:

Pan Evaporation = 100 mm

Effective Rainfall = 20 mm (after deducting losses due to runoff and deep percolation)

Crop Coefficient = 0.4

Irrigation Efficiency = 0.5

The amount of irrigation water (in mm) to be applied to the field in that month, is

(a) 80 (b) 40

(c) 20 (d) 0

Ans. (b)

Water required by crop = 100 × 0.4 mm = 40 mm

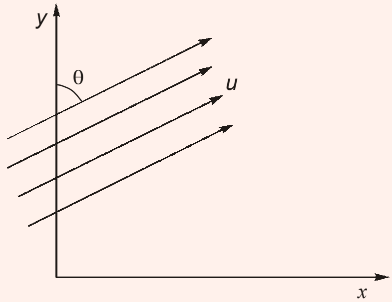
Effective rainfall = 20 mm

Additional water requried = 20 mm

Amount of water required after accounting irrigation efficiency = $\dfrac{20}{0.5}$ = 40 mm

End of Solution

Q.2 Uniform flow with velocity U makes an angle θ with the y-axis, as shown in the figure



The velocity potential (ϕ), is

(a) ±U (x sinθ − y cosθ) (b) ±U (y sinθ + x cosθ)

(c) ±U (y sinθ − x cosθ) (d) ±U (x sinθ + y cosθ)

Ans. (d)

Velocity in x-depth, $u_x = u\sin\theta$

Velocity in y-depth, $u_y = u\cos\theta$

$$-\frac{\partial\phi}{\partial x} = u_x$$

Integrating it $\phi = -u_x x + f(y) + c$

$$= -(u\sin\theta)x + f(y) + c \quad \text{...(i)}$$

$$-\frac{\partial\phi}{\partial y} = u_y$$

Integrating it

$$\phi = -u_y\, y + f(x) + c$$

$$= -(u\cos\theta)y + f(x) + c \quad \text{...(ii)}$$

By equation (i) and (ii),

$$\phi = -u(x\sin\theta + y\cos\theta)$$

If we take $\frac{\partial\phi}{\partial x} = u_x$ and $\frac{\partial\phi}{\partial y} = u_y$

Then $\phi = u(x\sin\theta + y\cos\theta)$

So, $\phi = \pm u(x\sin\theta + y\cos\theta)$

End of Solution

Q.3 An amount of 35.67 mg HCl is added to distilled water and the total solution volume is made to one litre. The atomic weights of H and Cl are 1 and 35.5, respectively. Neglecting the dissociation of water, the pH of the solution, is

(a) 2.50
(b) 2.01
(c) 3.01
(d) 3.50

Ans. (c)

$$HCl \rightarrow H^+ + Cl^-$$

1 mole of HCL gives 1 mole H^+ ions

36.5 gm of HCl gives 1 gm of H^+ ions

$$35.67 \text{ mg} = \frac{1}{36.5} \times 35.67 = 0.977 \text{ mg of } H^+$$

$$= \frac{0.977 \times 10^{-3}}{1} = 9.77 \times 10^{-4} \text{ moles of } H^+$$

$$pH = -\log_{10}[H^+] = -\log_{10}[9.77 \times 10^{-4}]$$

$$= -\log_{10}9.77 + 4\log_{10}10$$

$$= 4 - 0.989 = 3.01$$

End of Solution

Q.4 In a soil investigation work at a site, Standard Penetration Test (SPT) was conducted at every 1.5 m interval up to 30 m depth. At 3 m depth, the observed number of hammer blows for three successive 150 mm penetrations were 8, 6 and 9, respectively. The SPT-N-value at 3 m depth, is

(a) 14
(b) 17
(c) 23
(d) 15

Ans. (d)

No. of blows for each 150 mm penetration 8, 6 and 9.

We will not consider first 150 mm number of blows.

Hence, for last 300 mm, number of blows are 15.

Hence, observed SPT number = 15.

End of Solution

Q.5 In the following partial differential equation, θ is a function of t and z, and D and K are functions of θ

$$D(\theta)\frac{\partial^2\theta}{\partial z^2}+\frac{\partial K(\theta)}{\partial z}-\frac{\partial\theta}{\partial t}=0$$

The above equation is

(a) a second order linear equation

(b) a second order non-linear equation

(c) a second degree non-linear equation

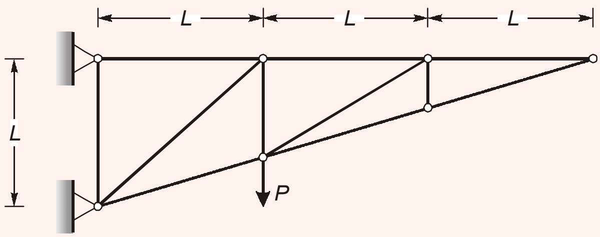
(d) a second degree linear equation

Ans. (b)

$\because$ 1st term of given *D*. Equation contains product of dependent variable with it's derivative, so it is non-linear and also we have 2nd order derivative so it's order is two i.e., 2nd order non linear equation.

End of Solution

Q.6 Consider the planar truss shown in the figure (not drawn to the scale)



Neglecting self-weight of the members, the number of zero-force members in the truss under the action of the load P, is

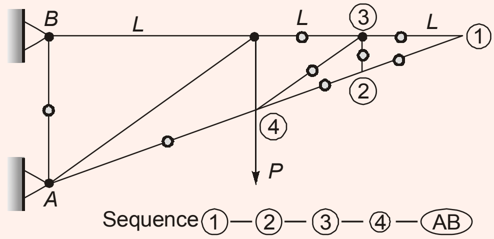
(a) 6

(b) 9

(c) 7

(d) 8

Ans. (d)

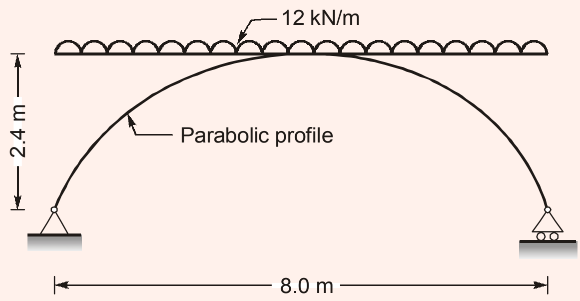


As $\Delta_{AB} = 0$, hence $F_{AB} = 0$

Total number of zero force member = 8

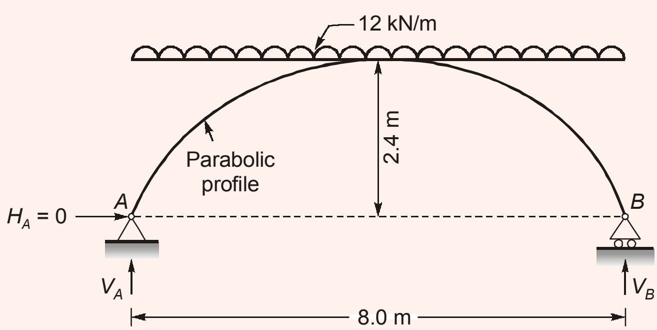
End of Solution

Q.7 A planar elastic structure is subjected to uniformly distributed load, as shown in the figure (not drawn to the scale)



Neglecting self-weight, the maximum bending moment generated in the structure (in kNm, round off to the nearest integer), is ________ .

Ans. (96)



$$V_A = V_B = \frac{wL}{2} = \frac{12 \times 8}{2} = 48 \text{ kN}$$

As horizontal thrust is zero so it behaves like a beam (curved beam)

$$M_{max} = \frac{wL^2}{8} (\text{At crown}) = \frac{12 \times 8^2}{8} = 96 \text{ kNm}$$

End of Solution

Q.8 A fully submerged infinite sandy slope has an inclination of 30° with the horizontal. The saturated unit weight and effective angle of internal friction of sand are 18 kN/m^3 and 38°, respectively. The unit weight of water is 10 kN/m^3. Assume that the seepage is parallel to the slope. Against shear failure of the slope, the factor of safety (round off to two decimal places) is ______.

Ans. **(0.60)**

$$\text{F.O.S.} = \frac{\gamma'}{\gamma_{sat}} \cdot \frac{\tan\phi}{\tan\beta} = \left(\frac{18-10}{18}\right)\frac{\tan 38°}{\tan 30°}$$

$$= 0.601$$

End of Solution

Q.9 The value of $\lim\limits_{x\to\infty} \dfrac{x^2 - 5x + 4}{4x^2 + 2x}$ is

(a) 0

(b) 1

(c) $\dfrac{1}{4}$

(d) $\dfrac{1}{2}$

Ans. **(c)**

It is in $\left(\dfrac{\infty}{\infty}\right)$ from so by L-Hospital Rule

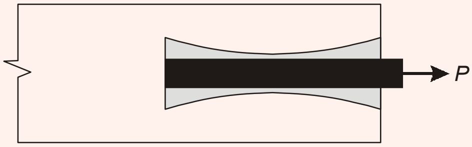
$$= \lim_{x\to\infty}\left(\frac{2x-5}{8x+2}\right) = \frac{\infty}{\infty}$$

$$= \lim_{x\to\infty}\left(\frac{2}{8}\right) = \left(\frac{1}{4}\right)$$

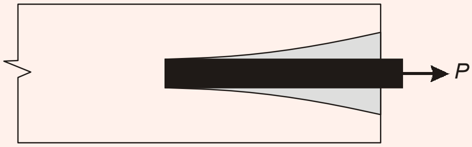
End of Solution

Q.10 A reinforcing steel bar, partially embedded in concrete, is subjected to a tensile force P. The figure that appropriately represents the distribution of the magnitude of bond stress (represented as hatched region), along the embedded length of the bar, is

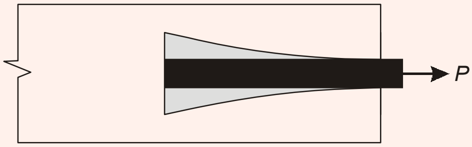
(a)



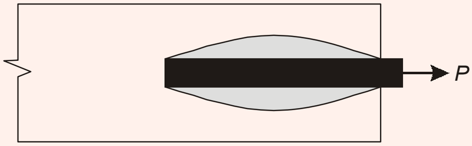
(b)



(c)



(d)



Ans. (b)

End of Solution

Q.11 Velocity of flow is proportional to the first power of hydraulic gradient in Darcy's law. The law is applicable to

(a) transitional flow in porous media
(b) turbulent flow in porous media
(c) laminar as well as turbulent flow in porous media
(d) laminar flow in porous media

Ans. (d)

Darcy's law is valid for laminar flow condition in porous media.

End of Solution

Q.12 The probability that a 50 year flood may NOT occur at all during 25 years life of a project (round off to two decimal places), is ________.

Ans. (0.60)

$$P = \frac{1}{T} = \frac{1}{50} = 0.02$$

$$q = 1 - P = 0.98$$

$\therefore$ Probability of non-occurance of an event is given by,

$$\begin{aligned} \text{Assurance} &= q^n \\ &= (0.98)^{25} \\ &= 0.603 \end{aligned}$$

End of Solution

Q.13 In a two-dimensional stress analysis, the state of stress at a point P is

$$[\sigma] = \begin{bmatrix} \sigma_{xx} & \tau_{xy} \\ \tau_{xy} & \sigma_{yy} \end{bmatrix}$$

The necessary and sufficient condition for existence of the state of pure shear at the point P, is

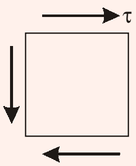
(a) $\tau_{xy} = 0$

(b) $(\sigma_{xx} - \sigma_{yy})^2 + 4\tau_{xy}^2 = 0$

(c) $\sigma_{xx} + \sigma_{yy} = 0$

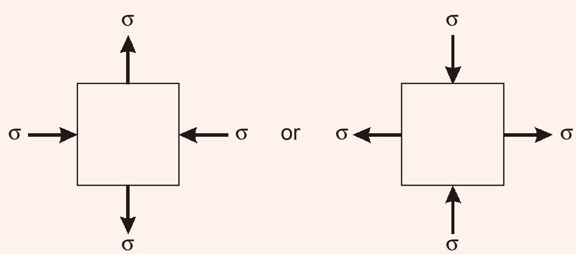
(d) $\sigma_{xx}\sigma_{yy} - \tau_{xy}^2 = 0$

Ans. (c)



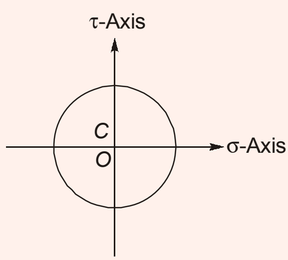
In pure shear condition

$$\sigma_x = 0,\ \sigma_y = 0,\ \tau_{xy} = \tau$$



$\sigma_{xx} = -\sigma$
$\sigma_{yy} = \sigma$
$\tau_{xy} = 0$

$\sigma_{xx} = \sigma$
$\sigma_{yy} = -\sigma$
$\tau_{xy} = 0$



For this condition
(c) is correct

$$\sigma_{xx} + \sigma_{yy} = 0$$

End of Solution

Q.14 The true value of ln(2) is 0.69. If the value of ln(2) is obtained by linear interpolation between ln(1) and ln(6), the percentage of absolute error (round off to the nearest integer), is

(a) 35

(b) 69

(c) 84

(d) 48

Ans. **(d)**

True value $\ln 2 = 0.69 = T$

x	$y = \ln x$
$x_0 = 1$	0
$x_1 = 6$	1.79

Divided differentiation

$$\frac{1.79-0}{6-1} = 0.358 = f[x_0, x_1]$$

Approx:

$$\ln 2 = f[x_0] + (x - x_0)\, f[x_0, x_1]$$
$$= 0 + (2-1)\, 0.358$$
$$= 0.358 = A$$

$$\%\ \text{error} = \frac{T-A}{T} \times 100 = 48.11\%$$

End of Solution

Q.15 In an urban area, a median is provided to separate the opposing streams of traffic. As per IRC : 86-1983, the desirable minimum width (in m, expressed as integer) of the median, is ________.

Ans. **(5)**

As per IRC : 86-1983

Desirable minimum width of median in urban roads = 5 m

And minimum width = 1.2 m

End of Solution

Q.16 In a drained tri-axial compression test, a sample of sand fails at deviator stress of 150 kPa under confining pressure of 50 kPa. The angle of internal friction (in degree, round off to the nearest integer) of the sample, is ________.

Ans. **(37)**

Sand ($C = 0$); $\sigma_d = 150$; $\sigma_3 = 50$; $\sigma_1 = 200$

$$\sigma_1 = \sigma_3 \tan^2\left(45 + \frac{\phi}{2}\right) + 2c\tan\left(45 + \frac{\phi}{2}\right)$$

$$200 = 50\tan^2\left(45 + \frac{\phi}{2}\right)$$

$$\phi = 36.87^\circ$$

So, the angle of internal friction to the nearest integer is 37°.

End of Solution

Q.17 During chlorination process, aqueous (aq) chlorine reacts rapidly with water to from Cl^-, HOCl, and H^+ as shown below

$$Cl_2\,(aq) + H_2O \rightleftharpoons HOCL + Cl^- + H^+$$

The most active disinfectant in the chlorination process from amongst the following, is

(a) H_2O
(b) H^+
(c) Cl^-
(d) HOCl

Ans. (d)

End of Solution

Q.18 A 4 m wide rectangular channel carries 6 m^3/s of water. The Manning's '*n*' of the open channel is 0.02. Considering g = 9.81 m/s^2, the critical velocity of flow (in m/s, round off to two decimal places) in the channel, is ________.

Ans. (2.45)

$$\text{Critical depth } (Y_C) = \left(\frac{q^2}{g}\right)^{1/3}$$

$$= \left(\frac{1.5^2}{9.81}\right)^{1/3} = 0.612 \text{ m}$$

$$\text{Critical velocity } (V_C) = \sqrt{gY_C} = \sqrt{9.81 \times 0.612} = 2.45 \text{ m/s}$$

End of Solution

Q.19 The Los Angeles test for stone aggregates is used to examine

(a) specific gravity
(b) abrasion resistance
(c) soundness
(d) crushing strength

Ans. (b)

End of Solution

Q.20 A river has a flow of 1000 million litres per day (MLD), BOD_5 of 5 mg/litre and Dissolved Oxygen (DO) level of 8 mg/litre before receiving the wastewater discharge at a location. For the existing environmental conditions, the saturation DO level is 10 mg/litre in the river. Wastewater discharge of 100 MLD with the BOD_5 of 200 mg/litre and DO level of 2 mg/litre falls at that location. Assuming complete mixing of wastewater and river water, the immediate DO deficit (in mg/litre, round off to two decimal places), is ________.

Ans. (2.54)

$$DO_{mix} = \frac{DO_s \cdot Q_S + DO_R \cdot Q_R}{Q_s + Q_R} = \frac{2 \times 100 + 8 \times 1000}{100 + 1000}$$

$$= 7.45 \text{ mg}/l$$

$$DO = DO_{sat} - DO_{mix} = 10 - 7.45 = 2.545 \text{ mg}/l$$

End of Solution

Q.21 During the process of hydration of cement, due to increase in Dicalcium Silicate (C_2S) content in cement clinker, the heat of hydration

(a) does not change
(b) decreases
(c) initially decreases and then increases
(d) increases

Ans. (b)

End of Solution

Q.22 Which one of the following statements is **NOT** correct?

(a) the cohesion of normally consolidated clay is zero when tri-axial test is conducted under consolidated undrained condition.
(b) In case of a point load, Boussinesq's equation predicts higher value of vertical stress at a point directly beneath the load as compared to Westergaard's equation.
(c) The ultimate bearing capacity of a strip foundation supported on the surface of sandy soil increase in direct proportion to the width of footing.
(d) A clay deposit with a liquidity index greater than unity is in a state of plastic consistency.

Ans. (d)

A clay deposit with liquidty index greater then 1, will be in liquid stage of consistency.

$$\because \quad I_L = \frac{w_n - w_p}{w_L - w_p} > 1$$

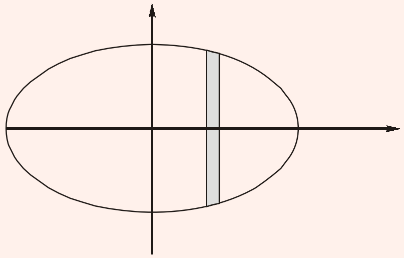
$$\therefore \quad w_n > w_L$$

End of Solution

Q.23 The area of an ellipse represented by an equation $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ is

(a) $\frac{4\pi ab}{3}$
(b) πab
(c) $\frac{\pi ab}{2}$
(d) $\frac{\pi ab}{4}$

Ans. (b)



$$\text{Area} = \iint (1)\,dy\,dx = \int_{x=-a}^{a} \int_{y=-\frac{b}{a}\sqrt{-x^2+a^2}}^{+\frac{b}{a}\sqrt{-x^2+a^2}} (1)\,dy\,dx$$

$$= 4\int_{x=0}^{a}\int_{y=0}^{\frac{b}{a}\sqrt{a^2-x^2}} (1)\, dy\, dx$$

$$= 4\int_{x=0}^{a}\int_{y=0}^{\frac{b}{a}\sqrt{a^2-x^2}} dx$$

$$= \pi ab$$

End of Solution

Q.24 A road in a hilly terrain is to be laid at a gradient of 4.5%. A horizontal curve of radius 100 m is laid at a location on this road. Gradient needs to be eased due to combination of curved horizontal and vertical profiles of the road. As per IRC, the compensated gradient (in %, round off to one decimal place), is ______.

Ans. **(4)**

Gradient = 4.5%, R = 100 m

Grade compensation $= \left(\frac{30+R}{R}\right) \ngtr \left(\frac{75}{R}\right)\% = \frac{30+100}{100} \ngtr \frac{75}{100} = 1.3\% \ngtr 0.75 \Big\} \; G.C = 0.75$

Compansated Gradient = Gradient G.C = 4.5% – 0.75 = 3.75 $\nless$ 4%

Hence C.G = 4%

End of Solution

Q.25 A body floating in a liquid is in a stable state of equilibrium if its

(a) metacentre lies below its centre of gravity

(b) metacentre lies above its centre of gravity

(c) metacentre coincides with its centre of gravity

(d) centre of gravity is below its centre of buoyancy

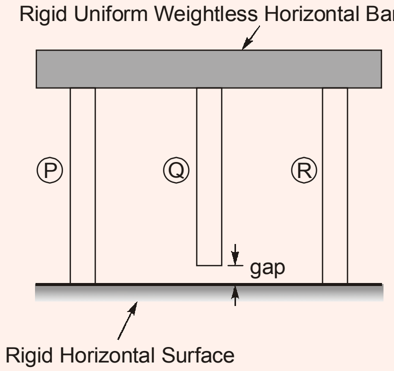
Ans. **(b)**

For stability of floating body M lies above G

$$GM > 0$$

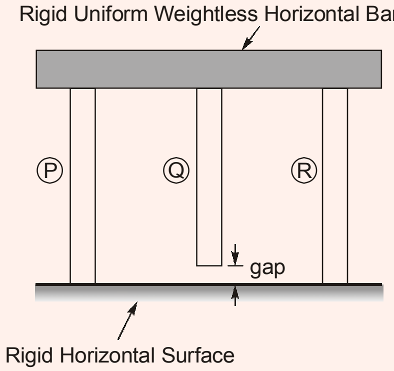
End of Solution

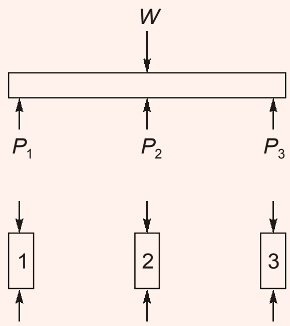
Q.26 A rigid, uniform, weightless, horizontal bar is connected to three vertical members P, Q and R as shown in the figure (not drawn to the scale). All three members have identical axial stiffness of 10 kN/mm. The lower ends of bars P and R rest on a rigid horizontal surface. When NO load is applied, a gap of 2 mm exists between the lower end of the bar Q and the rigid horizontal surface. When a vertical load W is placed on the horizontal bar in the downward direction, the bar still remains horizontal and gets displaced by 5 mm in the vertically downward direction.



The magnitude of the load W (in kN, round off to the nearest integer), is ______.

Ans. (130)





$$P_1 + P_1 + P_2 = W \quad \text{...(i)}$$

$$P_1 = P_3$$

$$\delta_1 = 5\text{ mm} = \frac{P_1 L}{AE} \qquad \frac{AE}{L} = 10\text{ kN/mm}$$

$$\delta_2 = 3\text{ mm} = \frac{P_2 L}{AE}$$

So,

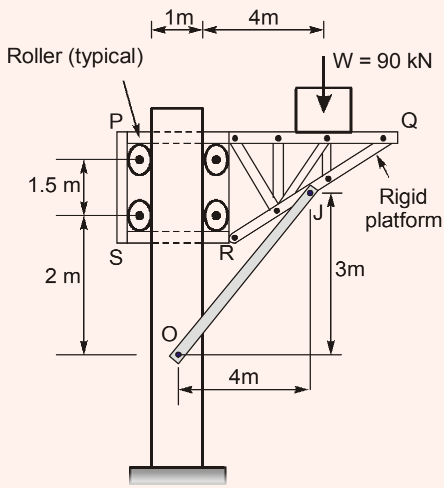
$$P_1 = 10 \times 5 = 50\text{ kN}$$

$$P_2 = 10 \times 3 = 30\text{ kN}$$

$$W = 2(50) + 30 = 130\text{ kN}$$

End of Solution

Q.27 A rigid weightless platform PQRS shown in the figure (not drawn to the scale) can slide freely in the vertical direction. The platform is held in position by the weightless member OJ and four weightless, frictionless rollers. Point O and J are pin connections. A block of 90 kN rests on the platform as shown in the figure.

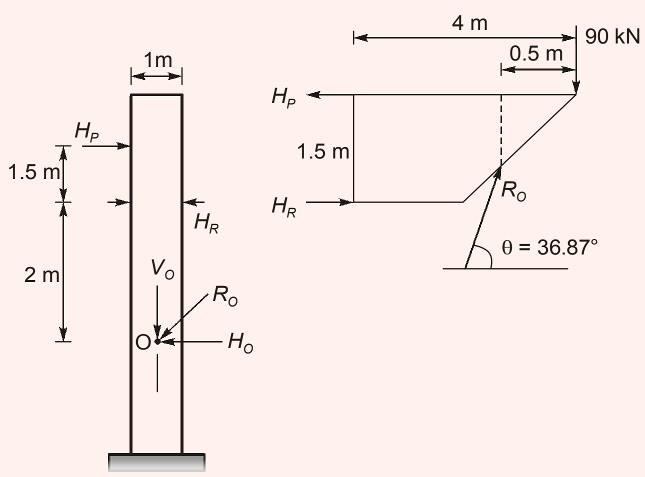


The magnitude of horizontal component of the reaction (in kN) at pin O, is

(a) 180 (b) 150

(c) 90 (d) 120

Ans. (d)



$$\Sigma y = 0$$

$$\Rightarrow \quad R_o \sin 36.87 - 90 = 0$$

$$R_o = \frac{90}{\sin 3687°} = 150 \text{ kN}$$

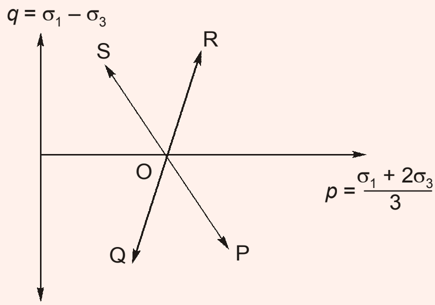
Horizontal reaction at $O = H_o$

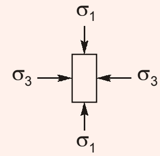
$$= R_o \cos 36.87 = 150 \times \cos 36.87$$

$$= 120 \text{ kN}$$

End of Solution

Q.28 The total stress paths corresponding to different loading conditions, for a soil specimen under the isotropically consolidated stress state (O), are shown below:





Stress Path	Loading Condition
OP	I. Compression loading (σ_1 – increasing; σ_3 – constant)
OQ	II. Compression unloading (σ_1 – constant; σ_3 – decreasing)
OR	III. Extension unloading (σ_1 – decreasing; σ_3 – constant)
OS	IV. Extension loading (σ_1 – constant; σ_3 – increasing)

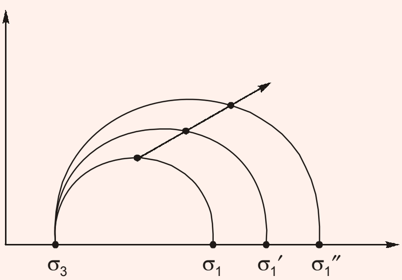
The correct match between the stress paths and the listed loading conditions, is

(a) OP–I, OQ–II, OR–IV, OS–III
(b) OP–III, OQ–II, OR–I, OS–IV
(c) OP–IV, OQ–III, OR–I, OS–II
(d) OP–I, OQ–III, OR–II, OS–IV

Ans. **(c)**

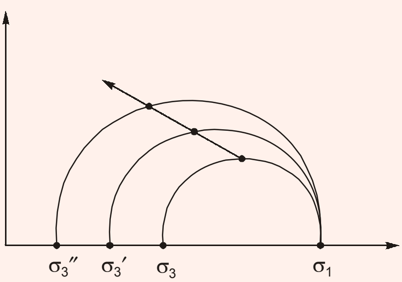
I. Compression loading

OR



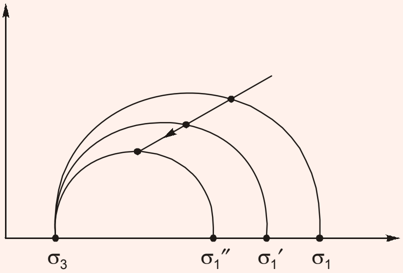
II. Compression unloading

OS



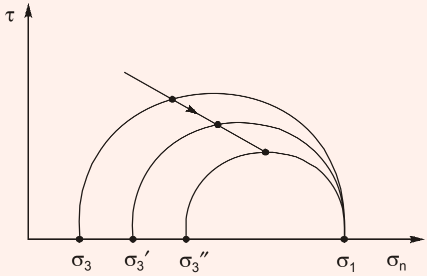
III. Exctension unloading

OQ



IV. Extension loading

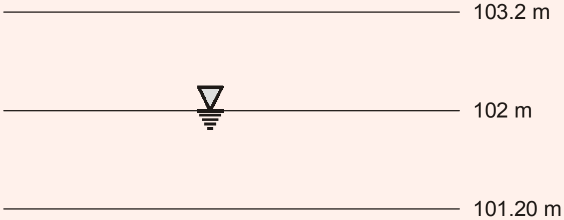
OP



End of Solution

Q.29 In a homogeneous unconfined aquifer of area 3.00 km^2, the water table was at an elevation of 102.00 m. After a natural recharge of volume 0.90 million cubic meter (Mm^3), the water table rose to 103.20 m. After this recharge, ground water pumping took place and the water table dropped down to 101.020 m. The volume of ground water pumped after the natural recharge, expressed (in Mm^3 and round off to two decimal places), is ______.

Ans. (1.5)



$$V_R = 0.9 \text{ Mm}^3$$

$$V = 3 \times (103.2 - 102)$$

$$= 3 \times 1.2 = 3.6 \text{ Mm}^3$$

$$y_s \text{ or } y_R = \frac{VR}{V} = \frac{0.9}{3.6}$$

Now,

$$y_s = \frac{V_D}{V}$$

$$V_D = \frac{0.9}{3.6}\left[3 \times (103.2 - 101.2)\right]$$

$$V_D = 1.5 \text{ Mm}^3$$

End of Solution

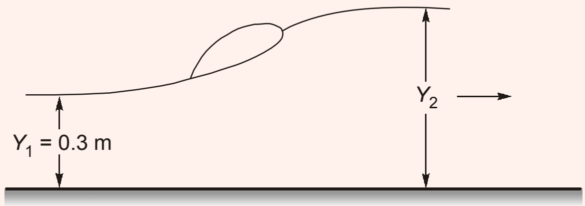
Q.30 Water flows at the rate of 12 m^3/s in a 6 m wide rectangular channel. A hydraulic jump is formed in the channel at a point where the upstream depth is 30 cm (just before the jump). Considering acceleration due to gravity as 9.81 m/s^2 and density of water as 1000 kg/m^3, the energy loss in the jump is

(a) 114.2 kW
(b) 141.2 J/s
(c) 141.2 h.p.
(d) 114.2 MW

Ans. (b)

Assuming channle bed to be horizontal and frictionless.

$$q = \frac{12}{6} = 2 \ m^3/s/m$$



$$\text{Initial Froude No. } (F_r) = \left(\frac{q^2}{gY_1^3}\right)^{1/2}$$

$$= \left(\frac{2^2}{9.81 \times 0.3^3}\right)^{1/2} = 3.88$$

From Belenger's Momentum equation for a rectangular channel

$$\frac{Y_2}{Y_1} = \frac{1}{2}\left(-1+\sqrt{1+8F_1^2}\right)$$

$$= \frac{1}{2}\left(-1+\sqrt{1+8\times 3.88^2}\right)$$

$$= 5.018$$

$$\therefore \quad Y_2 = 5.018 \times 0.3 = 1.505 \text{ m}$$

$$\text{Head loss in the jump } (h_L) = \frac{(Y_2 - Y_1)^3}{4Y_1Y_2}$$

$$= \frac{(1.505 - 0.3)^3}{4 \times 1.505 \times 0.3}$$

$$= 0.968 \text{ m}$$

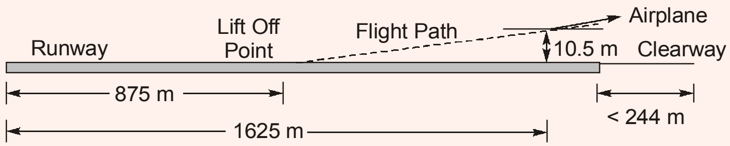
$$\text{Power lost in the jump} = \gamma_w Q h_L$$

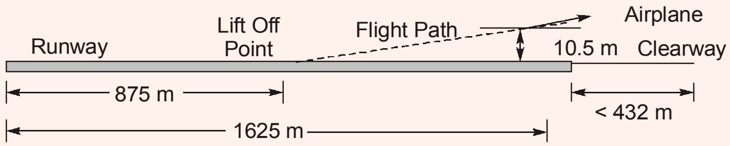
$$= (9.81 \times 12 \times 0.968) \text{ kW}$$

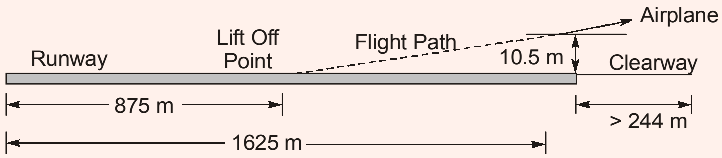
$$= 114.04 \text{ kW}$$

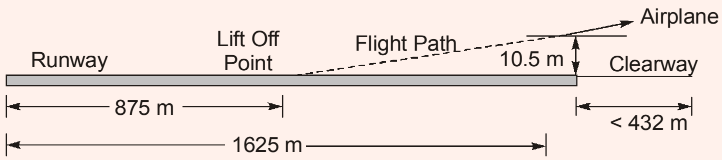
End of Solution

Q.31 The appropriate design length of a clearway is calculated on the basis of 'Normal Take-off' condition. Which one of the following options correctly depicts the length of the clearway? (Note: None of the option are drawn to scale)

(a) 

(b) 

(c) 

(d) 

Ans. (d)

For normal take off condition:

$$\text{Clearway} \ngtr \frac{1}{2}(1.5 \text{ take off distance} - 1.15 \text{ of lift off distance})$$

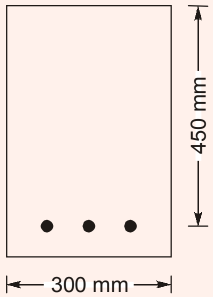
$$\ngtr \frac{1}{2}(1.15 \times 1625 - 1.15 \times 875)$$

$$\ngtr 431.25 \text{ m}$$

So clearway is less then for 432 m.

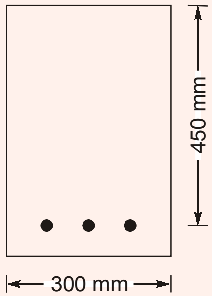
End of Solution

Q.32 The singly reinforced concrete beam section shown in the figure (not drawn to the scale) is made of M25 grade concrete and Fe500 grade reinforcing steel. The total cross-sectional area of the tension steel is 942 mm^2.



As per Limit State Design of IS 456 : 2000, the design moment capacity (in kNm round off to two decimal places) of the beam section, is ________.

Ans. **(158.25)**



M25 concrete
Fe500 steel

$$B = 300 \text{ mm}$$

$$d = 450 \text{ mm}$$

$$A_{st} = 942 \text{ mm}^2$$

$$M_u = ?$$

(i) $x_{u\lim} = 0.46 \times d = 0.46 \times 450 = 207 \text{ mm}$

(ii) $x_u = \dfrac{0.87 \cdot f_y \cdot A_{st}}{0.36 \cdot f_{ck} \cdot B} = \dfrac{0.87 \times 500 \times 942}{0.36 \times 25 \times 300} = 151.77 \text{ mm}$

(iii) $x_u < x_{u\lim}$ It is an under reinforcement section.

(iv) $M_u = 0.36 \cdot f_{ck} \cdot B \cdot x_u \cdot (d - 0.42 x_u)$

$$= 0.36 \times 25 \times 300 \times 151.77 \times (450 - 0.42 \times 151.77)/10^6$$

$$= 158.28 \text{ kN-m}$$

End of Solution

Q.33 For the Ordinary Differential Equation $\frac{d^2x}{dt^2} - 54\frac{dx}{dt} + 6x = 0$, with initial condition $x(0) = 0$ and $\frac{dx}{dt}(0) = 10$, the solution is

(a) $-10e^{2t} + 10e^{3t}$

(b) $5e^{2t} + 6e^{3t}$

(c) $10e^{2t} + 10e^{3t}$

(d) $-5e^{2t} + 6e^{3t}$

Ans. (a)

A.E. is $m^2 - 5m + 6 = 0 \Rightarrow$ m = 2, 3 so $C_f = C_1e^{2t} + C_2e^{3t}$.

PI = 0 and G. Solution is $x = CF + PI = C_1e^{2t} + C_2e^{3t}$ and $\frac{dx}{dt} = 2C_1e^{2t} + 3C_2e^{3t}$.

Now, using initial conditions we get $C_1 = -10$, $C_2 = 10$.

$$x = -10e^{2t} + 10e^{3t}$$

End of Solution

Q.34 The length and bearings of a traverse PQRS are:

Segment	Length (m)	Bearing
PQ	40	80°
QR	50	10°
RS	30	210°

The length of line segment SP (in m, round off to two decimal places), is ________.

Ans. (44.79)

$$\Delta L = 40\cos 80° + 50\cos 10° + 30\cos 210°$$
$$= 30.20$$
$$\Delta D = 40\sin 80° + 50\sin 10° + 30\sin 210°$$
$$= 33.07$$
$$\text{Length, SP} = \sqrt{\Delta L^2 + \Delta D^2} = 44.79 \text{ m}$$

End of Solution

Q.35 A continuous function $f(x)$ is defined. If the third derivative at x_i is to be computed by using the fourth order central finite-divided-difference scheme (the step length = h), the correct formula is

(a) $f'''(x_i) = \dfrac{-f(x_{i+3}) - 8f(x_{i+2}) + 13f(x_{i+1}) + 13f(x_{i-1}) + 8f(x_{i-2}) - f(x_{i-3})}{8h^3}$

(b) $f'''(x_i) = \dfrac{-f(x_{i+3}) + 8f(x_{i+2}) - 13f(x_{i+1}) + 13f(x_{i-1}) - 8f(x_{i-2}) + f(x_{i-3})}{8h^3}$

(c) $f'''(x_i) = \dfrac{f(x_{i+3}) - 8f(x_{i+2}) + 13f(x_{i+1}) + 13f(x_{i-1}) - 8f(x_{i-2}) - f(x_{i-3})}{8h^3}$

(d) $f'''(x_i) = \dfrac{f(x_{i+3}) - 8f(x_{i+2}) - 13f(x_{i+1}) + 13f(x_{i-1}) + 8f(x_{i-2}) + f(x_{i-3})}{8h^3}$

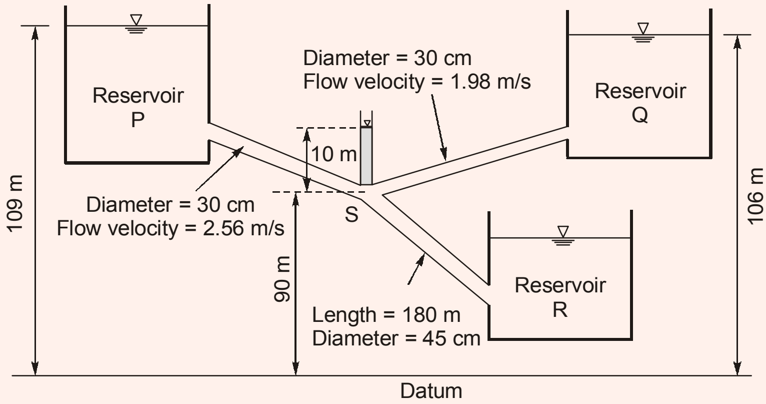
Ans. **(b)**

$$\left.\frac{\partial^3 u}{\partial x^3}\right|_{x_i} = \frac{-u_{i+3} + 8u_{i+2} - 13u_{i+1} + 13u_{i-1} - 8u_{i-2} + u_{i-3}}{8\Delta h^3}$$

$$f'''(x_i) = \frac{-f(x_{i+3}) + 8f(x_{i+2}) - 13f(x_{i+1}) + 13f(x_{i-1}) - 8f(x_{i-2}) + f(x_{i-3})}{8h^3}$$

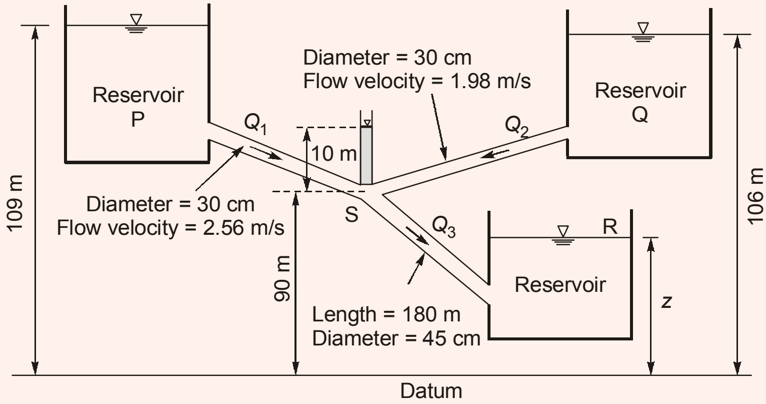
End of Solution

Q.36 Three reservoir P, Q and R are interconnected by pipes as shown in the figure (not drawn to the scale). Piezometric head at the junction S of the pipes is 100 m. Assume acceleration due to gravity as 9.81 m/s^2 and density of water as 1000 kg/m$^{`3}$. the length of the pipe from junction S to the inlet of reservoir R is 180 m.



Considering head loss only due to friction (with friction factor of 0.03 for all the pipes), the height of water level in the lowermost reservoir *R* (in m, round off to one decimal places) with respect to the datum, is ________.

Ans. (97.5)



Apply conutinuity $\quad Q_3 = Q_1 + Q_2$

$$= A_1V_1 + A_2V_2$$

$$= \frac{\pi}{4}(0.3)^2(2.56) + \frac{\pi}{4}(0.3)^2(1.98)$$

$$= 0.3209 \text{ m}^3/\text{s}$$

Apply energy eq. between (S) and (R)

$$H_s = H_r + h_f$$

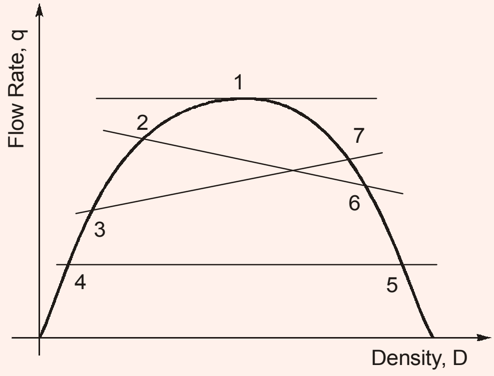
$$100 = z + \frac{8Q_3^2}{\pi^2 g} \times \frac{fL_3}{D_3^5}$$

$$100 = z + \frac{8(0.3209)^2}{\pi^2 g} \times \frac{(0.03)(180)}{(0.45)^5}$$

$$z = 97.51 \text{ m}$$

End of Solution

Q.37 The relationship between traffic flow rate (q) and density (D) is shown in the figure.



The shock wave condition is depicted by

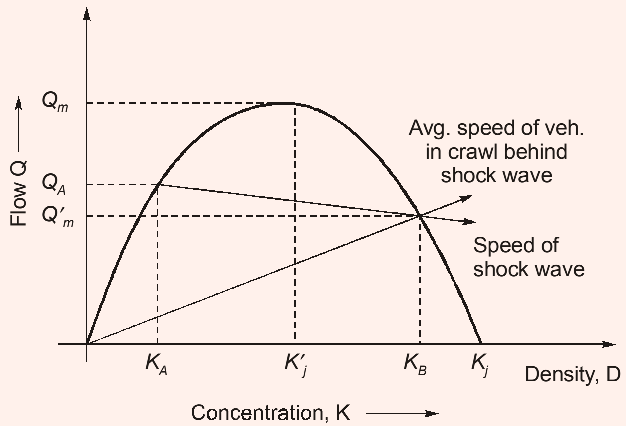
(a) flow with respect to point 4 and point 5($q_4 = q_5$)

(b) flow changing from point 3 to point 7 ($q_3 < q_7$)

(c) flow changing from point 2 to point 6 ($q_2 > q_6$)

(d) flow with respect to point 1 ($q_1 = q_{max}$)

Ans. (c)



End of Solution

Q.38 A stream with a flow rate of 5 m^3/s is having an ultimate BOD of 30 mg/litre. A wastewater discharge of 0.20 m^3/s having BOD_5 of 500 mg/litre joins the stream at a location and instantaneously gets mixed up completely. The cross-sectional area of the stream is 40 m^2 which remains constant. BOD exertion rate constant is 0.3 per day (logarithm base to *e*). The BOD (in mg/litre round off to two decimal places) remaining at 3 km downstream from the mixing location, is ________.

Ans. (49.57)

$$t = \frac{d}{v} \qquad \text{where, } v = \frac{Q_S + Q_R}{A} = \frac{0.2+5}{40} = 0.13 \text{ m/sec}$$

$$t = \frac{3\times 10^3}{0.13\times 86400} = 0.26 \text{ days}$$

$$BOD_5 = BOD_u(1 - e^{-k\times 5})$$

$$BOD_u = \frac{500}{(1-e^{-0.3\times 5})} = 643.66 \text{ mg}/l$$

$$DO_{mix} = \frac{Q_R BOD_u + Q_S \cdot BOD_u}{Q_S + Q_R}$$

$$= \frac{5 \times 30 + 0.2 \times 643.66}{5 + 0.2} = 53.6 \text{ mg}/l$$

$$L_t = L_0\, e^{-k \times t}$$

$$= 53.6 e^{-0.3 \times 0.26}$$

$$= 49.57 \text{ mg}/l$$

End of Solution

Q.39 Consider the system of equations

$$\begin{bmatrix} 1 & 3 & 2 \\ 2 & 2 & -3 \\ 4 & 4 & -6 \\ 2 & 5 & 2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 2 \\ 1 \end{bmatrix}$$

The value of x_3 (round off to the nearest integer), is _______.

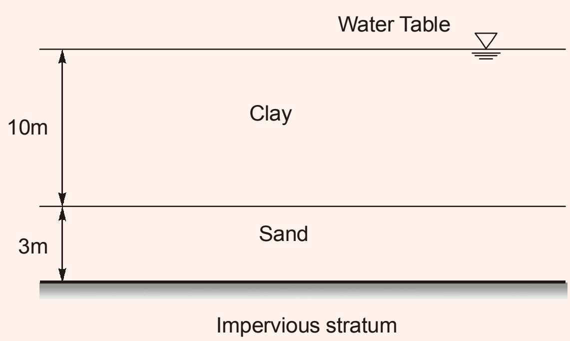
Ans. (3)

$$[A : B] = \begin{bmatrix} 1 & 3 & 2 & \vdots & 1 \\ 2 & 2 & -3 & \vdots & 1 \\ 4 & 4 & -6 & \vdots & 2 \\ 3 & 5 & 2 & \vdots & 1 \end{bmatrix} \xrightarrow[\text{an Echelon Form}]{\text{Converting into}} \begin{bmatrix} 1 & 3 & 2 & \vdots & 1 \\ 0 & -1 & -2 & \vdots & -1 \\ 0 & 0 & 1 & \vdots & 3 \\ 0 & 0 & 0 & \vdots & 0 \end{bmatrix}$$

$$\Rightarrow \quad \begin{bmatrix} 1 & 3 & 2 \\ 0 & -1 & -2 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 1 \\ -1 \\ 3 \\ 0 \end{bmatrix} \Rightarrow x_3 = 3$$

End of Solution

Q.40 A 10 m thick clay layer is resting over a 3 m thick sand layer and is submerged. A fill of 2 m thick sand with unit weight of 20 kN/m^3 is placed above the clay layer to accelerate the rate of consolidation of the clay layer. Coefficient of consolidation of clay is 9×10^{-2} m^2/year and coefficient of volume compressibility of clay is 2.2×10^{-4} m^2/kN. Assume Taylor's relation between time factor and average degree of consolidation.



The settlement (in mm, *round off to two decimal places*) of the clay layer, 10 years after the construction of the fill, is ________.

Ans. (18.83)

$$\Delta\bar{\sigma} = 2 \times 20 = 40 \text{ kN/m}^2$$

$$\Delta H = m_V \Delta\bar{\sigma} H$$

$$= 2.2 \times 10^{-4} \times 40 \times 10 \times 10^3 \text{ mm}$$

$$= 88 \text{ mm}$$

$$T_v = \frac{C \times t}{H^2} = \frac{9 \times 10^{-2} \times 10}{5^2} = 0.036$$

$$T_v = \frac{\pi}{4} U^2$$

$$U = \sqrt{\frac{0.036 \times 4}{\pi}} = 0.214$$

Δh after 10 years = 0.214 × 88 = 18.832 mm

End of Solution

Q.41 If C represents a line segment between (0, 0, 0) and (1,1, 1) in Cartesian coordinate system, the value (expressed as integer) of the line integral

$$\int_C [(y+z)dx + (x+z)dy + (x+y)dz]$$

is ________.

Ans. (3)

$$I = \int_C [(ydx + xdy) + (zdx + xdz) + (zdy + ydz)]$$

$$= \int_C [d(xy) + d(xz) + d(yz)] = (xy + yz + zx)_{(0,0,0)}^{(1,1,1)}$$

$$= (1 + 1 + 1) - (0 + 0 + 0) = 3$$

End of Solution

Q.42 Surface Overflow Rate (SOR) of a primary settling tank (discrete settling) is 20000 litre/m^2 per day. Kinematic viscosity of water in the tank is 1.01×10^{-2} cm^2/s. Specific gravity of the settling particles is 2.64. Acceleration due to gravity is 9.81 m/s^2. The minimum diameter (in μm, round off to one decimal place) of the particles that will be removed with 80% efficiency in the tank, is ________.

Ans. (14.46)

$$\eta = 80 = \frac{u_s}{V_s} \times 100$$

$$u_s = \frac{0.8 \times 20000 \times 10^{-3}}{86400} = 1.85 \times 10^{-4} \text{ m/sec}$$

$$u_s = \frac{(G-1)gd^2}{18\nu}$$

$$1.85 \times 10^{-4} = \frac{(2.64-1)\times 9.81 \times d^2}{18 \times 1.01 \times 10^{-2} \times 10^{-4}}$$

$$d = 1.446 \times 10^{-5} \text{ m}$$

$$= 14.46\ \mu\text{m}$$

End of Solution

Q.43 A gaseous chemical has a concentration of 41.6 μmol/m^3 in air at 1 atm pressure and temperature 293 K. The universal gas constant R is 82.05 × 10^{-6} (m^3 atm)/(mol K). Assuming that ideal gas law is valid, the concentration of the gaseous chemical (in ppm, round off to one decimal place), is ______.

Ans. **(1)**

$$PV = nRT$$

$$V = \frac{nRT}{P}$$

$$= \frac{41.6 \times 10^{-6} \times 32.05 \times 10^{-6}}{1} \times 293 = 10^{-6}\text{m}^3$$

41.6 μ mole of gas volume of 10^{-6} m^3

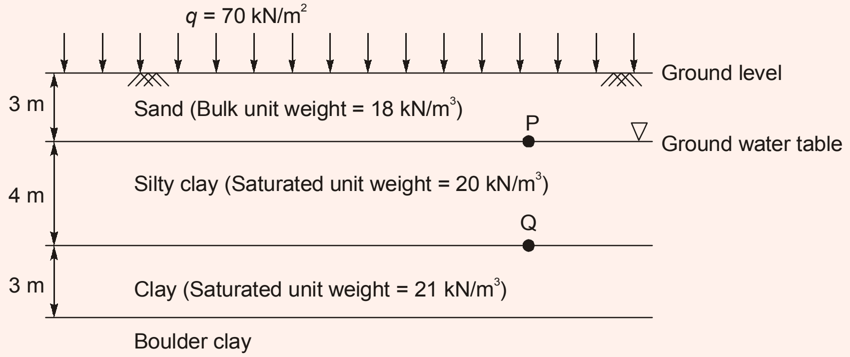
So, $$1 \text{ ppm} = \frac{1 \text{ part of gas}}{10^6 \text{ parts of air}} = \frac{1\text{ m}^3 \text{ of gas}}{10^6 \text{ m}^3 \text{ of air}}$$

$$1 \text{ ppm} = \frac{41.6 \times 10^6\ \mu\text{moles}}{10^6 \text{m}^3}$$

So, $41.6\ \mu \text{ moles/m}^3 = 1 \text{ ppm}$

End of Solution

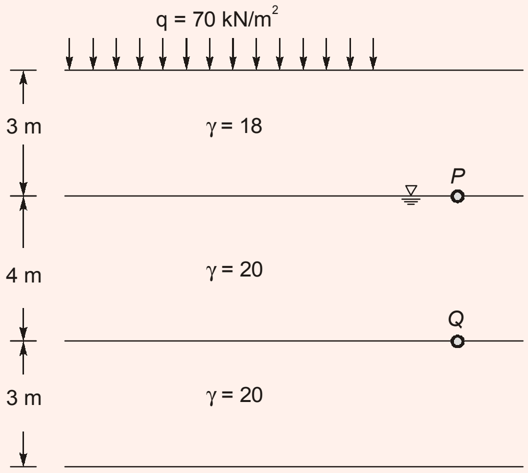
Q.44 The soil profile at a site up to a depth of 10 m is shown in the figure (not drawn to the scale). The soil is preloaded with a uniform surcharge (q) of 70 kN/m^2 at the ground level. The water table is at a depth of 3 m below ground level. The soil unit weight of the respective layers is shown in the figure. Consider unit weight of water as 9.81 kN/m^3 and assume that the surcharge (q) is applied instantaneously.



Immediately after preloading, the effective stresses (in kPa) at points P and Q respectively, are

(a) 36 and 126
(b) 36 and 90
(c) 54 and 95
(d) 124 and 204

Ans. (c)



Surcharge (q = 70 kN/m^2) is applied instantaneously hence excess pore pressure (u_i = 70 kPa) is developed at point P and Q [GWT level is at level P]

At point P: Total stress $\sigma = q + 3\gamma = 70 + 3 \times 18$

Pore water pressure = Hydrostatics pore pressure + Excess pore pressure

$= 0 + u_i = 0 + 70 = 70$ kN/m^2

Effective stress, $\bar{\sigma} = \sigma - u = 54$ kPa

At point Q: Total stress, $\sigma = q + 3\gamma + 4\gamma_{sat} = 70 + 3 \times 18 + 4 \times 20$

Pore pressure, u = Hydrostatics pore pressure + Excess pore pressure

$= 4\gamma_w + u_i = 4 \times 9.81 + 70$

Effective stress, $\bar{\sigma} = \sigma - u = 94.76$

End of Solution

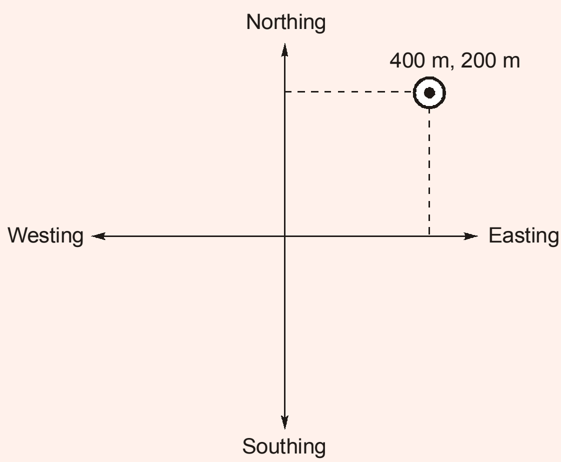
Q.45 An open traverse PQRST is surveyed using theodolite and the consecutive coordinates obtained are given in the table

Line	Consecutive Coordinates			
	Northing (m)	Southing (m)	Easting (m)	Westing (m)
PQ	110.2	–	45.5	–
QR	80.6	–	–	60.1
RS	–	90.7	–	70.8
ST	–	105.4	55.5	–

If the independent coordinates (Northing, Easting) of station P are (400 m, 200 m) the independent coordinates (in m) of station T, are

(a) 405.3, 229.9
(b) 394.7, 170.1
(c) 194.7, 370.1
(d) 205.3, 429.9

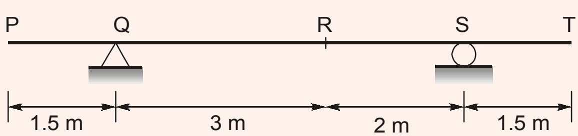
Ans. (b)



$$\Delta L = -5.3$$
$$\Delta D = -29.9$$
$$T, \text{Northing}\{400 + (-5.3) = 394.7$$
$$T, \text{Easting}\{200 + (-29.9) = 170.1$$
$$\text{T } [394.7 \text{ m}, \ 170.1 \text{ m}]$$

End of Solution

Q.46 Distributed load(s) of 50 kN/m may occupy any position(s) (either continuously or in patches) on the girder PQRST as shown in the figure (not drawn to the scale)

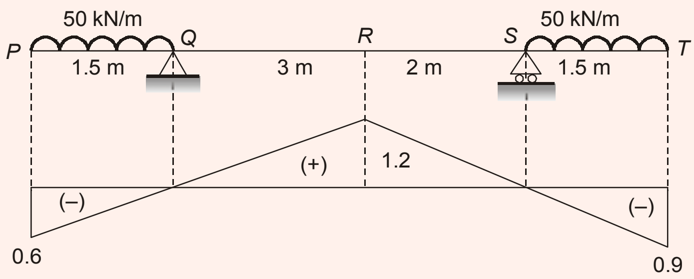


The maximum negative (hogging) bending moment (in kNm) that occurs at point R is

(a) 56.25 (b) 22.50

(c) 150.00 (d) 93.75

Ans. (a)



ILD for BM at R:

To get maximum hogging BM at R, keep UDL over PQ and ST.

$$\text{Max. –ve BM at R} = 50\left[-\frac{1}{2}\times 1.5\times 0.6\right] + 50\left[-\frac{1}{2}\times 1.5\times 0.9\right]$$

$$= 56.25 \text{ kNm}$$

End of Solution

Q.47 A water supply scheme transports 10 MLD (Million Litres per Day) water through a 450 mm diameter pipeline for a distance of 2.5 km. A chlorine dose of 3.50 mg/litre is applied at the starting point of the pipeline to attain a certain level of disinfection at the downward end. It is decided to increase the flow rate from 10 MLD to 13 MLD in the pipeline. Assume exponent for concentration, n = 0.86. With this increased flow, in order to attain the same level of disinfection, the chlorine does (in mg/litre) to be applied at the starting point should be

(a) 5.55 (b) 4.75

(c) 3.95 (d) 4.40

Ans. (b)

$$\text{Waterson law, } tc^h = \text{Constant}$$

$$t_1 c_1^n = t_2 c_2^n$$

$$\frac{d_1}{v_1} c_1^n = \frac{d_2}{v_2} c_2^n$$

$$\frac{d_1}{Q_1} A_1 c_1^n = \frac{d_2 A_2 c_2^n}{Q_2}$$

$$d_1 = d_2,\ A_1 = A_2$$

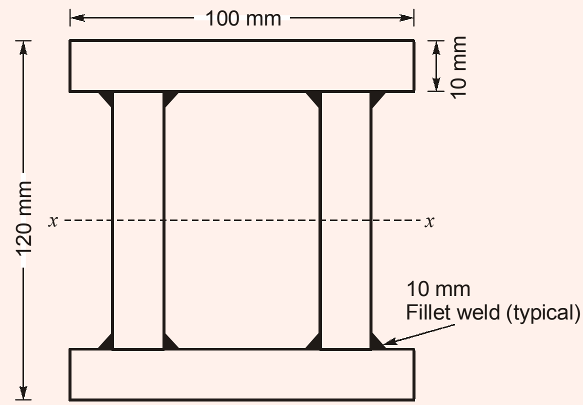
$$\frac{(3.5)^{0.86}}{10} = \frac{(c_2)^{0.86}}{13}$$

$$c_2 = \left(\frac{13}{10}\right)^{1/0.86} \times 3.5 = 4.747$$

$$= 4.75 \text{ mg}/l$$

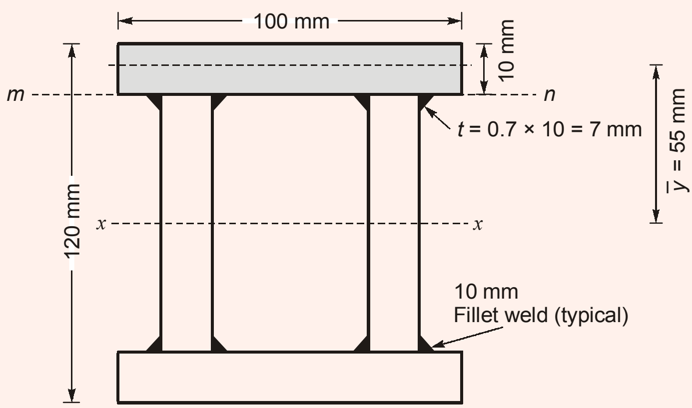
End of Solution

Q.48 The flange and web plates of the doubly symmetric built-up section are connected by continuous 10 mm thick fillet welds as shown in the figure (not drawn to the scale). The moment of inertia of the section about its principal axis X-X is 7.73×10^6 mm^4. The permissible shear stress in the fillet welds is 100 N/mm^2. The design shear strength of the section is governed by the capacity of the fillet welds.



The maximum shear force (in kN, round off to one decimal place) that can be carried by the section, is ________.

Ans. (393.5)



q = Shear stress at the level mn in the weld = 100 MPa = $\dfrac{FA\bar{y}}{Ib}$

F = Shear force at the given section

A = Area of the cross-section above the level mn = 100×10 mm^2

$\bar{y}$ = C.G. of shaded area above the level mn = $60 - 5 = 55$ m

$$I = 7.73 \times 10^6 \text{ mm}^4$$

$$b = \text{Width of weld at mn (4 welds)} = 4 \times t = 4 \times 7 = 28 \text{ mm}$$

t = Throat thickness

$$= 0.7 \times s = 0.7 \times 10 \times 4 = 28 \text{ mm}$$

$$\therefore \qquad 100 = \frac{F \times (100 \times 10) \times 55}{7.73 \times 10^6 \times 28}$$

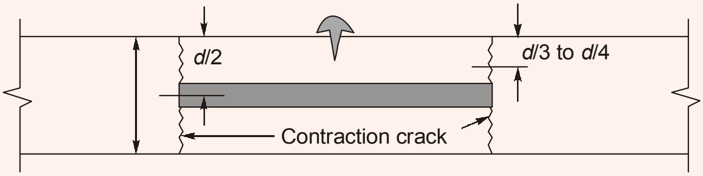
$$F = \frac{100 \times 7.73 \times 10^6 \times 28}{1000 \times 55} = 393.527 \text{ kN}$$

$$= 393.5 \text{ kN}$$

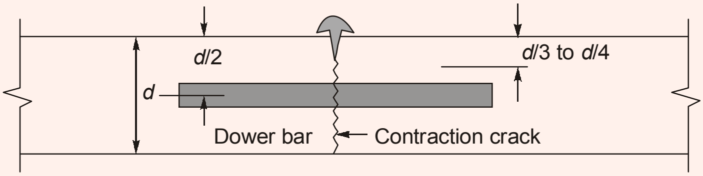
End of Solution

Q.49 A dowel bar is placed at a contraction joint. When contraction occurs, the concrete slab cracks at predetermined location(s). Identify the arrangement, which shows the correct placement of dowel bar and the place of occurrence of the contraction crack(s).

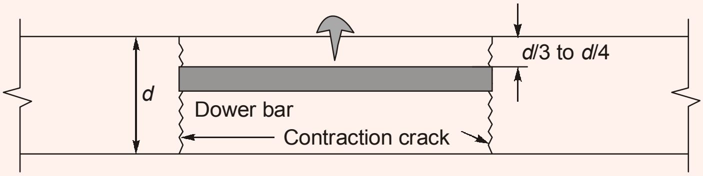
(a)



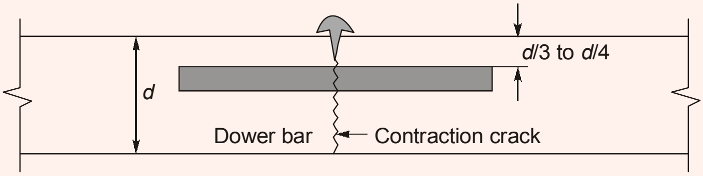
(b)



(c)



(d)

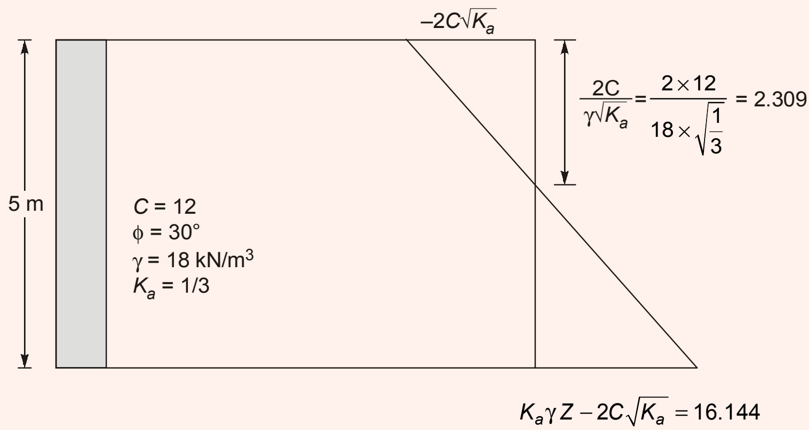


Ans. (b)

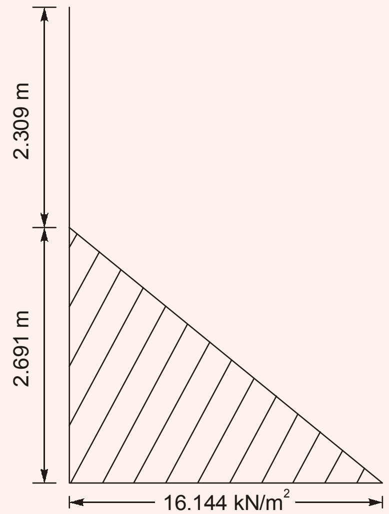
End of Solution

Q.50 A vertical retaining wall of 5 m height has to support soil having unit weight of 18 kN/m^3, effective cohesion of 12 kN/m^2, and effective friction angle of 30°. As per Rankine's earth pressure theory and assuming that a tension crack has occurred, the lateral active thrust on the wall per meter length (in kN/m, round off to two decimal places), is ______.

Ans. **(21.71)**



After tension crack



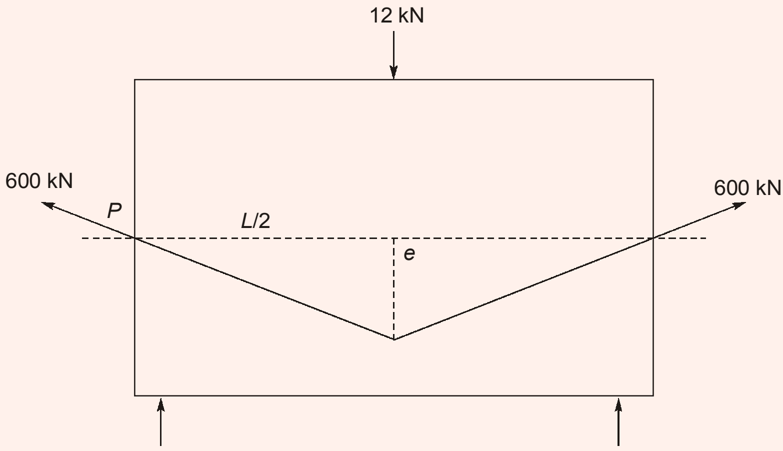
$$P_a = \frac{1}{2} \times 16.144(5 - 2.309)$$

$$= 21.714 \text{ kN/m}$$

End of Solution

Q.51 A simply supported prismatic concrete beam of rectangular cross-section, having a span of 8 m, is prestressed with an effective prestressing force of 600 kN. The eccentricity of the prestressing tendon is zero at supports and varies linearly to a value of e at the mid-span. In order to balance an external concentrated load of 12 kN applied at the mid-span, the required value of e (in mm, round off to the nearest integer) of the tendon, is _______.

Ans. (40)



$$P = 600 \text{ kN}$$

$$\text{Simply supported span} = L = 8 \text{ m}$$

To support a point load applied at mid span (W)

$$= 12 \text{ kN}$$

$$\text{Balancing load} = \text{Point load}$$

$$2P \sin\theta = W$$

$$2P\left(\frac{e}{L/2}\right) = 2$$

$$\frac{2Pe \times 2}{L} = W$$

$$\frac{4Pe}{L} = W$$

$$e = \frac{WL}{4P} = \frac{12000 \text{ N} \times 8000 \text{ mm}}{4 \times 600 \times 1000 \text{ N}}$$

$$= 40 \text{ mm}$$

End of Solution

Q.52 Traffic volume count has been collected on a 2 lane road section which needs upgradation due to severe traffic flow condition. Maximum service flow rate per lane is observed as 1280 veh/h at level of service 'C'. The Peak Hour Factor is reported as 0.78125. Historical traffic volume count provides Annual Average Daily Traffic as 122270 veh/day. Directional split of the traffic flow is observed to be 60 : 40. Assuming that traffic stream consists of 'All Cars' and all drivers are 'Regular Commuters', the number of extra lane(s) (round off to the next higher integer) to be provide, is ________.

Ans. **(6)**

Directional design hourly volume (DDHV)

$$\text{DDHV} = \text{AADT} \times \text{K} \times \text{D}$$

where, D = Volume proportion in major direction, K = The proportion of AADT occuring in peak hour.

$$\text{DDHV} = 12270 \times 0.6 \times K \qquad [\because \ K \text{ Assumed } 1]$$

$$= 7362$$

$$f_{HV} = \text{Heavy veh. adjustment factor} = 1 \text{ for car}$$

$$f_P = \text{Road user familarity adjustment factor}$$

$$= 1 \text{ for regular commuters}$$

As per HCM,

Number of lanes required,

$$N = \frac{DDHV}{PHF \times MSF \times F_{HV} \times f_p}$$

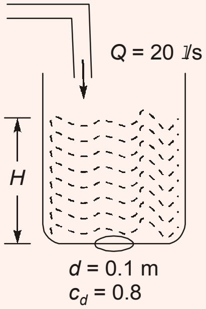
$$= \frac{7362}{0.78125 \times 1280 \times 1 \times 1} = 7.362 = 8 \text{ lanes}$$

Number of extra lanes = 8 – 2 = 6 lanes

End of Solution

Q.53 A circular water tank of 2 m diameter has a circular orifice of diameter 0.1 m at the bottom. Water enters the tank steadily at a flow rate of 20 litre/s and escapes through the orifice. The coefficient of discharge of the orifice is 0.8. Consider the acceleration due to gravity as 9.81 m/s^2 and neglect frictional loses. The height of the water level (in m, round off to two decimal places) in the tank at the steady state, is ______.

Ans. **(0.52)**



Assume H is the level of weter in the tank in steady condition.

For steady water level in the tank

$$\text{Discharge through orifice} = \text{Water enters in the tank}$$

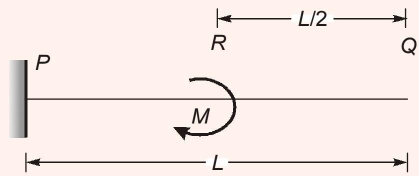
$$c_d \cdot a \cdot \sqrt{2gH} = 20 \times 10^{-3}$$

$$0.8 \times \frac{\pi}{4}(0.1)^2 \sqrt{2gH} = 0.02$$

$$H = 0.5164 \text{ m}$$

End of Solution

Q.54 A cantilever beam PQ of uniform flexural rigidity (EI) is subjected to a concentrated moment M at R as shown in the figure.



The deflection at the free end Q is

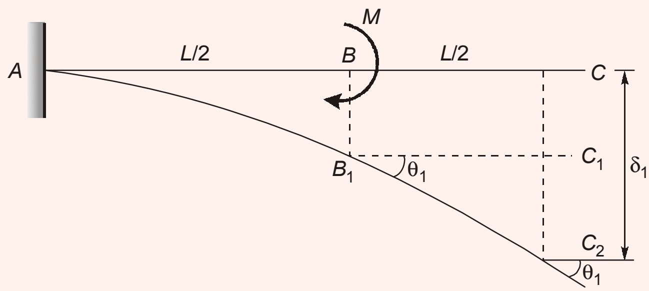
(a) $\dfrac{ML^2}{6EI}$

(b) $\dfrac{ML^2}{4EI}$

(c) $\dfrac{3ML^2}{4EI}$

(d) $\dfrac{3ML^2}{8EI}$

Ans. (d)



$$\delta_c = \delta_1 = CC_1 + C_1C_2$$

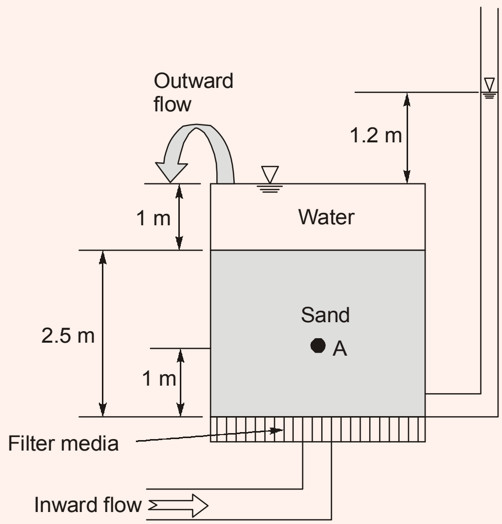
$$= BB_1 + C_1C_2$$

$$= \frac{M\left(\frac{L}{2}\right)^2}{2EI} + \frac{M\left(\frac{L}{2}\right)}{EI}\left(\frac{L}{2}\right)$$

$$\delta_c = \frac{3}{8}\frac{ML^2}{EI}$$

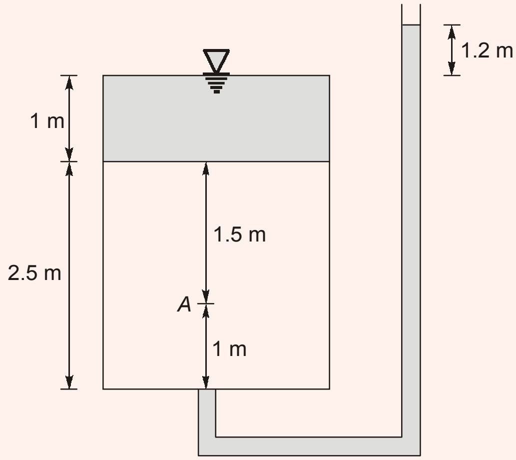
End of Solution

Q.55 Water flows in the upward direction in a tank through 2.5 m thick sand layer as shown in the figure. The void ratio and specific gravity of sand are 0.58 and 2.7, respectively. The sand is fully saturated. Unit weight of water is 10 kN/m^3.



The effective stress (in kPa, round off to two decimal places) at point A, located 1 m above the base of tank, is ________.

Ans. (8.94)



$$\gamma_{suv} = \left(\frac{G-1}{1+e}\right)\gamma_\omega = \left(\frac{2.7-1}{1+0.58}\right)\times 10 = 10.759$$

$$\bar{\sigma} = z\gamma_{suv} - iz\gamma_\omega$$

$$= 1.5(\gamma_{suv}) - \left(\frac{1.2}{2.5}\right)\times 1.5\times\gamma_\omega$$

$$= 8.939 \text{ kN/m}^2$$

End of Solution

■■■■

SECTION A : GENERAL APTITUDE

Q.1 Select the word that fits the analogy:

Partial : Impartial : : Popular : ________

(a) Impopular (b) Dispopular

(c) Mispopular (d) Unpopular

Ans. (d)

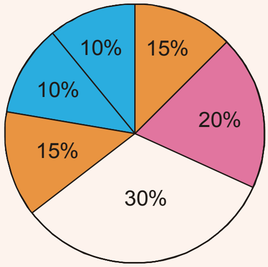
Partial and Impartial are opposite, in the same way popular and unpopular are opposite words.

End of Solution

Q.2 The monthly distribution of 9 Watt LED bulbs sold by two firms X and Y from January to June 2018 is shown in the pie-chart and the corresponding table. If the total number of LED bulbs sold by two firms during April-June 2018 is 50000, then the number of LED bulbs sold by the firm Y during April-June 2018 is ________.

Months	Ratio of LED bulbs sold by two firms X : Y
January	7 : 8
February	2 : 3
March	2 : 1
April	3 : 2
May	1 : 4
June	9 : 11

January	15%
February	20%
March	30%
April	15%
May	10%
June	10%



(a) 11250 (b) 9750

(c) 8250 (d) 8750

Ans. (*)

LED bulbs sold

By
$$Y_{April} = \frac{2}{5} \times 15 = 6\% \quad \text{...(A)}$$

$$Y_{May} = \frac{4}{5} \times 10 = 8\%$$

$$Y_{June} = \frac{10}{20} \times 11 = 5.5\%$$

LED bulb sold by Y during April-June

$$A + B + C = (6 + 8 + 5.5)\% = 19.5\%$$

Total LED bulb sold by X and Y 35% this value = 50000
So, LED bulb sold by Y (April to June)

$$\frac{50000}{35}\times 19.5 = 27857.142$$

[As 35% of total = 5000

$$\text{Total} = \frac{50000}{0.35} = 142857.142$$

Y (April- June) = 19.5% of total 0.195 × 1442857.14 = 2785.142]

No option is matching.

Mistake in paper was that examiner intended to give total as 50000 and the options were place accordingly as 19.5% of 50000 = 9750 which is (d).

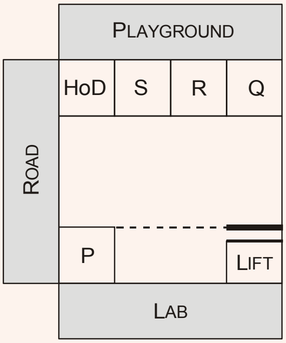
But this will be wrong as total is NOT 50000 as per language. So correct answer is 27857.142.

Which matches with none of options.

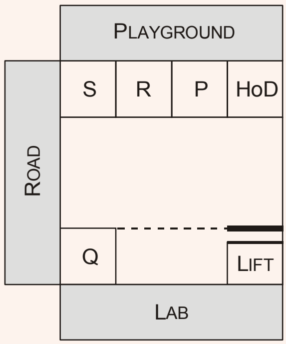
End of Solution

Q.3 After the inauguration of the new building, the head of department (HOD) collated faculty preferences for office space. P wanted a room adjacent to the lab. Q wanted to be close to the lift. R wanted a view of the playground and S wanted a corner office. Assuming that everyone was satisfied, which among the following shows a possible allocation?

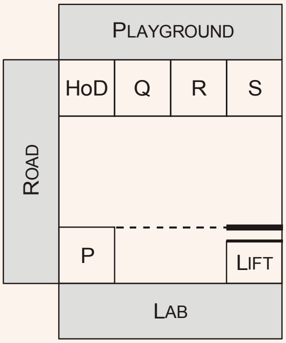
(a)



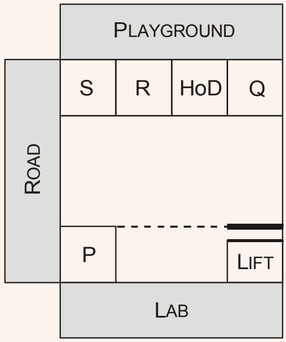
(b)



(c)



(d)



Ans. (d)

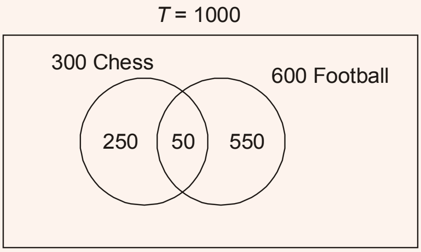
End of Solution

Q.4 In a school of 1000 students, 300 students play chess and 600 students play football. If 50 students play both chess and football, the number of students who play neither is ________.

(a) 150 (b) 50

(c) 100 (d) 200

Ans. (a)



Total number of students playing sports = 850

Total number of students not playing sports = 1000 – 850 = 150

End of Solution

Q.5 Select the most appropriate word that can replace the underlined word without changing the meaning of the sentence:

Now-a-days, most children have a tendency to <u>belittle</u> the legitimate concerns of their parents.

(a) Applaud (b) Begrudge

(c) Disparage (d) Reduce

Ans. (c)

Belittle means to undervalue/ underestimate some as unimportant. Disparage fits in the most appropriate manner.

End of Solution

Q.6 For the year 2019, which of the previous year's calendar can be used?

(a) 2011 (b) 2013

(c) 2012 (d) 2014

Ans. (b)

Year	Number of odd days
2013	1
2014	1
2015	1
2016	2
2017	1
2018	1
Total	**7**

Number of odd days in 2019 = 1, so 2013 calendar is same as 2019.

End of Solution

Q.7 If $f(x) = x^2$ for each $x \in (-\infty, \infty)$, then $\frac{f(f(f(x)))}{f(x)}$ is equal to ________.

(a) $f(x)$
(b) $(f(x))^4$
(c) $(f(x))^2$
(d) $(f(x))^3$

Ans. (d)

$$f(x) = x^2$$
$$f(f(f(x))) = f(f(x^2)) = f(x^4) = (x^4)^2 = x^8$$

So, $$\frac{f(f(f(x)))}{f(x)} = \frac{x^8}{x^2} = x^6 = (x^2)^3 = (f(x))^3$$

End of Solution

Q.8 Rescue teams deployed ________ disaster hit areas combat ________ a lot of difficulties to save the people.

(a) with, at
(b) to, to
(c) with, with
(d) in, with

Ans. (d)

End of Solution

Q.9 Nominal interest rate is defined as the amount paid by the borrower to the lender for using the borrowed amount for a specific period of time. Real interest rate calculated on the basis of actual value (inflation-adjusted), is approximately equal to the difference between nominal rate and expected rate of inflation in the economy.

Which of the following assertions is best supported by the above information?

(a) Under low inflation, real interest rate is low and borrowers get benefited.
(b) Under high inflation, real interest rate is low and borrowers get benefited.
(c) Under low inflation, real interest rate is high and borrowers get benefited.
(d) Under high inflation, real interest rate is low and lenders get benefited.

Ans. (b)

End of Solution

Q.10 The ratio of 'the sum of the odd positive integers from 1 to 100' to 'the sum of the even positive integers from 150 to 200' is ________.

(a) 50 : 91
(b) 1 : 1
(c) 1 : 2
(d) 45 : 95

Ans. (a)

$$\frac{\text{Sum of old numbers from 1 to 100}}{\text{Sum of even numbers from 150 to 200}} = \frac{50^2}{175 \times 26} = \frac{50 \times 50}{175 \times 26} = \frac{2500}{4550}$$

Ratio = 50 : 91

From 1 to 100 = 50 odd number

From 150 to 200 = 26 even number

End of Solution

SECTION B : TECHNICAL

Q.1 For an axle load of 15 tonne on a road, the Vehicle Damage Factor (round off to two decimal places), in terms of the standard axle load of 8 tonne, is ________.

Ans. (12.35)

$$\text{Axle load} = 15\ \text{T}$$
$$\text{Standard axle load} = 8\ \text{T}$$
$$\text{VDF} = \left[\frac{15}{8}\right]^4 = 12.35$$

End of Solution

Q.2 Muskingum method is used in

(a) hydrologic channel routing
(b) hydraulic channel routing
(c) hydrologic reservoir routing
(d) hydraulic reservoir routing

Ans. (a)

End of Solution

Q.3 The traffic starts discharging from an approach at an intersection with the signal turning green. The constant headway considered from the fourth or fifth headway position is referred to as

(a) saturation headway
(b) effective headway
(c) discharge headway
(d) intersection headway

Ans. (a)

End of Solution

Q.4 Soil deposit formed due to transportation by wind is termed as

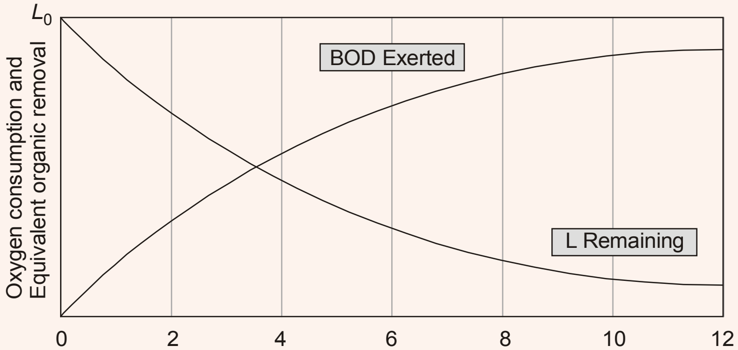
(a) lacustrine deposit
(b) alluvial deposit
(c) estuarine deposit
(d) aeolian deposit

Ans. (d)

Soil deposited by wind is Aeolian soil.

End of Solution

Q.5 The relationship between oxygen consumption and equivalent biodegradable organic removal (i.e. BOD) in a closed container with respect to time is shown in the figure.



Assume that the rate of oxygen consumption is directly proportional to the amount of degradable organic matter and is expressed as $\frac{dL_t}{dt} = -kL_t$, where, L_1 (in mg/litre) is the oxygen equivalent of the organics remaining at time t and k (in d^{-1}) is the degradation rate constant. L_0 is the oxygen of organic matter at time, $t = 0$

In the above context, the correct expression is

(a) $L_t = L_0(1 - e^{-kt})$ (b) $BOD_t = L_0 - L_t$

(c) $L_0 = L_t e^{-kt}$ (d) $BOD_5 = L_5$

Ans. (b)

End of Solution

Q.6 A one-dimensional consolidation test is carried out on a standard 19 mm thick clay sample. The oedometer's deflection gauge indicates a reading of 2.1 mm, just before removal of the load, without allowing any swelling. The void ratio is 0.62 at this stage. The initial void ratio (round off to two decimal places) of the standard specimen is ________.

Ans. (0.82)

Oedometer reading = 2.1 mm

16 mm thick, $e = 0.62$

$$\frac{\Delta H}{H_0} = \frac{\Delta e}{1+e_0} = \frac{e_0 - e_f}{1+e_0}$$

$$\frac{2.1\text{ mm}}{19\text{ mm}} = \frac{e_0 - 0.62}{1+e_0}$$

$$e_0 = 0.82$$

End of Solution

Q.7 The velocity components in the x and y directions for an incompressible flow are given as $u = (-5 + 6x)$ and $v = -(9 + 6y)$, respectively. The equation of the streamline is

(a) $(-5 + 6x)(9 + 6y) = \text{constant}$ (b) $\frac{-5+6x}{9+6y} = \text{constant}$

(c) $\frac{9+6y}{-5+6x} = \text{constant}$ (d) $(-5+6x) - (9+6y) = \text{constant}$

Ans. (a)

Given : $u = -5 + 6x$

$v = -(9 + 6y)$

Equation of streamline

$$\frac{dx}{u} = \frac{dy}{v}$$

$$\frac{dx}{-5+6x} = \frac{dy}{-(9+6y)}$$

Integrating it,

$$\ln(-5+6x)^{1/6} = -\ln(9+6y)^{1/6} + \ln C^{1/6}$$

$$\frac{1}{6}\ln(-5+6x)\cdot(9+6y) = \frac{1}{6}\ln C$$

Take antilog,

$$(-5 + 6x)(9 + 6y) = \text{constant}$$

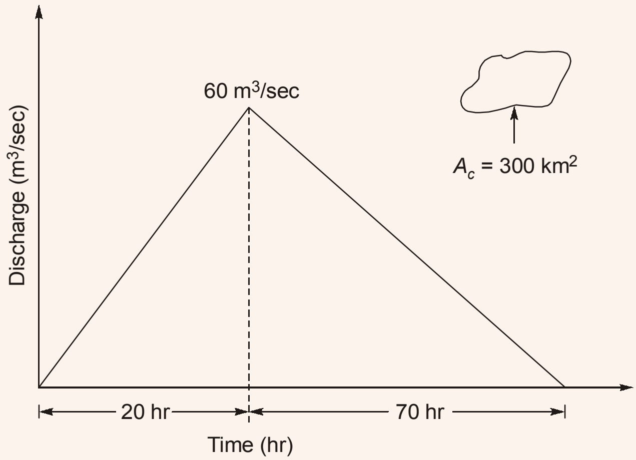
$$u.v = \text{constant}$$

End of Solution

Q.8 A triangular direct runoff hydrograph due to a storm has a time base of 90 hours. The peak flow of 60 m^3/s occurs at 20 hours from the start of the storm. The area of catchment is 300 km^2. The rainfall excess of the storm (in cm), is

(a) 5.40 (b) 2.00
(c) 3.24 (d) 6.48

Ans. **(c)**



$$\Rightarrow \left[\frac{\frac{1}{2}\times 60\,m^3/s \times 90 \times 3600\ s}{300\times 10^6 m^2}\times 100\right] cm = \text{Rainfall excess}$$

$\therefore$ Rainfall excess = 3.24 cm

End of Solution

Q.9 24-h traffic count at a road section was observed to be 1000 vehicles on a Tuesday in the month of July. If daily adjustment factor for Tuesday is 1.121 and monthly adjustment factor for July is 0.913, the Annual Average Daily Traffic (in veh/day, round off to the nearest integer) is _______.

Ans. **(1023)**

$$T_{24} = 1000 \text{ veh (Tuesday)}$$
$$\text{DAF} = 1.121$$
$$\text{AADT} = ?$$
$$\text{MAF} = 0.913$$
$$T_{week} = T_{24} \times \text{DAF}$$
$$= 1000 \times 1.121 = 1121$$
$$\text{AADT} = MAF \times ADT = (0.913 \times 1121)$$
$$= 1023.473$$
$$= 1023 \text{ VPD}$$

End of Solution

Q.10 Velocity distribution in a boundary layer is given by $\frac{u}{U_\infty} = \sin\left(\frac{\pi}{2}\frac{y}{\delta}\right)$, where u is the velocity at vertical coordinate y, U_∞ is the free stream velocity and δ is the boundary layer thickness. The values of U_∞ and δ are 0.3 m/s and 1.0 m, respectively. The velocity gradient $\left(\frac{\partial u}{\partial y}\right)$ (in s^{-1}, round off to two decimal places) at $y = 0$, is ________.

Ans. **(0.47)**

Given : $\frac{u}{u_\infty} = \sin\left(\frac{\pi}{2} \cdot \frac{y}{\delta}\right)$

$$u_\infty = 0.3 \text{ m/s}$$
$$\delta = 1 \text{ m}$$

$$\frac{du}{dy} = \frac{d}{dy} u_\infty \cdot \sin\left(\frac{\pi}{2} \cdot \frac{y}{\delta}\right)$$

$$= \frac{u_\infty \cdot \pi}{2\delta} \cos\left(\frac{\pi}{2} \cdot \frac{y}{\delta}\right)$$

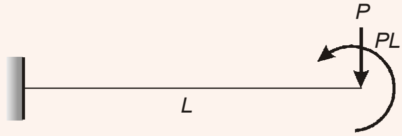
At $y = 0$ and $\delta = 1$

$$\left.\frac{du}{dy}\right|_{y=0} = \frac{0.3\pi}{2(1)} \cos\left(\frac{\pi}{2} \cdot \frac{0}{1}\right)$$

$$= 0.47 \text{ s}^{-1}$$

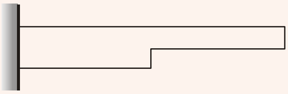
End of Solution

Q.11 A weightless cantilever beam of span L is loaded as shown in the figure. For the entire span of the beam, the material properties are identical and the cross-section is rectangular with constant width.



From the flexure-critical perspective, the most economical longitudinal profile of the beam to carry the given loads amongst the options given below, is

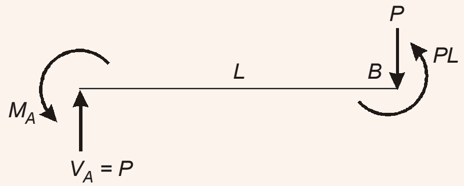
(a) 

(b) 

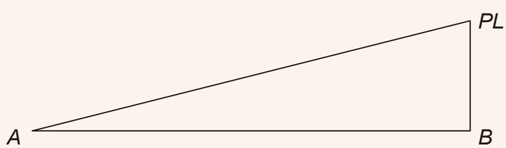
(c) 

(d) 

Ans. (a)



$$(-PL) + (PL) + (-M_A) = 0$$
$$M_A = 0$$



Bending moment diagram

For most economical,
Maximum cross-section is given where maximum bending moment occurs.

So, option (a) is correct.

End of Solution

Q.12 Two identically sized primary settling tanks receive water for Type-I settling (discrete particles in dilute suspension) under laminar flow conditions. The surface overflow rate (SOR) maintained in the two tanks are 30 m^3/m^2.d and 15 m^3/m^2.d. The lowest diameters of the particles, which shall be settled out completely under SORs of 30 m^3/m^2.d are designated as d_{30} and d_{15} respectively. The ratio $\dfrac{d_{30}}{d_{15}}$ (round off to two decimal places), is ________.

Ans. (1.41)

For type-I setting, Stokes law is applicable.

$$V_s \propto d^2$$

$$\frac{d_{30}^2}{d_{15}^2} = \frac{30}{15} = 2$$

$$\frac{d_{30}}{d_{15}} = \sqrt{2} = 1.41$$

End of Solution

Q.13 As per **IS 456:2000**, the pH value of water for concrete mix shall NOT be less than

(a) 6.0
(b) 5.0
(c) 4.5
(d) 5.5

Ans. (a)

1. Minimum pH value of water for concrete = 6.0

As per IS code provision no. 5.4.2, the pH value of water shall not less than 6.0.

End of Solution

Q.14 Superpassage is a canal cross-drainage structure in which

(a) canal water flows under pressure below a natural stream
(b) natural stream water flows under pressure below a canal
(c) canal water flows with free surface below a natural stream
(d) natural stream water flows with free surface below a canal

Ans. (c)

End of Solution

Q.15 A soil has dry weight of 15.5 kN/m^3, specific gravity of 2.65 and degree of saturation of 72%. Considering the unit weight of water as 10 kN/m^3, the water content of the soil (in %, round off to two decimal places) is ________.

Ans. (19.28)

$$\gamma_d = 15.5 \text{ kN/m}^3, \quad G = 2.65, \quad S = 72\%$$

$$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.65 \times 10}{1+e} = 15.5$$

$$e = 0.7096$$

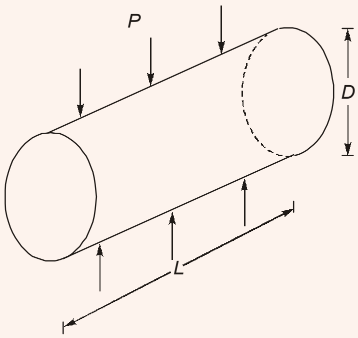
$$w = \frac{Se}{G} = \frac{0.72 \times 0.7096}{2.65} = 0.1928$$

$$w = 19.28\%$$

End of Solution

Q.16 The maximum applied load on a cylindrical concrete specimen of diameter 150 mm and length 300 mm tested as per the split tensile strength test guidelines of **IS 5816 : 1999** is 157 kN. The split tensile strength (in MPa, round off to one decimal place) of the specimen is _______.

Ans. **(2.2)**



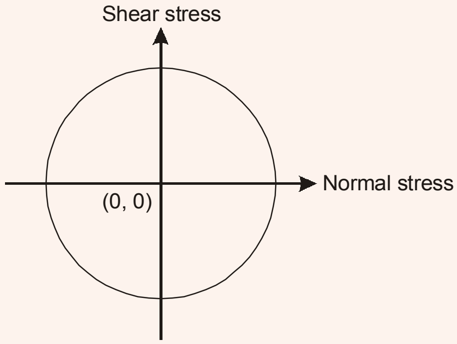
$$P = 157 \text{ kN}$$
$$D = 150 \text{ mm}$$
$$L = 300 \text{ mm}$$

In split tensile strength test, split tensile strength of concrete

$$f_{et} = \frac{2P}{\pi DL} = \frac{2 \times 157000}{\pi \times 150 \times 300}$$
$$= 2.22 \text{ N/mm}^2$$

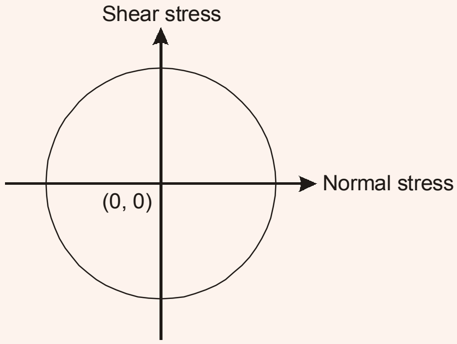
End of Solution

Q.17 The state of stress represented by Mohr's circle shown in the figure is



(a) hydrostatic stress (b) uniaxial tension
(c) biaxial tension of equal magnitude (d) pure shear

Ans. **(d)**



In pure shear condition, Mohr's circle has its center at origin.

End of Solution

Q.18 The ratio of the plastic moment capacity of a beam section to its yield moment capacity is termed as

(a) aspect ratio
(b) load factor
(c) shape factor
(d) slenderness ratio

Ans. (c)

$$\text{Ratio of } \frac{M_p}{M_y} = \text{Shape factor}$$

End of Solution

Q.19 A sample of 500 g dry sand, when poured into a 2 litre capacity cylinder which is partially filled with water, displaces 188 cm^3 of water. The density of water is 1 g/cm^3. The specific gravity of the sand is

(a) 2.55
(b) 2.72
(c) 2.66
(d) 2.52

Ans. (c)

$$W_s = 500 \text{ gm}$$

$$V_s = 188 \text{ cc}$$

$$\gamma_s = \frac{W_s}{V_s}$$

$$G_s = \frac{\gamma_s}{\gamma_w} = \frac{500/188}{1} = 2.66$$

End of Solution

Q.20 The value of $\lim_{x \to \infty} \frac{\sqrt{9x^2 + 2020}}{x + 7}$ is

(a) 1
(b) 3
(c) $\frac{7}{9}$
(d) Indeterminable

Ans. (b)

$$\lim_{x \to \infty} \frac{3x\sqrt{1 + \frac{2020}{x^2}}}{x\left(1 + \frac{7}{x}\right)} = 3$$

End of Solution

Q.21 The ordinary differential equation $\frac{d^2u}{dx^2} - 2x^2u + \sin x = 0$ is

(a) linear and homogeneous (b) nonlinear and homogeneous
(c) nonlinear and nonhomogeneous (d) linear and nonhomogeneous

Ans. **(d)**

Its solution is of the type $u = f(x)$, i.e., dependent variable is u.
Hence, given equation is Linear & Non-Homogeneous.

End of Solution

Q.22 A gas contains two types of suspended particle having average sizes of 2 μm and 50 μm. Amongst the options given below, the most suitable pollution control strategy for removal of these particles is

(a) electrostatic precipitator followed by cyclonic separator
(b) bag filter followed by electrostatic precipitator
(c) settling chamber followed by bag filter
(d) electrostatic precipitator followed by venturi scrubber

Ans. **(c)**

End of Solution

Q.23 The integral

$$\int_0^1 \left(5x^3 + 4x^2 + 3x + 2\right) dx$$

is estimated numerically using three alternative methods namely the rectangular, trapezoidal and Simpson's rules with a common step size. In this context, which one of the following statement is TRUE?

(a) Simpson's rule as well as rectangular rule of estimation will give non zero error.
(b) Only Simpson's rule of estimation will give zero error.
(c) Simpson's rule, rectangular rule as well as trapezoidal rule of estimation will give non-zero error.
(d) Only the rectangular rule of estimation will given zero error.

Ans. **(b)**

Because integral is a polynomial of 3rd degree so Simpson's rule will give error free answer.

End of Solution

Q.24 A fair (unbiased) coin is tossed 15 times. The probability of getting exactly 8 Heads (round off to three decimal places), is ________.

Ans. **(0.196)**

$$P(H) = \frac{1}{2}$$

$$P(T) = \frac{1}{2}$$

Probability of getting exactly 8 heads out of 15 trial $= {}^{15}C_8\left[\frac{1}{2}\right]^8 \times \left[\frac{1}{2}\right]^{15-8}$

$$= 0.196$$

End of Solution

Q.25 The following partial differential equation is defined for $u : u(x, y)$

$$\frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial x^2};\ y \geq 0;\ x_1 \leq x \leq x_2$$

The set of auxiliary conditions necessary to solve the equation uniquely, is

(a) one initial condition and two boundary conditions

(b) three initial conditions

(c) two initial conditions and one boundary condition

(d) three boundary conditions

Ans. (a)

Given: DE is $\frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial x^2};\ y \geq 0;\ x_1 \leq x \leq x_2$

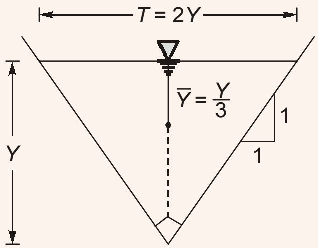
$\because$ y is given as ≥ 0 so we take it as time.

Hence, above equation is nothing but one-D heat equation which requires one initial condition and two boundary condition.

End of Solution

Q.26 A hydraulic jump occurs, in a triangular (V-shaped) channel with side slopes 1:1 (vertical to horizontal). The sequent depths are 0.5 m and 1.5 m. The flow rate (in m^3/s, round off to two decimal places) in the channel is ________.

Ans. (1.73)



$$A = \frac{1}{2} \times 2Y \times Y = Y^2$$

$$\bar{Y} = \frac{Y}{3}$$

For a horizontal and frictionless channel

$$\text{Specific Force } (F) = A\bar{Y} + \frac{Q^2}{Ag} = \text{Constant}$$

$$\Rightarrow \quad Y^2\left(\frac{Y}{3}\right) + \frac{Q^2}{(Y^2)g} = \text{Constant}$$

$$\Rightarrow \quad \frac{Y^3}{3} + \frac{Q^2}{gY^2} = \text{Constant}$$

If Y_1 and Y_2 are conjugate depths

$$\frac{Y_1^3}{3}+\frac{Q^2}{gY_1^2} = \frac{Y_2^3}{3}+\frac{Q^2}{gY_2}$$

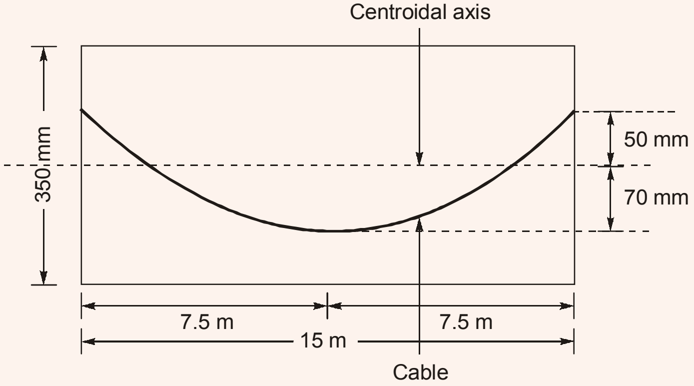
$$\Rightarrow \quad \frac{0.5^3}{3}+\frac{Q^2}{g\times 0.5^2} = \frac{1.5^3}{3}+\frac{Q^2}{g\times 1.5^2}$$

$$\Rightarrow \quad \frac{1.5^3}{3}-\frac{0.5^3}{3} = \frac{Q^2}{g}\left(\frac{1}{0.5^2}-\frac{1}{1.5^2}\right)$$

$$Q = 1.728 \text{ m}^3/\text{sec}$$

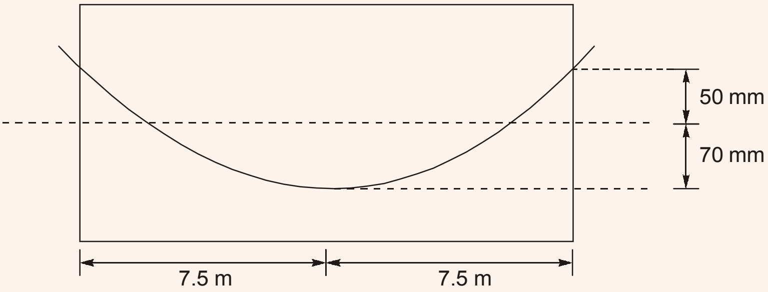
End of Solution

Q.27 A concrete beam of span 15 m, 150 mm wide and 350 mm deep is prestressed with a parabolic cable as shown in the figure (not drawn to the scale). Coefficient of friction for the cable is 0.35, and coefficient of wave effect is 0.0015 per metre.



If the cable is tensioned from one end only, the percentage loss (round off to one decimal place) in the cable force due to friction, is ________.

Ans. (4.49)



Jacking from one end

$$x = L = 15 \text{ m}$$

Wobble correction factor, $K = 0.0015$

Coefficient of friction $= 0.35 = \mu$

P = Not given

p_0 = Unknown

Change of gradient, $\alpha = \tan\alpha = \frac{8h}{L} = \frac{8 \times 120}{15000} = 0.064$

% loss of stress in steel due to friction

$$= \frac{p_0(Kx + \mu\alpha)}{p_0} \times 100$$

$= (0.0015 \times 15 + 0.35 \times 0.064) \times 100$

$= 4.49\%$

End of Solution

Q.28 The Fourier series to represent $x - x^2$ for $-\pi \le x \le \pi$ is given by

$$x - x^2 = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos nx + \sum_{n=1}^{\infty} b_n \sin nx$$

The value of a_0 (round off to two decimal places), is _______.

Ans. (–6.58)

$$a_0 = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x)dx = \frac{1}{\pi}\int_{-\pi}^{\pi} (x - x^2)dx = \frac{-1}{\pi}\int_{0}^{\pi} 2x^2 dx$$

$$= -\frac{1}{\pi}\left(\frac{2x^3}{3}\right)_0^{\pi} = -\frac{2}{3\pi}\left[\pi^3\right] = \frac{-2\pi^2}{3} = -6.58$$

End of Solution

Q.29 The diameter and height of a right circular cylinder are 3 cm and 4 cm, respectively. The absolute error in each of these two measurements is 0.2 cm. The absolute error in the computed volume (in cm^3, round off to three decimal places), is _______.

Ans. (5.18)

Let diameter, x = 3 and height = y = 4 and error = ± 0.2

$$V = \pi\left(\frac{x}{2}\right)^2 y = \frac{\pi x^2 y}{4}$$

$\therefore$ $V = f(x, y)$

So, $$dV = \left(\frac{\partial V}{\partial x}\right)dx + \left(\frac{\partial V}{\partial y}\right)dy$$

i.e., $$dV = \left(\frac{1}{2}\pi xy\right)dx + \left(\frac{\pi x^2}{4}\right)dy$$

$$= \frac{1}{2}\pi \times 3 \times 4 \times (0.2) + \frac{\pi}{4} \times (3)^2 \times (0.2) = 1.65\pi$$

$= 1.65 \times 3.14 = 5.18$ (approx)

i.e., absolute error = | 5.18 | = 5.18

End of Solution

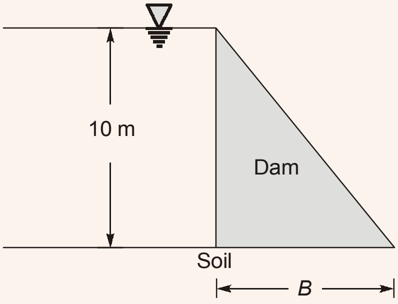
Q.30 The ion product of water (pK_w) is 14. If a rain water sample has a pH of 5.6, the concentration of OH^- in the sample (in 10^{-9} mol/litre, round off to one decimal place), is ________.

Ans. (3.98)

$$pH + pOH = 14$$
$$pOH = 14 - 5.6 = 8.4$$
$$-\log [OH^-] = 8.4$$
$$[OH^-] = 10^{-8.4} \text{ moles}/lt$$
$$= 10^{-8.4+9} \times 10^{-9} \text{ moles}/lt$$
$$= 3.98 \times 10^{-9} \text{ moles}/lt$$

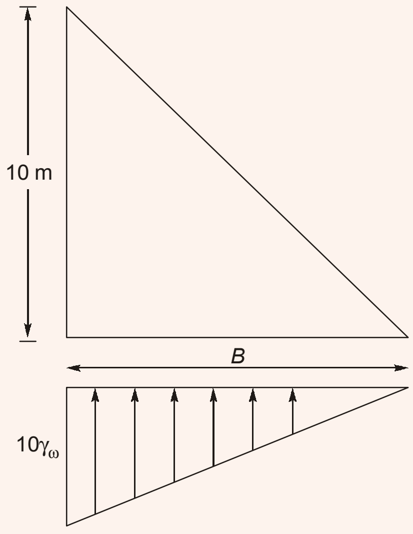
End of Solution

Q.31 A concrete dam holds 10 m of static water as shown in the figure (not drawn to the scale). The uplift assumed to vary linearly from full hydrostatic head at the heel, to zero at the toe of dam. The coefficient of friction between the dam and foundation soil is 0.45. Specific weights of concrete and water are 24 kN/m^3 and 9.81 kN/m^3, respectively.



For NO sliding condition, the required minimum base width B (in m, round off to two decimal places) is __________.

Ans. (15.873 m)



$$\mu = 0.45$$

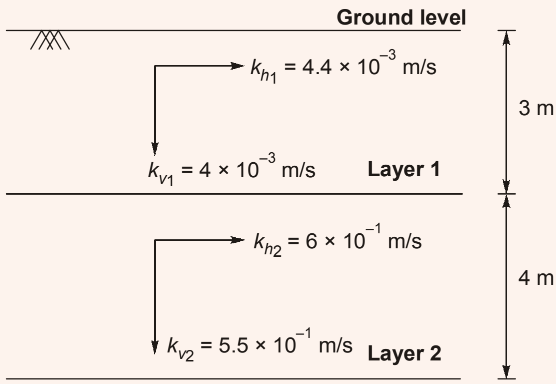
$$\gamma_{conc.} = 24 \text{ kN/m}^3$$

$$B_{\text{min sliding}} = \frac{10}{0.45(2.4-1)}$$

$$= 15.873 \text{ m}$$

End of Solution

Q.32 Permeability tests were carried out on the samples collected from two different layers as shown in the figure (not drawn to the scale). The relevant horizontal (k_h) and vertical (k_v) coefficients of permeability are indicated for each layer.



The ratio of the equivalent horizontal to vertical coefficients of permeability, is

(a) 37.29
(b) 80.20
(c) 0.03
(d) 68.25

Ans. (a)

$$\frac{k_{eq.H}}{k_{eq.V}} = \frac{\dfrac{\Sigma K_i Z_i}{\Sigma Z_i}}{\dfrac{\Sigma Z_i}{\Sigma \dfrac{Z_i}{K_i}}} = \frac{\dfrac{4.4 \times 10^{-3} \times 3 + 6 \times 10^{-1} \times 4}{7}}{\dfrac{7}{\dfrac{3}{4 \times 10^{-3}} + \dfrac{4}{5.5 \times 10^{-1}}}}$$

$$= \frac{0.3447}{9.24 \times 10^{-3}} = 37.29$$

End of Solution

Q.33 A sample of water contain an organic compound $C_8H_{16}O_8$ at a concentration of 10^{-3} mol/litre. Given that the atomic weight of C = 12 g/mol, H = 1 g/mol, and O = 16 g/mol, the theoretical oxygen demand of water (in g of O_2 per litre, round off to two decimal places), is __________.

Ans. **(0.256)**

$C_8H_{16}O_8$ of conc. 10^{-3} moles/*lt* required O_2 (in gm/*lt*)

$$C_8H_{16}O_8 + 8O_2 \rightarrow 8CO_2 + 8H_2O$$
$$1 \text{ mole} \quad 8 \text{ mole}$$

1 mole of $C_8H_{16}O_2$ requires 8 moles of O_2 for its decomposition

$$240 \text{ gm} = 128 \text{ gm}$$

or $$10^{-3} \text{ moles} = 8 \times 10^{-3} \text{ moles}$$
$$= 8 \times 10^{-3} \times 32$$
$$= 0.256 \text{ gm}/lt$$

End of Solution

Q.34 A constant head permeability test was conducted on a soil specimen under a hydraulic gradient of 2.5. The soil specimen has specific gravity of 2.65 and saturated water content of 20%. If the coefficient of permeability of the soil is 0.1 cm/s, the seepage velocity (in cm/s, round off to two decimal places) through the soil specimen is ________.

Ans. **(0.72)**

$$\text{Void ratio, } e = \frac{wG}{s} = \frac{0.2 \times 2.65}{1} = 0.53$$

$$\text{Porosity, } n = \frac{e}{1+e} = 0.3464$$

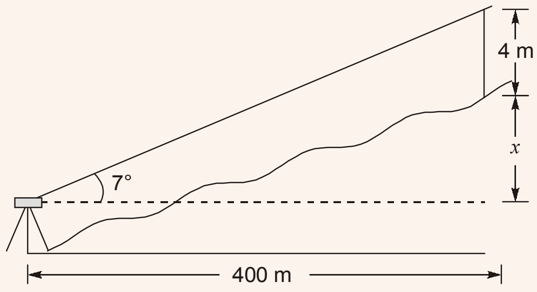
$$\text{Seepage velocity, } V_s = \frac{v}{n} = \frac{Ki}{n}$$

$$= \frac{0.1 \times 2.5}{0.3464} = 0.72 \text{ cm/sec}$$

End of Solution

Q.35 A theodolite is set up at station A. The RL of instrument axis is 212.250 m. The angle of elevation to the top of a 4 m long staff, held vertical at station B, is 7°. The horizontal distance between station A and B is 400 m. Neglecting the errors due to curvature of earth and refraction, the RL (in m, round off to three decimal places) of station B is ________.

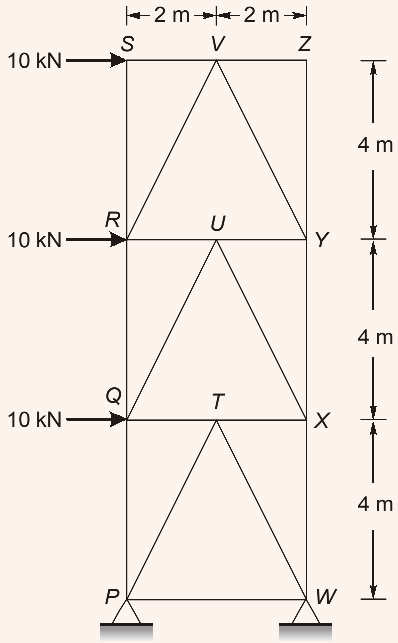
Ans. **(257.363)**



$$V = 400 \tan 7° = 49.113$$
$$x = (49.113 - 4) = 45.113$$
$$RL_B = 212.25 + 45.113 = 257.363 \text{ m}$$

End of Solution

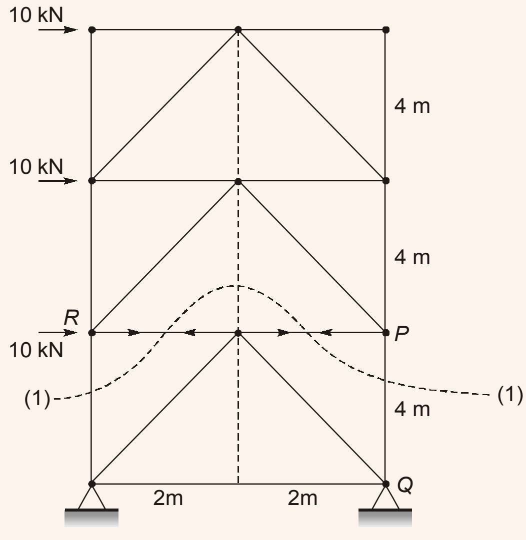
Q.36 The plane truss has hinge supports at P and W and is subjected to the horizontal forces as shown in the figure (not drawn to the scale).



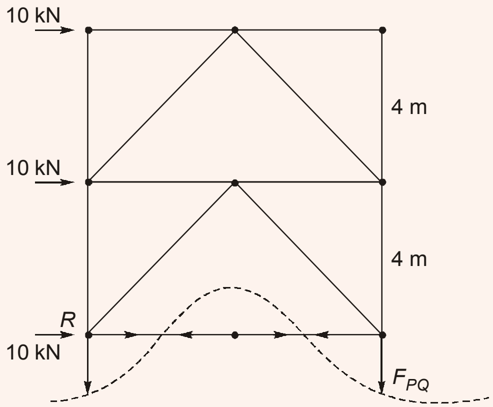
Representing the tensile force with '+' sign and the compressive force with '–' sign, the force in member *XW* (in kN, round off to the nearest integer), is ________.

Ans. **(–30 kN)**

Force in *PQ*



Considering the section above (1) – (1)
Taking moment about 'R'



$$\Sigma M_{RL} = 0$$

$$(10 \times 4) + (10 \times 8) + F_{PQ} \times 4 = 0$$

$$F_{PQ} = -\frac{120}{4} = -30 \text{ kN} = 30 \text{ kN (Comp.)}$$

End of Solution

Q.37 A 4 × 4 matrix [P] is given below

$$[P] = \begin{bmatrix} 0 & 1 & 3 & 0 \\ -2 & 3 & 0 & 4 \\ 0 & 0 & 6 & 1 \\ 0 & 0 & 1 & 6 \end{bmatrix}$$

The eigen values of [P] are

(a) 0, 3, 6, 6
(b) 1, 2, 3, 4
(c) 1, 2, 5, 7
(d) 3, 4, 5, 7

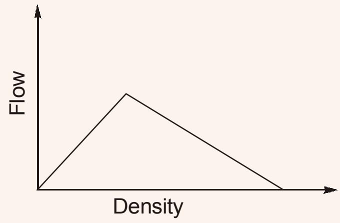
Ans. **(c)**

$$|P| = 70 \text{ and Trace } (P) = 15$$

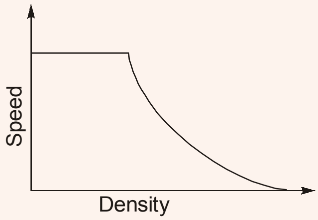
So, only option, i.e., (c) (1, 2, 5, 7) satisfies.

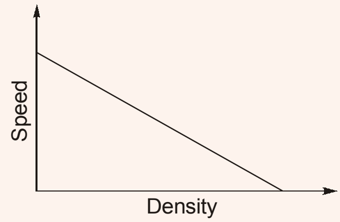
End of Solution

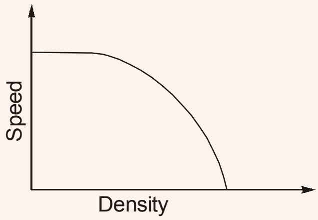
Q.38 The flow-density relationship of traffic on a headway is shown in the figure

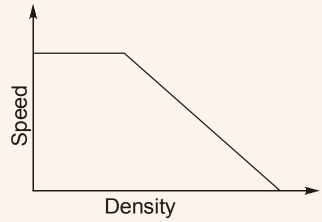


The correct representation of speed-density relationship of the traffic on this highway is

(a) 

(b) 

(c) 

(d) 

Ans. (a)

End of Solution

Q.39 Alkalinity of water, in equivalent/litre (eq/litre), is given by

$$\left\{HCO_3^-\right\} + 2\left\{CO_3^{2-}\right\} + \left\{OH^-\right\} - \left\{H^+\right\}$$

where, { } represents concentration in mol/litre. For a water sample, the concentration of HCO_3^- = 2×10^{-3} mol/litre, CO_3^{2-} = 3.04×10^{-4} mol/litre and the pH of water = 9.0. The atomic weights are : Ca = 40; C = 12; and O = 16. If the concentration of OH^- and H^+ are NEGLECTED, the alkalinity of the water sample (in mg/litre as $CaCO_3$), is

(a) 65.2
(b) 50.0
(c) 100.0
(d) 130.4

Ans. (d)

Alkalinity of water sample is due to presence of

$[HCO_3^-]$ and $[CO_3^{2-}]$

Total alkalinity = 1 mole of $[HCO_3^-]$ + 2 mole of $[CO_3^{2-}]$ in terms of $CaCO_3$

$= (2 \times 10^{-3} \times 50 + 2 \times 3.04 \times 10^{-4} \times 50) \times 10^3$ mg/l

= 130.4 mg/l as $CaCO_3$

End of Solution

Q.40 Group-I gives a list of test methods for evaluating properties of aggregates. Group-II gives the list of properties to be evaluated.

Group-I : Test Methods	Group-II: Properties
P. Soundness test	1. Strength
Q. Crushing test	2. Resistance to weathering
R. Los Angeles abrasion test	3. Adhesion
S. Stripping value test	4. Hardness

The correct match of test methods under Group-I to properties under Group-II, is

(a) P-4, Q-1, R-2, S-3
(b) P-2, Q-4, R-3, S-1
(c) P-2, Q-1, R-4, S-3
(d) P-3, Q-4, R-1, S-2

Ans. **(c)**

End of Solution

Q.41 A waste to energy plant burns dry solid waste of composition : Carbon = 35%, Oxygen = 26%, Hydrogen = 10%, Sulphur = 6%, Nitrogen = 3% and Inerts = 20%. Burning rate is 1000 tonnes/d. Oxygen in air by weight is 23%. Assume complete conversion of Carbon to CO_2. Hydrogen to H_2O, Sulphur to SO_2 and Nitrogen to NO_2. Given Atomic weighs : H = 1, C = 12, N = 14, O = 16, S = 32.

The stoichiometric (theoretical) amount of air (in tonnes/d, round off to the nearest integer) required for complete burning of this waste, is ________.

Ans. **(6957)**

$$\underbrace{C}_{12} + \underbrace{O_2}_{32} \longrightarrow CO_2$$

Oxygen required for 350 tonne/day

$$\frac{32}{12} \times 350 = 933.33$$

$$\underbrace{4H}_{4} + \underbrace{O_2}_{32} \longrightarrow 2H_2O$$

Oxygen required for 100 tonne/day

$$\frac{32}{4} \times 100 = 800$$

$$\underbrace{S}_{32} + \underbrace{O_2}_{32} \longrightarrow SO_2$$

Oxygen required for 60 tonne/day

$$\frac{32}{32} \times 60 = 60$$

$$\underbrace{N}_{14} + \underbrace{O_2}_{32} \longrightarrow NO_2$$

Oxygen required for 60 tonne/day

$$\frac{32}{14} \times 30 = 68.57$$

$$\text{Total } O_2 = 1861.9 \text{ tonne/day}$$

$$\text{Available } O_2 \text{ in waste} = 260 \text{ tonne/day}$$

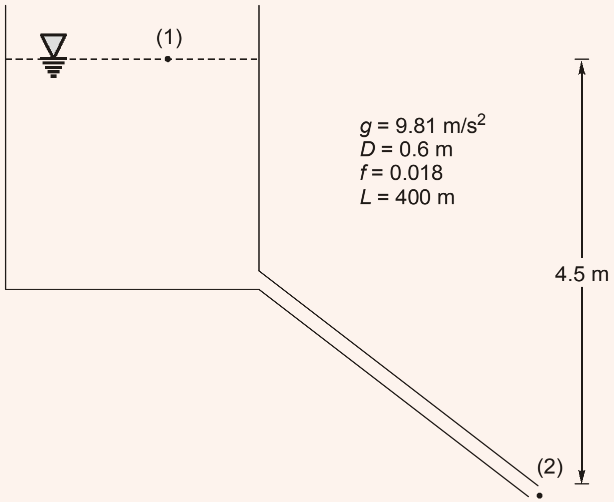
$$\text{Required} = 1861.9 - 260 = 1601.9 \text{ tonne/day}$$

$$\text{Amount of air required} = \frac{1601.9}{0.23} = 6964.78 \text{ tonne/day} \simeq 6965 \text{ tonne/day}$$

End of Solution

Q.42 A cast iron pipe of diameter 600 mm and length 400 m carries water from a tank and discharges freely into air at a point 4.5 m below the water surface in the tank. The friction factor of the pipe is 0.018. Consider acceleration due to gravity as 9.81 m/s^2. The velocity of the flow in pipe (in m/s, round off to two decimal places) is ________.

Ans. **(2.56)**



Apply energy equation between (1) and (2)

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+z_1 = \frac{P_2}{\rho g}+\frac{V_2^2}{2g}+z_2+h_f$$

$$4.5 = \frac{f\cdot L\cdot V^2}{2gD}+0.5\frac{V^2}{2g}+\frac{V^2}{2g}$$

$$4.5 = \frac{(0.018)(400)\cdot V^2}{2(9.81)(0.6)}+\frac{1.5V^2}{2g}$$

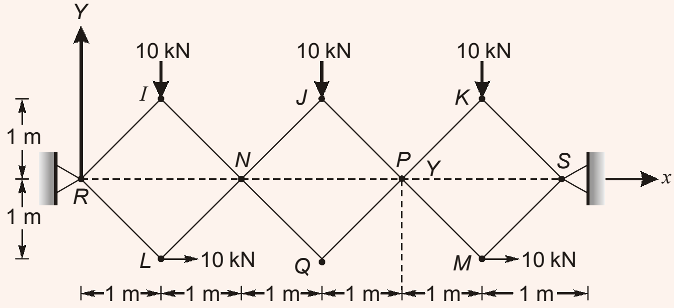
$$4.5 = \frac{12V^2}{2g}+\frac{1.5V^2}{2g}$$

$$V^2 = 6.54$$

$$V = 2.557 \text{ m/s} \simeq 2.56 \text{ m/s}$$

End of Solution

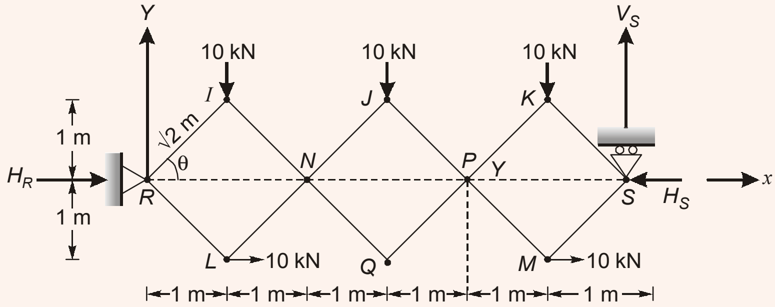
Q.43 Joints I, J, K, L, Q and M of the frame shown in the figure (not drawn to the scale) are pins. Continuous members IQ and IJ are connected through a pin at N. Continuous members JM and KQ are connected through a pin at P. The frame has hinge supports at joints R and S. The loads acting at joints I, J and K are along the negative Y direction and the loads acting at joints I, M are along the positive X direction.



The magnitude of the horizontal component of reaction (in kN) at S, is

(a) 15
(b) 10
(c) 5
(d) 20

Ans. (a)



Remove hinge at support S and replace it with roller support as shown in the figure.

Ist **Step :** Find coordinates of all the points where forces are acting.

$$y_I = \sqrt{2}\sin\theta,\ y_j = \sqrt{2}\sin\theta, y_k = \sqrt{2}\sin\theta$$

$$x_L = \sqrt{2}\cos\theta,\ x_m = 5\sqrt{2}\cos\theta, x_S = 6\sqrt{2}\cos\theta$$

IInd **Step :** Find virtual displacements of all the points.

$$\delta y_I = \sqrt{2}\cos\theta d\theta,\ \delta y_j = \sqrt{2}\cos\theta d\theta,\ \delta y_k = \sqrt{2}\cos\theta d\theta$$

$$\delta x_L = -\sqrt{2}\sin\theta d\theta,\ \delta x_m = -5\sqrt{2}\sin\theta d\theta,\ \delta x_S = -6\sqrt{2}\sin\theta d\theta$$

IIIrd **Step :** Use principle of virtual work to find unknown horizontal force H_S

$$\Rightarrow \qquad \delta U = 0$$

$$= \left[-10\times\sqrt{2}\cos\theta d\theta\right]\times 3 + \left[10\times-\sqrt{2}\sin\theta d\theta\right] + \left[10\times-5\sqrt{2}\sin\theta d\theta\right] - \left[H_s\times-6\sqrt{2}\sin\theta d\theta\right]$$

$$H_s = \frac{30\sqrt{2}\cos\theta + 10\sqrt{2}\sin\theta + 50\sqrt{2}\sin\theta}{6\sqrt{2}\sin\theta}$$

Substituting, $\theta = 45°$, $H_s = \dfrac{90}{6} = 15$ kN

Note : Sign conventions

If a force acts along positive x or positive y-axis, take it as positive.
If a force acts along negative x or negative y-axis, take it as negative.

End of Solution

Q.44 The design speed of a two-lane two-way road is 60 km/h and the longitudinal coefficient of friction is 0.36. The reaction time of a driver is 2.5 seconds. Consider acceleration due to gravity as 9.8 m/s^2. The intermediate sight distance (in m, round off to the nearest integer) required for the load is ________.

Ans. **(162)**

Given : $f = 0.36$; $v = 60$ km; $g = 9.8$ m/s^2; $t_R = 2.5$s

$$\text{SSD} = \left(0.278Vt_R + \frac{V^2}{254f}\right)$$

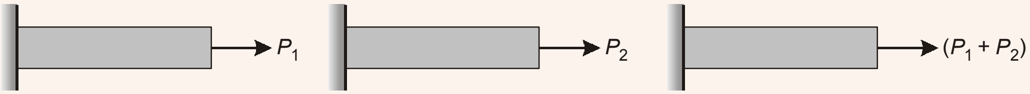
$$= 0.278 \times 60 \times 2.5 + \frac{60^2}{254 \times 0.36}$$

$$= 41.7 + 39.37 = 81 \text{ m}$$

$$\text{ISD} = 2 \times \text{SSD} = 81 \times 2 = 162 \text{ m}$$

End of Solution

Q.45 A prismatic linearly elastic bar of length, L, cross-sectional area A, and made up of a material with Young's modulus E, is subjected to axial tensile force as shown in the figures. When the bar is subjected to axial tensile force P_1 and P_2, the strain energies stored in the bar are U_1 and U_2, respectively.



If U is the strain energy stored in the same bar when subjected to an axial tensile force $(P_1 + P_2)$, the correct relationship is

(a) $U = U_1 - U_2$
(b) $U = U_1 + U_2$
(c) $U < U_1 + U_2$
(d) $U > U_1 + U_2$

Ans. **(d)**

$$U_1 = \frac{P_1^2 L}{2AE}$$

$$U_2 = \frac{P_2^2 L}{2AE}$$

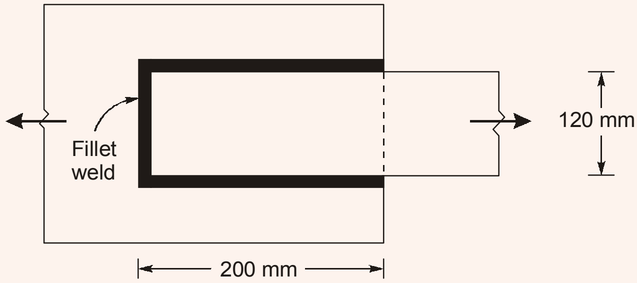
$$U = \frac{(P_1 + P_2)^2 L}{2AE}$$

$$(P_1 + P_2)^2 > P_1^2 + P_2^2$$

$$U > U_1 + U_2$$

End of Solution

Q.46 Two steel plates are lap jointed in a workshop using 6 mm thick fillet weld as shown in the figure (not drawn to the scale). The ultimate strength of the weld is 410 MPa.

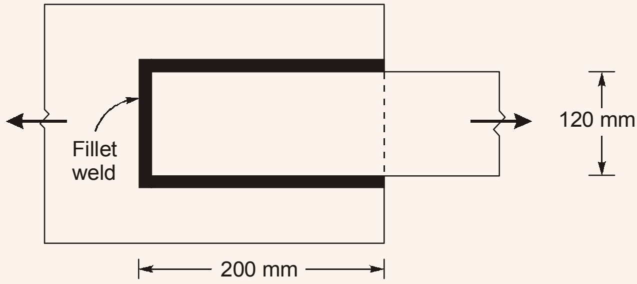


As per Limit State Design is **IS 800 : 2007**, the design capacity (in kN, round off to three decimal places) of the welded connection, is _______.

Ans. (413.586)

Design capacity of welded connection

$$P_s = f_b \times l_{eff} \times t_t$$



$$P = \frac{410}{\sqrt{3} \times 1.25} \times 520 \times 0.7 \times 6$$

$$= \frac{716352}{\sqrt{3}} = 413586 \text{ N}$$

$$= 413.586 \text{ kN}$$

End of Solution

Q.47 For the hottest month of the year at the proposed airport site, the monthly mean of the average daily temperature is 39°C. The monthly mean of the maximum daily temperature is 48°C for the same month of the year. From the given information, the calculated Airport Reference Temperature (in°C), is

(a) 42
(b) 39
(c) 36
(d) 48

Ans. **(a)**

$$T_a = 39°\text{C}$$
$$T_m = 48°\text{C}$$

$$\text{ATR} = T_a + \left(\frac{T_m - T_a}{3}\right)$$

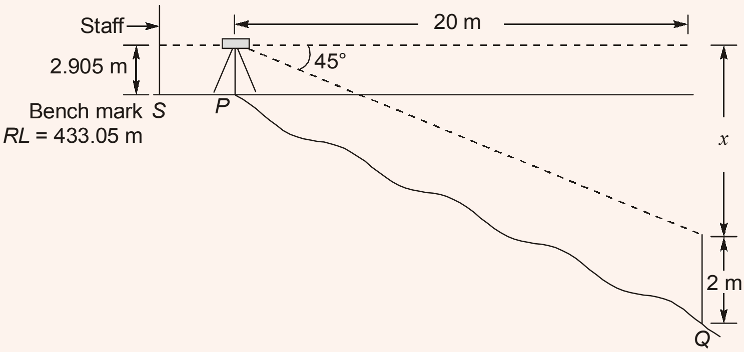
$$= 39 + \left(\frac{48-39}{3}\right) = 42°\text{C}$$

End of Solution

Q.48 A theodolite was set up at a station P. The angle of depression to a vane 2 m above the foot of a staff held at another station Q was 45°. The horizontal distance between stations P and Q is 20 m. The staff reading at a benchmark S of RL 433.050 m is 2.905 m. Neglecting the errors due to curvature and refraction, the RL of the station Q (in m), is

(a) 431.050
(b) 435.955
(c) 413.050
(d) 413.955

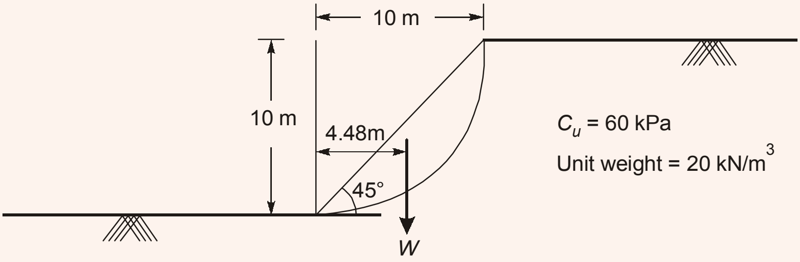
Ans. **(d)**



$$\frac{x}{20} = \tan 45°$$
$$x = 20 \text{ m}$$
$$\text{RL of } Q = 433.05 + 2.905 - x - 2$$
$$= 433.05 + 2.905 - 20 - 2$$
$$= 413.955 \text{ m}$$

End of Solution

Q.49 A 10 m high slope of dry clay soil (unit weight = 20 kN/m^3), with a slope angle of 45° and the circular slip surface, is shown in the figure (not drawn to the scale). The weight of the slip wedge is denoted by W. The undrained unit cohesion (c_u) is 60 kPa.

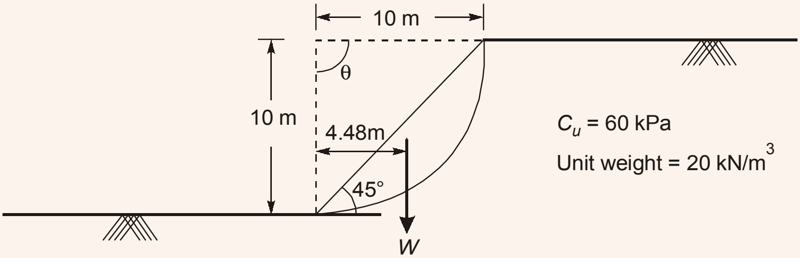


The factor of safety of the slope against slip failure, is

(a) 0.58 (b) 1.84

(c) 1.57 (d) 1.67

Ans. (*)



Consider unit length of slope

$$\text{Area of circular arc} = \frac{\theta}{360} \times \pi r^2 - \text{Area of } \Delta$$

$$= \frac{90}{360} \times \pi \times 10^2 - \frac{1}{2} \times 10 \times 10 = 28.54 \text{ m}^2$$

$$\text{Height of wedge} = \text{Volume} \times \gamma = (\text{Area} \times 1) \times \gamma$$

$$= 28.54 \times 1 \times 20 = 570.8 \text{ kN}$$

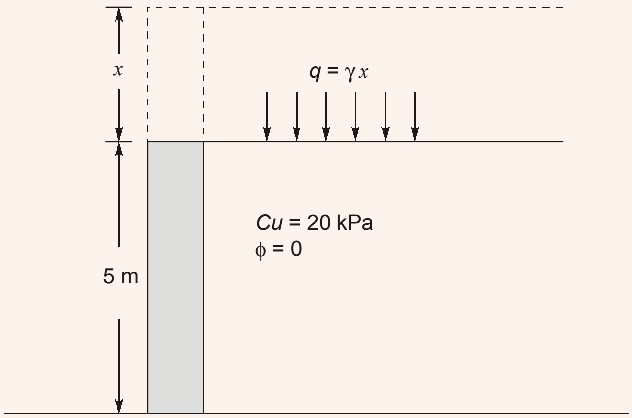
$$\text{FOS} = \frac{M_R}{M_0} = \frac{[c \times (r\theta)] \times r}{W \times x} = \frac{60 \times 10 \times \frac{\pi}{2} \times 10}{570.8 \times 4.48}$$

$$= 3.68$$

End of Solution

Q.50 A 5 m high vertical wall has a saturated clay backfill. The saturation unit weight and cohesion of clay are 18 kN/m^3 and 20 kPa, respectively. The angle of internal friction of clay is zero. In order to prevent development of tension zone, the height of the wall is required to be increased. Dry sand is used as backfill above the clay for the increased portion of the wall. The unit weight and angle of internal friction of sand are 16 kN/m^3 and 30°, respectively. Assume that the back of the wall is smooth and top of the backfill is horizontal. To prevent the development of tension zone, the minimum height (in m, round off to one decimal place) by which the wall has to be raised, is ________.

Ans. (2.5)



To prevent tension crack,

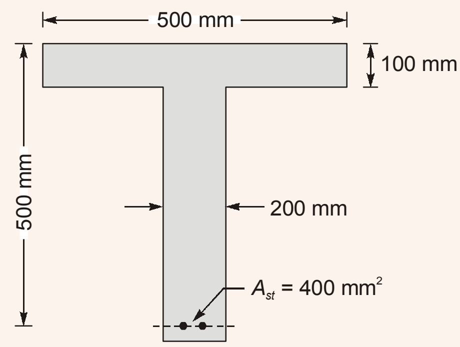
$$q = \frac{2c}{\sqrt{k_a}} = \frac{2 \times 20}{1} = 40$$

$$q = \gamma_d x = 40$$

$$x = \frac{40}{16} = 2.5 \text{ m}$$

End of Solution

Q.51 The cross-section of the reinforced concrete beam having an effective depth of 500 mm is shown in the figure (not drawn to the scale). The grades of concrete and steel used are M35 and Fe550, respectively. The area of tension reinforcement is 400 mm^2. It is given that corresponding to 0.2% proof stress, the material safety factor is 1.15 and the yield strain of Fe550 steel is 0.0044.

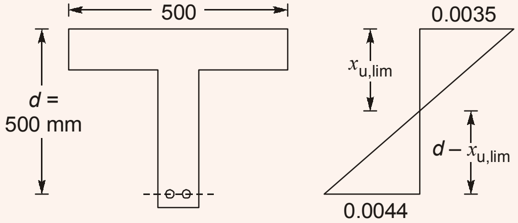


As per **IS 456:2000**, the limiting depth (in mm, round off to the nearest integer) of the neutral axis measured from the extreme compression fiber, is ________.

Ans. **(221.52)**

For a RCC T-Beam

(For limiting depth of neutral axis)



Considering $d = 500$ mm

$$\frac{0.0035}{x_{u,\lim}} = \frac{0.0044}{d - x_{u,\lim}}$$

$$d - x_{u,\lim} = \frac{0.0044}{0.0035} \times x_{u,\lim}$$

$$35 \times 500 = 35x_{u,\lim} + 44x_{u,\lim}$$

$$= 79x_{u,\lim}$$

$$x_{u,\lim} = \frac{35 \times 500}{79} = 221.52 \text{ mm}$$

Limiting depth of neutral axis

$$x_{0,\lim} = 221.52 \text{ mm}$$

End of Solution

Q.52 Crops are grown in a field having soil, which has field capacity of 30% and permanent wilting point of 13%. The effective depth of root zone is 80 cm. Irrigation water is supplied when the average soil moisture drops to 20%. Consider density of the soil as 1500 kg/m^3 and density of water as 1000 kg/m^3. If the daily consumptive use of water for the crops is 2 mm, the frequency of irrigating the crops (in days), is

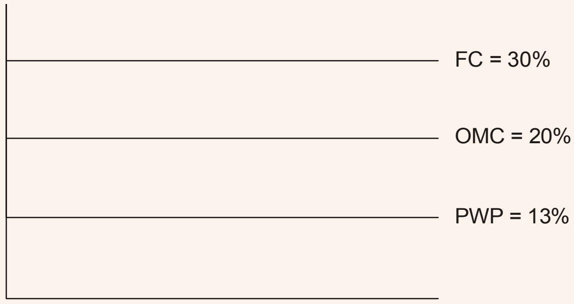
(a) 7 (b) 13

(c) 10 (d) 11

Ans. **(*)**

$$FC = 30\%$$

$$PWP = 13\%$$



$$d_w = \frac{\gamma_d}{\gamma_w} \cdot d \times (FC - OMC)$$

$$= \frac{1500}{1000} \times 80(0.3 - 0.2)$$

$$= 12 \text{ cm or } 120 \text{ mm}$$

$$\text{Consumptive use} = 2 \text{ mm/day}$$

$$\text{So, frequency of irrigation} = \frac{120}{2} = 60 \text{ days}$$

End of Solution

Q.53 The planar structure RST shown in the figure is roller-supported at S and pin-supported at R. Members RS and ST have uniform flexural rigidity (EI) and S is a rigid joint. Consider only bending deformation and neglect effects of self-weight and axial stiffening.

When the structure is subjected to a concentrated horizontal load P at the end T, the magnitude of rotation at the support R, is

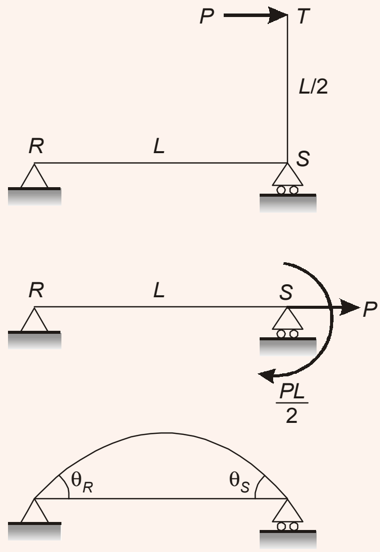
(a) $\frac{PL}{6EI}$

(b) $\frac{PL^3}{12EI}$

(c) $\frac{PL^2}{6EI}$

(d) $\frac{PL^2}{12EI}$

Ans. **(d)**



$$\theta_R = \frac{(PL/2)L}{6EI}$$

$$\theta_R = \frac{PL^2}{12EI}$$

End of Solution

Q.54 An ordinary differential equation is given below

$$6\frac{d^2y}{dx^2} + \frac{dy}{dx} - y = 0$$

The general solution of the above equation (with constant C_1 and C_2), is

(a) $y(x) = C_1 e^{-\frac{x}{3}} + C_2 x e^{\frac{x}{2}}$

(b) $y(x) = C_1 e^{-\frac{x}{3}} + C_2 e^{\frac{x}{2}}$

(c) $y(x) = C_1 x e^{-\frac{x}{3}} + C_2 e^{\frac{x}{2}}$

(d) $y(x) = C_1 e^{\frac{x}{3}} + C_2 e^{-\frac{x}{2}}$

Ans. **(d)**

$$\frac{6d^2y}{dx^2} + \frac{dy}{dx} - y = 0$$

$$(6D^2 + D - 1)y = 0$$

$$6D^2 + 3D - 2D - 1 = 0$$

$$3D(2D + 1) - 1(2D + 1) = 0$$

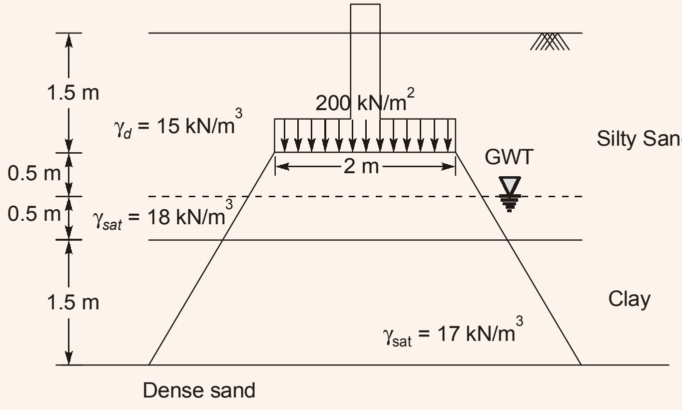
$$(2D + 1)(3D - 1) = 0$$

$$D = \frac{-1}{2},\; D = \frac{1}{3}$$

$$y = C_1 e^{x/3} + C_2 e^{-x/2}$$

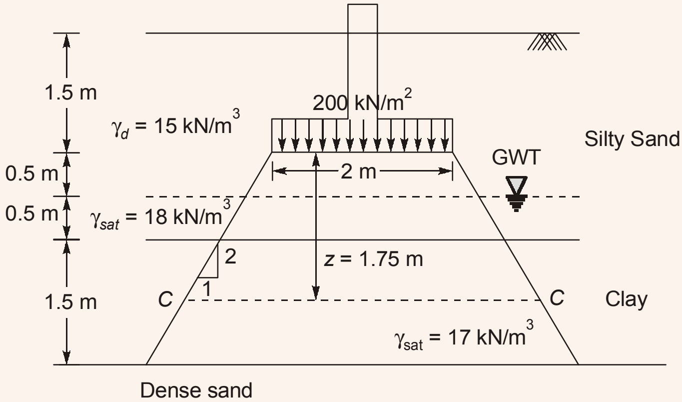
End of Solution

Q.55 A footing of size 2 m × 2 m transferring a pressure of 200 kN/m^2, is placed at a depth of 1.5 m below the ground as shown in the figure (not drawn to the scale). The clay stratum is normally consolidated. The clay has specific gravity of 2.65 and compression index of 0.3



Considering 2 : 1 (vertical to horizontal) method of load distribution and γ_w = 10 kN/m^3, the primary consolidation settlement (in mm, round off to two decimal places) of the clay stratum is ________.

Ans. (74.27)



For clay layer,

$$\gamma_{sat} = \left(\frac{G+e}{1+e}\right)\gamma_w \Rightarrow \left(\frac{2.65+e}{1+e}\right)10 = 17 \text{ kN/m}^3$$

$$e_0 = 1.357$$

1. $$H_0 = 1.5 \text{ m}$$

2. $$(\bar{\sigma}_0)_{c-c} = [2\gamma_d + 0.5\gamma_{sat} + 0.75\gamma_{sat}] - 1.25\gamma_w$$
$$= (2 \times 15 + 0.5 \times 18 + 0.75 \times 17) - 1.25 \times 10$$
$$= 39.25 \text{ kN/m}^2$$

3. $$\Delta\bar{\sigma} = \frac{\text{Force}}{\text{Area}} = \frac{qB^2}{(B+2nZ)^2} = \frac{200 \times 2 \times 2}{\left(2 + 2 \times \frac{1}{2} \times 1.75\right)^2} = 56.88 \text{ kN/m}^2$$

4. $$\Delta H = \frac{H_0 C_C}{1+e_0}\log\left(\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}\right)$$
$$= \frac{1.5 \times 0.3}{1+1.357}\log\left(\frac{39.25+56.88}{39.25}\right)$$
$$= 74.27 \text{ mm}$$

End of Solution

■■■■

GATE 2019

Civil Engineering

Solved Papers

Section : General Aptitude

01. The lecture was attended by quite _________ students, so the hall was not very _______.

(a) few, quite (b) a few, quite (c) few, quiet (d) a few, quiet

01. Ans: (d)

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

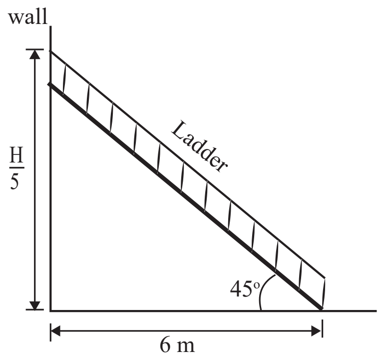
End of Solution

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

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

02. Ans: (d)

Sol:



A ladder is 6 m away from the base.

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

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

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

H = 30 m

End of Solution

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

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

03. Ans: (a)

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

End of Solution

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

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

04. Ans: (a)

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

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

Logic:- 2[Letter's Number]

End of Solution

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

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

05. Ans: (d)

Sol: creating. use gerund after preposition.

End of Solution

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

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

06. Ans: (b)

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

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

Side of large square = x

side of small square = x - 5

Relation between Areas,

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

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

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

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

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

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

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

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

Possible is $x = 10$

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

so, x not existing.

Answer is $x = 10$

End of Solution

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

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

07. Ans: (d)

Sol: Total players = 300

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

$x = 5$ players

% of players playing atleast

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

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

End of Solution

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

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

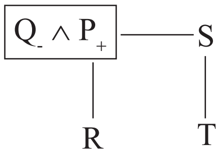
(c) S is the aunt of T (d) S is the aunt of R

08. Ans: (c)

Sol: Male = +

Female = –

Couple = ∧



Parent, child = $\left|\begin{array}{l}\text{P}\\ \text{Child}\end{array}\right.$

Siblings = “ __ ”

There symbols use for solutions

“S is Anut of T” is False because “S” is parent of “T”.

End of Solution

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

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

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

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

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

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

09. Ans: (b)

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

End of Solution

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

What does the word ‘arrived’ mean in the paragraph above?

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

10. Ans: (c)

Sol: Means gained importance.

End of Solution

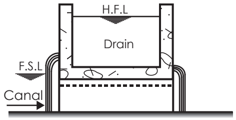
01. If the path of an irrigation canal is below the bed level of a natural stream, the type of cross-drainage structure provided is

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

01. Ans: (c)

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

$\rightarrow$ Super passage



(b) Superpassage

End of Solution

02. Which one of the following is correct?

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

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

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

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

02. Ans: (a)

Sol: $$\underset{x\to 0}{\mathrm{lt}}\ \frac{\sin 4x}{\sin 2x} = \underset{x\to 0}{\mathrm{lt}}\left(\frac{\frac{\sin 4x}{x}}{\frac{\sin 2x}{x}}\right) = \frac{4}{2} = 2$$

and $\underset{x\to 0}{\mathrm{lt}}\ \frac{\tan x}{x} = 1$

End of Solution

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

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

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

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

03. Ans: (b)

Sol: For an ill conditioned traingle in triangulation survey, any angle can be less than 38, and can be greater than 120°. For traingles Q and S, the above condition is valid.

End of Solution

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

(a) P_A is always great than P_T

(b) P_A is always equal to P_T

(c) P_A is always smaller than P_T

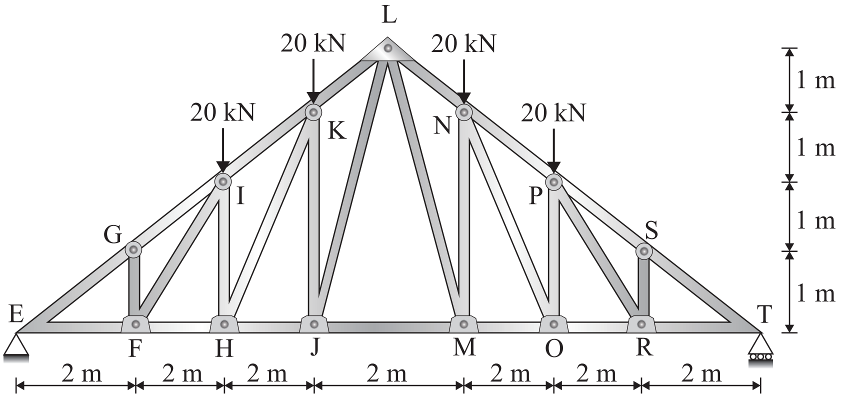
(d) There is no definite relationship between P_A and P_T

04. Ans: (d)

Sol: There is no definite relationship between P_A and P_T

End of Solution

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

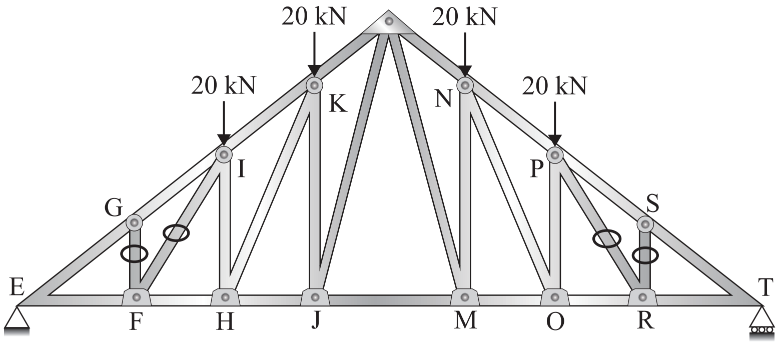


Which one of the options contains ONLY zero force members in the truss?

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

05. Ans: (b)

Sol:



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

End of Solution

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

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

06. Ans: (c)

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

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

Comparing with equation a – ω^2 .x

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

End of Solution

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

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

07. Ans: (d)

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

$\sigma_{th} = 0$

End of Solution

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

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

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

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

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

08. Ans: (a)

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

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

End of Solution

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

09. Ans: 0.52

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

peak 5 min rate = 160 veh/5min

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

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

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

End of Solution

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

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

11. Ans: (c)

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

End of Solution

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

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

11. Ans: (c)

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

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

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

End of Solution

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

12. Ans: 2094.9

Sol: $G_s = 2.65$,

$\gamma_w = 1000$ kg/m^3

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

w = 10%

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

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

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

End of Solution

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

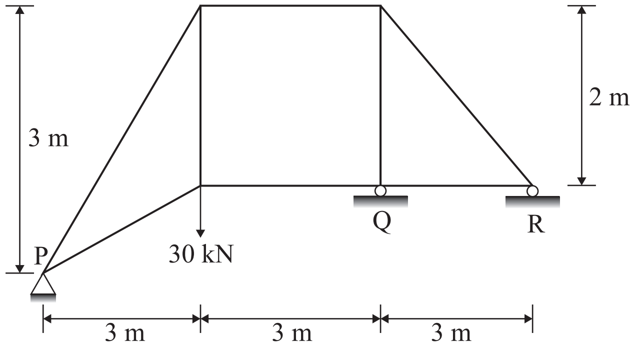
(a) Ozone (b) Volatile Organic Carbon (VOC) (c) Carbon Monoxide (d) Hydrocarbon

13. Ans: (a)

Sol: Ozone is a dangerous secondary air contaminant.

End of Solution

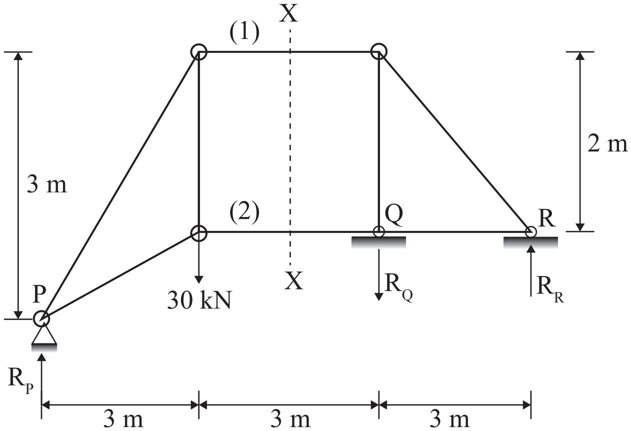
14. Consider the pin-jointed plane truss shown in the figure (not drawn to scale). Let R_P, R_Q and R_R denote the vertical reactions (upward positive) applied by the supports at P, Q and R respectively, on the truss. The correct combination of (R_P, R_Q, R_R) is represented by



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

14. Ans: (a)

Sol:



Adopting method of sections and taking LHS of the section

$\Sigma F_y = 0$

$R_P = 30$ kN

For complete truss,

$\Sigma M_R = 0$

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

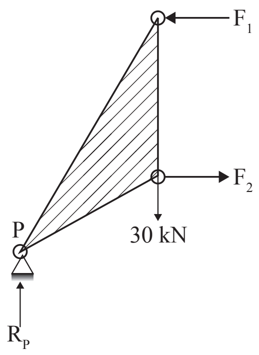
$R_Q = 30$ kN (↓)

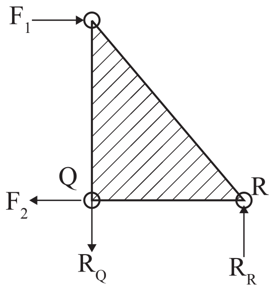
Taking RHS of section,

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

Thus, $R_Q = 30$ kN (↓),

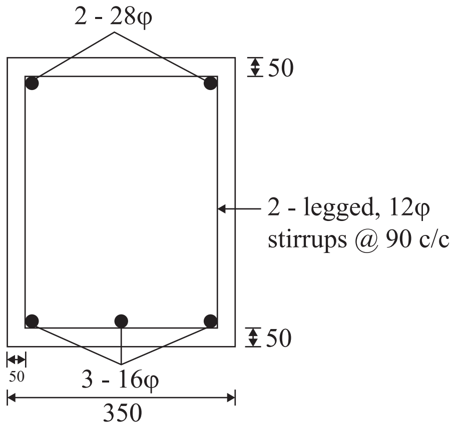
$R_R = 30$ kN (↑)





End of Solution

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



All dimensions are in mm

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

15. Ans: (b)

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

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

End of Solution

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

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

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

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

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

16. Ans: (d)

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

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

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

End of Solution

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

17. Ans: 17.9

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

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

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

$q = 0.9441$

$q = 1 - p$,

$p = 1 - q = 0.0559$

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

$T = 17.89$ years

End of Solution

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

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

18. Ans: (b)

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

$+G\% \rightarrow$ upward gradient

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

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

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

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

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

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

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

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

19. Ans: (c)

Sol: Normal strain in the plane of maximum shear strain

$\varepsilon_x = 0.0030$

$\varepsilon_y = 0.0020$

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

$= 0.0025$

End of Solution

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

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

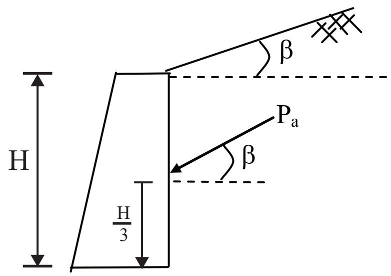
(b) P_a acts at a height H/2 from the base of the wall and at an angle ϕ with the horizontal

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

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

20. Ans: (c)

Sol:



End of Solution

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

21. Ans: 0.001

Sol: Simple bending equation

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

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

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

End of Solution

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

22. Ans: 100

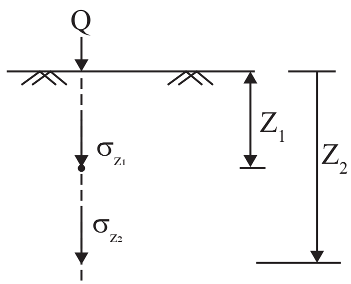
Sol: If particles of diameter 0.35 mm are completely removed (i.e., 100 % removed) then particles of size larger than 0.35 mm are also 100 % removed.

End of Solution

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

23. Ans: 4

Sol:



As per Boussinesq's equation,

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

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

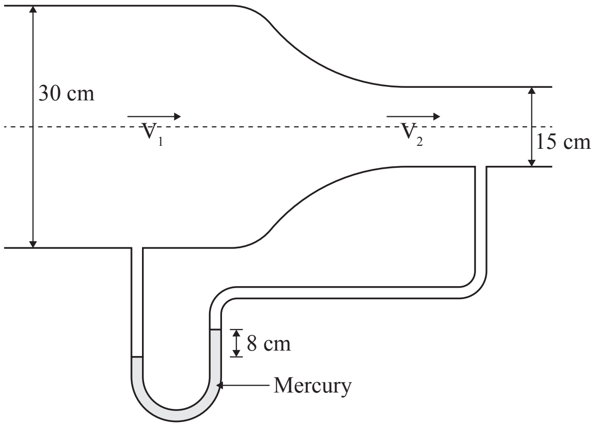
$$\sigma_Z \propto \frac{1}{Z^2}$$

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

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

End of Solution

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



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

24 Ans : 0.081

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

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

where $Z_1 = Z_2$

$$V_2 = 4V_1 \quad (\text{ as } d_1 = 2d_2)$$

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

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

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

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

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

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

$= 21.095$

$V_2 = 4.593$ m/s

Discharge $= \dfrac{\pi}{4} \times 0.15^2 \times 4.593 = 0.0816$ m³/s

End of Solution

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

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

25. Ans: (d)

Sol:

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

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

where,

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

f_{bd} = design bending stress

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

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

$\therefore$ Hence, there is no reduction for semi-compact section.

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

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

End of Solution

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

26. Ans: 1.20 m

Sol: Given,

$z = 0.8$ m ,

$n = 0.4$ m

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

$L = 4$ m ,

$B = 3$ m,

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

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

$v_s = 0.05$ m/sec

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

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

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

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

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

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

End of Solution

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

27. Ans: 1800

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

Jam density, $K_m = 120$ kmph

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

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

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

End of Solution

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

28. Ans: (270)

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

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

For sand, C = 0

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

Given:

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

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

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

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

$$\therefore N_q = 10$$

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

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

$$= 750 \text{ kN/m}^2$$

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

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

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

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

$$= 270 \text{ kPa}$$

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

29. Ans: 41.0714

Sol:

k = 22.4, M = 46

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

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

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

End of Solution

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

30. Ans: 50.94

Sol: 0.5 × 0.5 × 0.5 (Box)

= 0.125 m^3 (Total volume)

wt of aggregates = 187.5 kg

sp. gravity = 2.5 ⇒ Unit weight = 2.5 × 9.81 kN/m^3

= 24.525 kN/m^3

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

$$= 0.9375 \text{ kg}$$

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

$$= 0.075 \text{ m}^3$$

volume of voids = 0.125 - 0.075

= 0.05 m^3

⇒ wt of water in voids = 0.05 × 1000 kg

= 50 kg

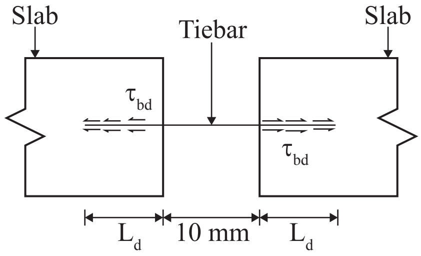
wt of water required to fill the box = 50 + 0.9375

= 50.94 kg

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

31. Ans:700 mm

Sol:



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

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

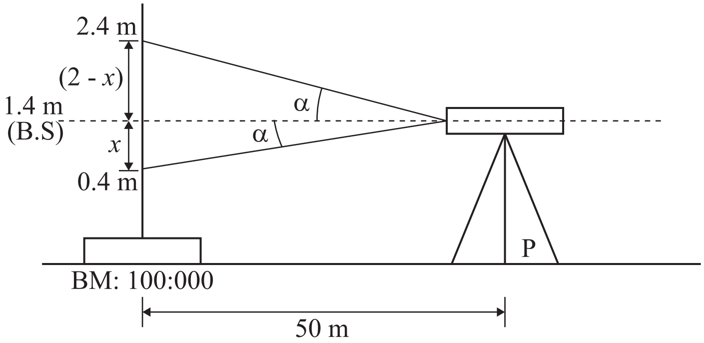
$= 700$ mm

End of Solution

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

32. Ans: 100

Sol:



x = 50 tan α;

2 – x = 50 tan α

∴ x = 2 – x

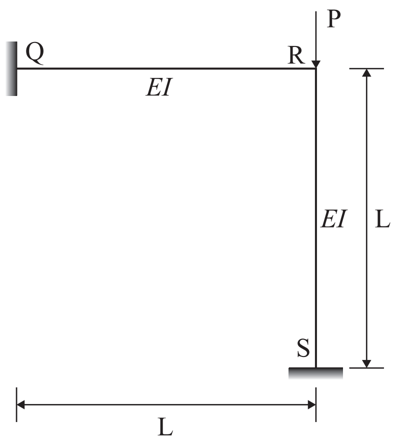
2x = 2;

x = 1 m

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

End of Solution

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



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

33. **Ans: (d)**

Sol: Adopting moment distribution method:

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

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

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

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

End of Solution

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

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

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

34. Ans: (d)

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

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

From above two equations, we get

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

Hence, option (d) is correct.

End of Solution

35. A reinforced concrete circular pile of 12 m length and 0.6 m diameter is embedded in stiff clay which has an undrained unit cohesion of 110 kN/m^2. The adhesion factor is 0.5. The net Ultimate Pullout (uplift) Load for the pile (in kN, round off to 1 decimal place) is ____________

35. Ans: 1328.9

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

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

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

where γ_c = unit wt. of concrete = 25 kN/m^3

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

$= 1328.894$ kN say 1328.9 kN

End of Solution

36. Sedimentation basin in a water treatment plant is designed for a flow rate of 0.2 m^3/s. The basin is rectangular with a length of 32 m, width of 8 m, and depth of 4 m. Assume that the settling velocity of these particles is governed by the Stoke's law. Given: density of the particles = 2.5 g/cm^3; density of water = 1 g/cm^3; dynamic viscosity of water = 0.01 g/(cm.s); gravitational acceleration = 980 cm/s^2. If the incoming water contains particles of diameter 25 μm (spherical and uniform), the removal efficiency of these particles is

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

36. Ans: (c)

Sol:

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

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

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

$\mu = 0.01\ gm/cm - sec = 1 \times 10^{-3}\ kg/m - sec$

$d = 25\ \mu m = 25 \times 10^{-6}\ m^2$

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

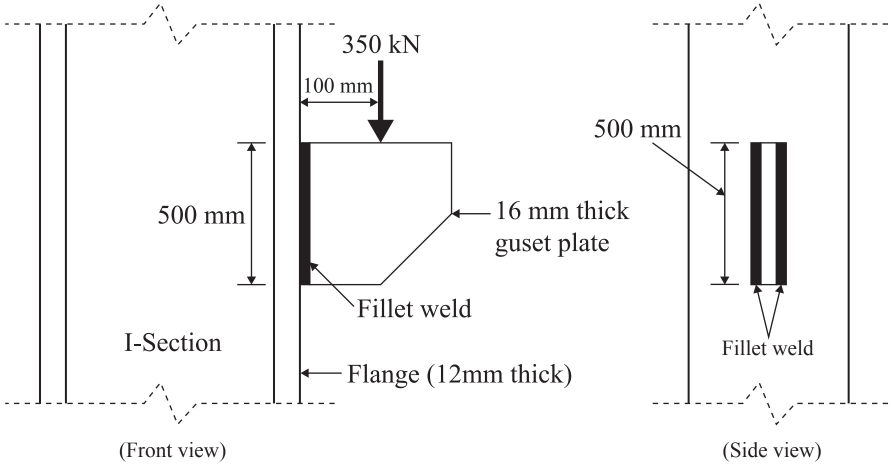
$$v_0 = \frac{Q}{A_s} = \frac{Q}{L \times B} = \frac{0.2}{32 \times 8} = 7.8125 \times 10^{-4}\ m/sec$$

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

$$\eta = \frac{v_s}{v_0}\times 100 = \frac{5.1041\times10^{-4}}{7.8125\times10^{-4}}\times 100 = 65.33\% \simeq 65\%$$

End of Solution

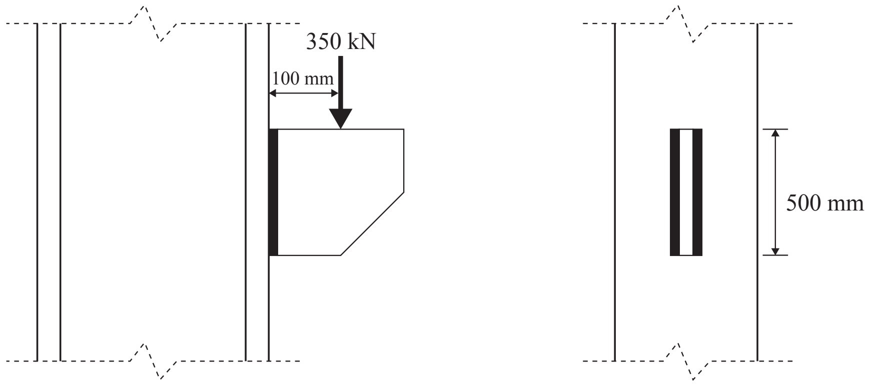
37. A 16 mm thick gusset plate is connected to the 12 mm thick flange plate of an I-section using fillet welds on both sides as shown in the figure (not drawn to scale). The gusset plate is subjected to a point load of 350 kN acting at a distance of 100 mm from the flange plate. Size of fillet weld is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



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

37. Ans:105.35 MPa

Sol:



Given:

Direct concentrated load (P) = 350 kN

Eccentricity (e) = 100 mm

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

Size of weld (S) = 10 mm

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

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

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

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

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

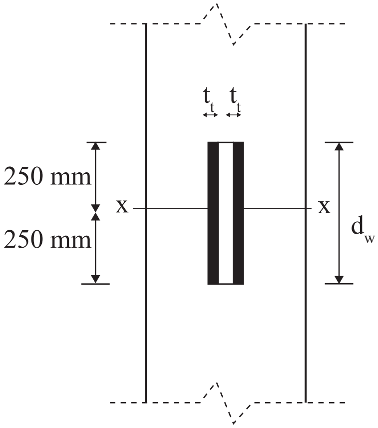
- Bending normal stress acting at ith point from Neutral axis $[f_i] = \dfrac{M}{I}.y_i$

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

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

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

$$= 60 \text{ MPa}$$



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

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

End of Solution

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

38. Ans: 0.18

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

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

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

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

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

End of Solution

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

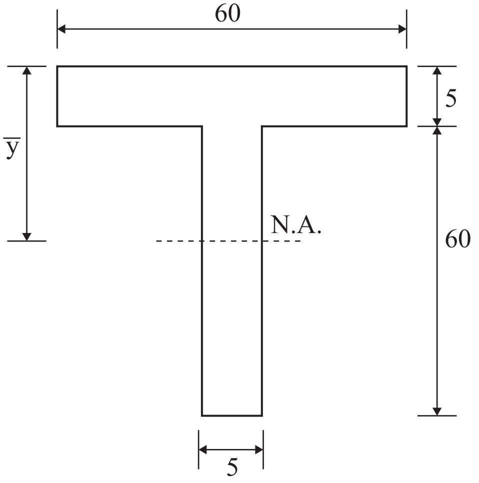
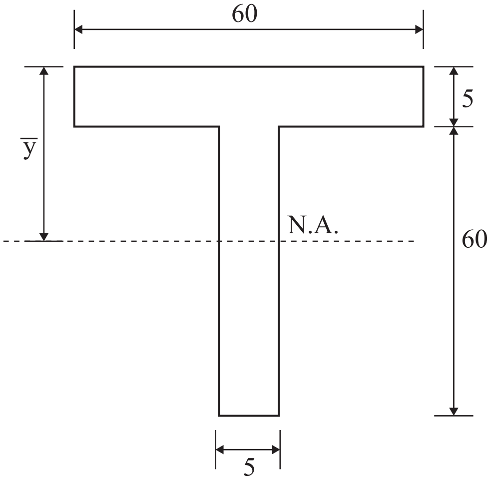


Figure not to scale
All dimension are in mm

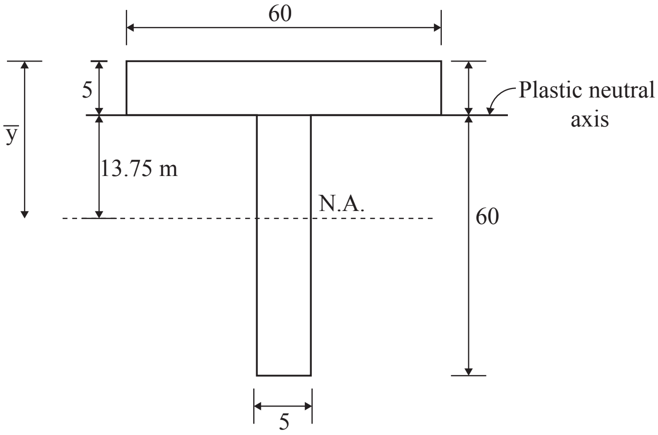
(a) 13.75 mm
(b) 12.25 mm
(c) 15.25 mm
(d) 10.75 mm

39. Ans: (a)

Sol:



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



End of Solution

40. Consider a laminar flow in the x-direction between two infinite parallel plates (Couette flow). The lower plate is stationary and the upper plate is moving with a velocity of 1 cm/s in the x-direction. The distance between the plates is 5 mm and the dynamic viscosity of the fluid is 0.01 N-s/m². If the shear stress on the lower plate is zero, the pressure gradient, $\frac{\partial p}{\partial x}$, (in N/m² per m, round off to 1 decimal place) is ____________

40 Ans: 8.0

Sol: Given flow is a couette flow with pressure gradient

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

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

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

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

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

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

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

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

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

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

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

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

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

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

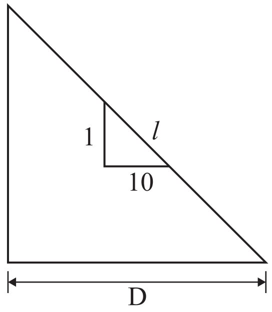
End of Solution

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

(a) 284.5 m
(b) 285.6 m
(c) 285.0 m
(d) 283.6 m

41. Ans: (d)

Sol:



$L = 30$ m, $L' = 30 - 0.05 = 29.95$ m

$L' = 85.5$ m

$\therefore$ Correct length

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

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

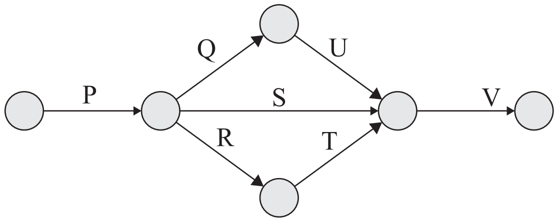
$$\cos\theta = \frac{10}{\sqrt{10^2+1^2}} = 0.995$$

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

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

End of Solution

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



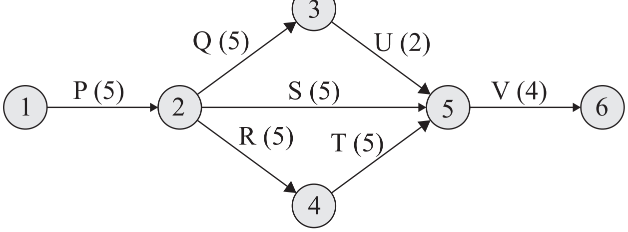
Activity	Normal duration (days)	Crash duration (days)	Normal cost (INR)	Crash cost (INR)
P	6	4	15000	25000
Q	5	2	6000	12000
R	5	3	8000	9500
S	6	3	7000	10000
T	3	2	6000	9000
U	2	1	4000	6000
V	4	2	20000	28000

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

42. Ans: 1,49,500

Sol:

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



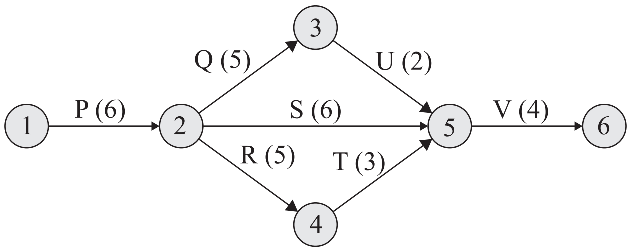
Activity	Cost slope (Rs./day) = $\frac{\Delta C}{\Delta T}$
P	$\frac{25000-15000}{6-4} = 5000$
Q	$\frac{12000-6000}{5-2} = 2000$
R	$\frac{9500-8000}{5-3} = 750$
S	$\frac{10000-7000}{6-3} = 1000$
T	$\frac{9000-6000}{3-2} = 3000$
U	$\frac{6000-4000}{2-1} = 2000$
V	$\frac{28000-20000}{4-2} = 4000$

Indirect cost = Rs. 5000
Crashing possibility = 18 - 17 = 1 day
To reduce the project duration by 1 day, the following options available.

Option	Cost slope
P	5000
R	750
T	3000
V	4000

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

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



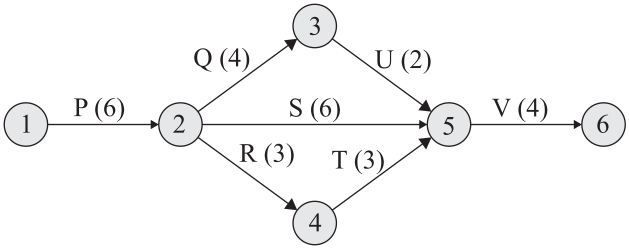
The reduce the project duration by 1 day

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

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

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

Project duration = 16 days.



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

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

= 1,49,500 /-

End of Solution

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

43. Ans: 8.00

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

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

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

$$\therefore t = 20.22 \text{ min}$$

$$Q = 36 \text{ m}^3/\text{hr}$$

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

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

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

44. Ans: 11.1

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

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

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

$\therefore\ \phi' = 30°, F = 1.5$

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

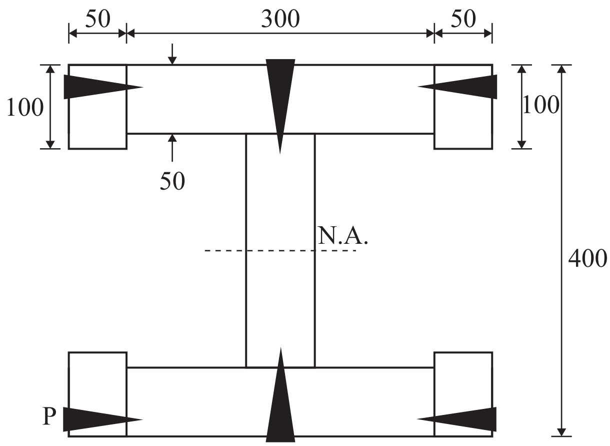
$$F = \frac{\gamma'}{\gamma_{sat}} \cdot \frac{\tan\phi'}{\tan i}$$

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

$i = 11.095\ \text{ say } 11.1°$

End of Solution

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



All demiensions are in mm

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

45. Ans: (a)

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

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

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

$= 0.08\ N/mm^2$

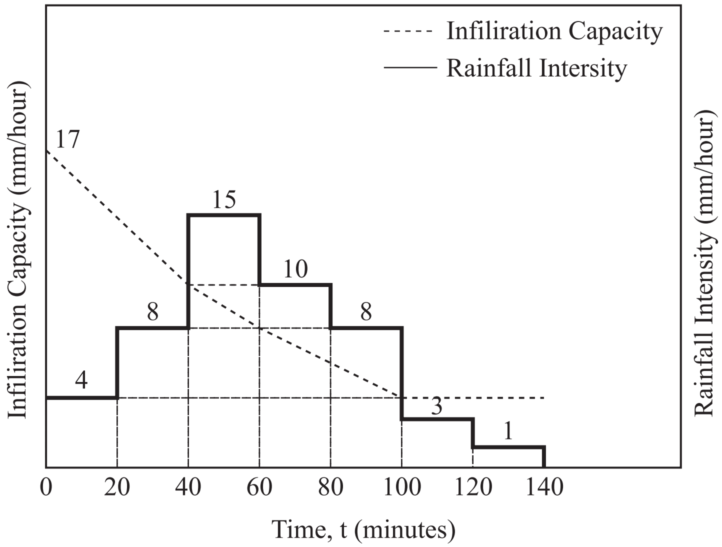
The shear force acting on nail at 'P'.

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

$= 240\ N$

End of Solution

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



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

46. Ans: 7.00

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

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

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

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

$= 4\text{ mm}$

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

End of Solution

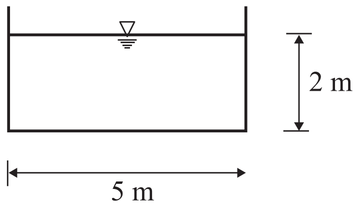
47. A rectangular open channel has a width of 5 m and a bed slope of 0.001. For a uniform flow of depth 2 m, the velocity is 2 m/s. The Manning's roughness coefficient for the channel is

(a) 0.033 (b) 0.017

(c)0.002 (d) 0.050

47. Ans: (b)

Sol:



Given: $V = 2\text{ m/sec}, S = 0.001$

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

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

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

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

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

$n = 0.0169 \simeq 0.017$

End of Solution

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

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

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

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

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

48. Ans: (a)

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

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

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

Hence, option (a) is correct.

End of Solution

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

49. Ans: 6

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

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

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

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

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

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

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

$\Rightarrow m = 1, 2$

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

$y = c_1x + c_2x^2$

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

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

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

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

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

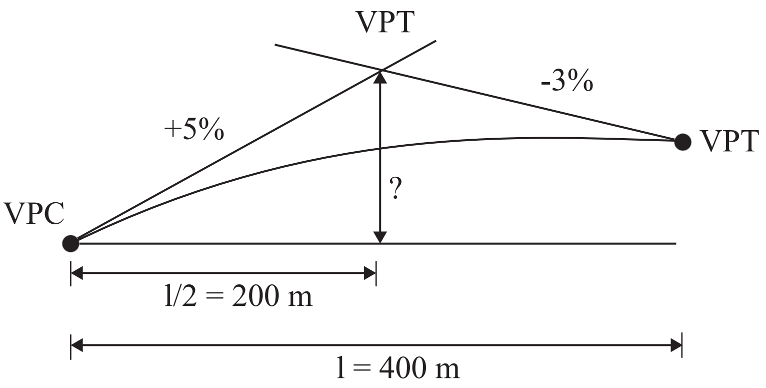
End of Solution

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

50. Ans: 10

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

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



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

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

End of Solution

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

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

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

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

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

51. Ans: (a)

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

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

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

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

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

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

$$\Rightarrow x = e$$

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

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

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

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

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

End of Solution

52. For the following statements:

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

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

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

The correct combination of the statements is

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

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

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

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

52. Ans: (d)

Sol:

P: True

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

Q: True

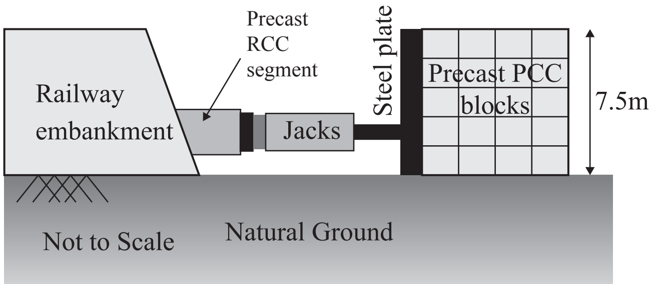
For a perfectly rigid footing resting on surface of sand deposit, the contact pressure distribution is zero at the edges and maximum at centre. However, for a very deep rigid footing on sand, the contact pressure distribution may tend to become like that of rigid footing on clayey soil, with edge contact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

R: True

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

End of Solution

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



At each stage, the jacks are required to apply a force of 1875 kN to push the segment. The jacks will react against the rigid steel plate placed against the reaction arrangement. The footprint area of reaction arrangement on natural ground is 37.5 m². The unit weight of PCC block is 24 kN/m³. The properties of the natural ground are $c = 17$ kPa; $\phi = 25^{\circ}$ and $\gamma = 18$ kN/m³. Assuming that the reaction arrangement has rough interface and has the same properties that of soil, the factor of safety (round off to 1 decimal place) against shear failure is __________

53. Ans: 2.0

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

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

Shear resistance below the Precast PCC block is, $S = C.A + W.\tan\phi$

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

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

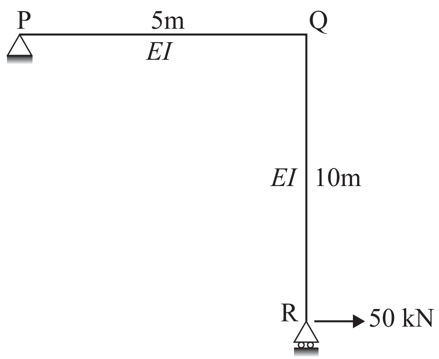
$$F = \frac{C.A + N.\tan\phi}{T} \qquad \text{(Since, } N = W\text{)}$$

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

$= 2.0187$ say 2.0

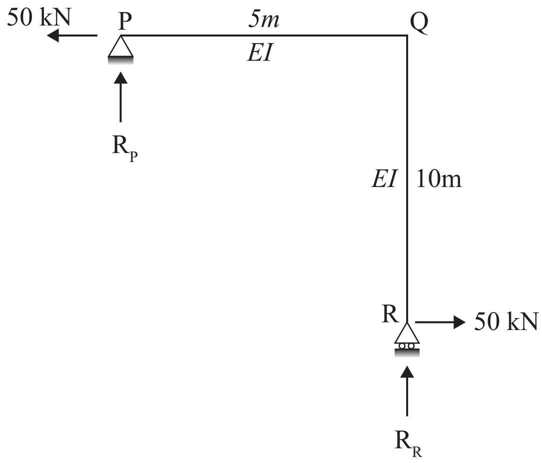
End of Solution

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



54. Ans: 25 mm

Sol:



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

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

$R_R = -100$ kN (↓)

$R_P = 100$ kN (↑)

$EI = 10^6$ kN-m^2

Using unit load method:

The horizontal displacement at 'R'

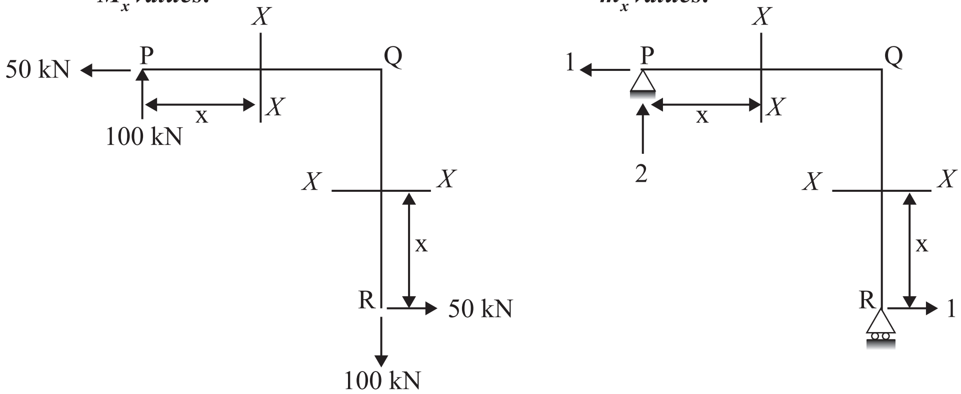
$$\delta_{HR} = \int_0^L \frac{M_x\, m_x}{EI} dx$$

where,

M_x = BM at X-X due to real loads

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

M_x values: ***m_x values:***



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

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

$R_P = 2$ kN (↑)

Sign conventions:

Sagging +ve

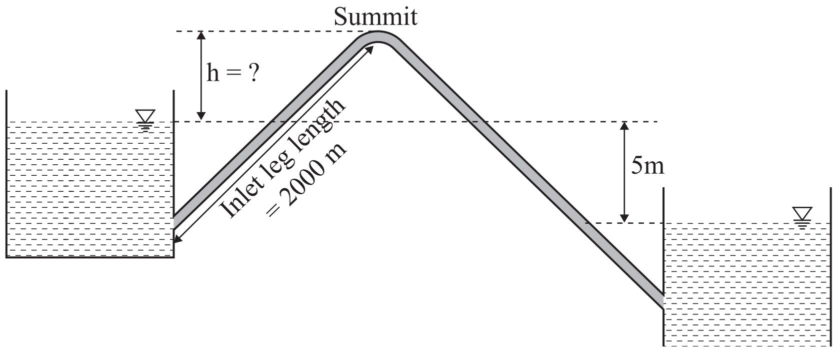
Hogging -ve

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

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

End of Solution

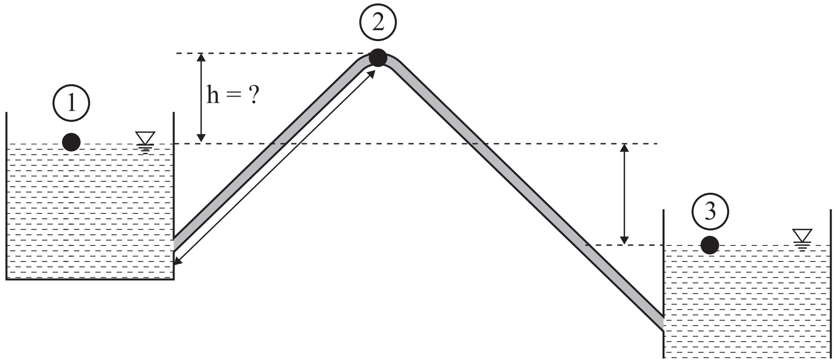
55. Two water reservoirs are connected by a siphon (running full) of total length 5000 m and diameter of 0.10 m, as shown below (figure not drawn to scale).



The inlet leg length of the siphon to its summit is 2000 m. The difference in the water surface levels of the two reservoirs is 5 m. Assume the permissible minimum absolute pressure at the summit of siphon to be 2.5 m of water when running full. Given: friction factor, f = 0.02 throughout, atmospheric pressure = 10.3 m of water, and acceleration due to gravity g = 9.81 m/s^2. Considering only major loss using Darcy-Weisbach equation, the maximum height of the summit of siphon from the water level of upper reservoir, h (in m, round off to 1 decimal place) is ______________.

55. Ans: 5.8 m

Sol:



Applying Bernoulli's equation between 1 & 3

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

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

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

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

$v = 0.313$ m/s

Applying Bernoulli's equation between 1 & 2

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

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

$h = 5.798$ m

≈ 5.8 m

End of Solution

Section : General Aptitude

01. Hima Das was ____ only Indian athlete to win _____ gold for India.

(a) the a (b) the, many

(c) an, a (d) an, the

01. Ans: (a)

End of Solution

02. Daytime temperatures in Delhi can ______ 40^oC.

(a) Peak (b) get

(c) Reach (d) Stand

02. Ans: (c)

Sol: reach. Means touch

End of Solution

03. A retaining wall with measurements 30 m× 12 m × 6 m was constructed with bricks of dimensions 8cm × 6cm × 6cm. If 60% of the wall consists of bricks, the number of bricks used for the construction is ______ lakhs.

(a)45 (b) 40

(c)30 (d) 75

03. Ans: (a)

Sol: Volume of the wall : (3000 × 1200 × 600) cu. cm

Volume of all bricks put together = 0.6 × (3000 × 1200 × 600) cu.cm

Volume of each brick = (8 × 6 × 6) cu.cm

No of bricks used $= \dfrac{0.6 \times 3000 \times 1200 \times 600}{8 \times 6 \times 6}$

= 4500000 or 45 lakhs

End of Solution

04. The growth rate of ABC Motors in 2017 was the same ______ XYZ Motors in 2016.

(a)as that off (b) as off

(c)as that of (d) as those of

04. Ans: (c)

Sol: as that of. growth rate is singular number.

End of Solution

05. Suresh wanted to lay a new carpet in his new mansion with an area of 70 × 55 sq. mts. However an area of 550 sq. mts. Had to be left out for flower pots. If the cost of carpet is Rs.50 per sq. mts., How much money (in Rs) will be spent by Suresh for the carpet now?

(a) 1, 65, 000 (b) 2, 75, 000

(c) 1, 92, 500 (d) 1, 27, 500

05. Ans: (a)

Sol: Area to be computed = [(70 × 55) – 550] or 3300 sq. m

Total cost of carpeting = 3300 × cost per sq.m

= 3300 × 50 rs

= Rs 1, 65,000

End of Solution

06. The Newspaper reports that over 500 hectares of tribal land spread across 28 tribal settlements in Mohinitam-puram forest division have already been "alienated". A top forest official said, "First the tribals are duped out of their land holdings. Second, the families thus rendered landless are often forced to encroach further into the forests".

On the basis of the information available in the paragraph, ______ is/are responsible for duping the tribals.

(a) landless families (b) forest officials

(c) it cannot be inferred who (d) the newspaper

06. Ans: (c)

Sol: cannot be inferred. Para doesn't mention who is responsible.

End of Solution

07. An oil tank can be filled by pipe X in 5 hours and pipe Y in 4 hours, each pump working on its own. When the oil tank is full and the drainage hole is open, the oil is drained in 20 hours. If initially the tank was empty and someone started the two pumps together but left the drainage hole open, how many hours will it take for the tank to be filled? (Assume that the rate of drainage is independent of the Head)

(a) 2.00 (b) 2.50 (c) 4.00 (d) 1.50

07. Ans: (b)

Sol: Work done by pipes x,y and drain in the = $\frac{1}{5}, \frac{1}{4} \& \left(\frac{-1}{20}\right)$ says

$\therefore$ work done by pipes x, y and drain together = $\left(\frac{1}{5}+\frac{1}{4}-\frac{1}{20}\right)$ or $\frac{8}{20}$ or $\frac{2}{5}$

$\therefore$ The time taken to fill the tank = $\frac{5}{2}$ hrs or 2.5 hrs

End of Solution

08. Population of state X increased by x% and the population of state Y increased by y% from 2001 to 2011. Assume that x is greater than y. Let P be the ratio of the population of state X to state Y in a given year. The percentage increase in P from 2001 to 2011 is _________.

(a) $\frac{100(x-y)}{100+y}$ (b) $x-y$

(c) $\frac{x}{y}$ (d) $\frac{100(x-y)}{100+x}$

08. Ans: (a)

Sol: Let population of two states in 2001 ha asb ratio

τ_{max} $P = \frac{a}{b}$

Population of two states in 2011 = a + x/ya , b + y^2/yb respectively

Ratio of population in 2011 i.e P in 2011 = $\frac{a+x/ga}{b+y/gb}$

$= \frac{100a+ax}{100b+by}$

End of Solution

09. "Popular Hindi fiction, despite – or perhaps because of – its wide reach, often does not appear in our cinema. As ideals that viewers are meant to look up to rather than identify with, Hindi film protagonists usually read books of aspirational value: textbooks, English books, or high value literature."

Which one of the following CANNOT be inferred from the paragraph above?

(a) Textbooks, English books or high literature have aspirational value, but not popular Hindi fiction

(b) Protagonists in Hindi movies, being ideals for viewers, read only books of aspirational value

(c) People do not look up to writers of textbooks, English books or high value literature

(d) Though popular Hindi fiction has wide reach, it often does not appear in the movies

09. Ans: (b)

Sol: para says usually. Not only

End of Solution

10. Mohan, the manager, wants his four workers to work in pairs. No pair should work for more than 5 hours. Ram and John have worked together for 5 hours. Krishna and Amir have worked as a team for 2 hours. Krishna does not want to work with Ram. Whom should Mohan allot to work with John, if he wants all the workers to continue working?

(a) Amir (b) Krishna (c) Ram (d) None of the three

10. Ans: (b)

Sol: As Krishna does not want to work with Ram, he has to work only with John.

$\therefore$ Mohan should allot Krishna to John to work as a pair.

Note: Krishna already worked with Amir as a pair.

End of Solution

Section : Civil Engineering

01. If the fineness modulus of a sample of fine aggregates is 4.3, the mean size of the particles in the sample is between

(a) 1.18 mm and 2.36 mm (b) 2.36 mm and 4.75 mm
(c) 300 μm and 600 μm (d) 150 μm and 300 μm

01. Ans: (a)

Sol: F.M of mean size 2.36 = 5

F.M of mean size 1.18 = 4

Hence for F.M of 4.3, the mean size of aggregate will be between 1.18 mm and 2.36 mm.

End of Solution

02. Euclidean norm (length) of the vector $[4 \quad -2 \quad -6]^T$ is

(a) $\sqrt{56}$ (b) $\sqrt{24}$
(c) $\sqrt{48}$ (d) $\sqrt{12}$

02. Ans: (a)

Sol:

Let $X = \begin{bmatrix} 4 \\ -2 \\ -6 \end{bmatrix}$

$$\text{Norm } X = \|X\| = \sqrt{(4)^2 + (-2)^2 + (-6)^2}$$
$$= \sqrt{16+4+36}$$
$$= \sqrt{56}$$

End of Solution

03. The value of the function f(x) is given at n distinct values of x and its value is to be interpolated at the point x*, using all the n points. The estimate is obtained first by the Lagrange polynomial, denoted by I_L, and then by the Newton polynomial, denoted by I_N. Which one of the following statements is correct?

(a) I_L and I_N are always equal (b) I_L is always greater than I_N
(c) No definite relation exists between I_L and I_N (d) I_L is always less than I_N

03. Ans: (a)

End of Solution

04. A vehicle is moving on a road of grade +4% at a speed of 20 m/s. Consider the coefficient of rolling friction as 0.46 and acceleration due to gravity as 10 m/s^2. On applying brakes to reach a speed of 10 m/s, the required braking distance (in m, round off to nearest integer) along the horizontal, is _______.

04. Ans: 30 m

Sol: Given,

Upward gradient, G = 4% = 0.04 (upgrade is taken as +ve)

Initial speed, $v_1 = 20$ m/s

Coefficient of friction (rolling), f = 0.46

Acceleration due to gravity, g = 10 m/s^2

Final velocity due to break application (reduced), $v_2 = 10$ m/s

$$\text{Breaking distance , } S_b = \frac{\left(v_1^2 - v_2^2\right)}{2g(f+G)}$$

$$= \frac{\left(20^2 - 10^2\right)}{2\times 10(0.46+0.04)} = 30 \text{ m}$$

End of Solution

05. An anisotropic soil deposit has coefficient of permeability in vertical and horizontal directions as k_z and k_x respectively. For constructing a flow net, the horizontal dimension of the problem's geometry is transformed by a multiplying factor of

(a) $\frac{k_z}{k_x}$ (b) $\sqrt{\frac{k_x}{k_z}}$ (c) $\sqrt{\frac{k_z}{k_x}}$ (d) $\frac{k_x}{k_z}$

05. Ans: (c)

End of Solution

06. The characteristic compressive strength of concrete required in a project is 25 MPa and the standard deviation in the observed compressive strength expected at site is 4 MPa. The average compressive strength of cubes tested at different water-cement (w/c) ratios using the same material as is used for the project is given in the table.

w/c(%)	45	50	55	60
Average compressive strength of cubes (MPa)	35	25	20	15

The water-cement ratio (in percent, roundoff to the lower integer) to be used in the mix is ____

06. Ans: 46

Sol: Mean strength $f_m = f_{ck} + 1.65\ \sigma$

$= 25 + 1.65 \times 4$

$= 31.6$ MPa

From table

f_m(MPa)	w/c (%)
35	45%
31.6	?
25	50%

W/C ratio required $= 45 + \dfrac{50-45}{35-25} \times (35-31.6) = 46.7\% \simeq 46\%$

End of Solution

07. The following inequality is true for all x close to 0. $2 - \dfrac{x^2}{3} < \dfrac{x \sin x}{1 - \cos x} < 2$

What is the value $\lim\limits_{x \to 0} \dfrac{x \sin x}{1 - \cos x}$?

(a)2 (b) 1 (c) 0 (d) ½

07. Ans: (a)

Sol: $\underset{x \to 0}{\mathrm{Lt}} \dfrac{x \sin x}{1 - \cos x}$

$= \underset{x \to 0}{\mathrm{Lt}} \dfrac{\dfrac{\sin x}{x}}{\dfrac{1 - \cos x}{x^2}}$

$= \dfrac{1}{\dfrac{1}{2}}$

= 2

End of Solution

08. The Laplace transform of sinh(at) is

(a) $\frac{s}{s^2 - a^2}$ (b) $\frac{a}{s^2 + a^2}$ (c) $\frac{s}{s^2 + a^2}$ (d) $\frac{a}{s^2 - a^2}$

08. Ans: (d)

Sol: Laplace transform of sinh(at)

$$L\{\sinh(at)\} = \frac{a}{s^2 - a^2}$$

End of Solution

09. Structural failures considered in the mechanistic method of bituminous pavement design are

(a) Fatigue and Rutting (b) Shear and Slippage

(c) Rutting and Shear (d) Fatigue and Shear

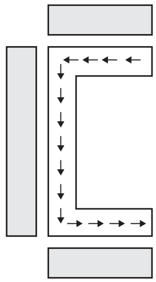
09. Ans: (a)

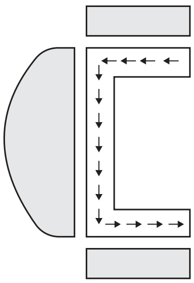
Sol: Mechanistic empirical method for flexible pavement design consider the following structural failures

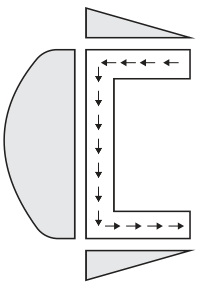
1. Fatigue 2. Rutting

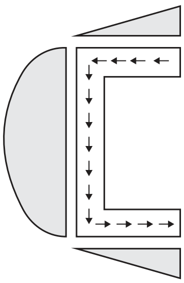
End of Solution

10. For a channel section subjected to a downward vertical shear force at its centroid, which one of the following represents the correct distribution of shear stress in flange and web?

a. 

b. 

c. 

d. 

10. Ans: (c)

Sol: Shear flow in horizontal member (flange) is linear with zero at free end and in vertical member (web) it is parabolic.

Therefore the suitable option is (c).

End of Solution

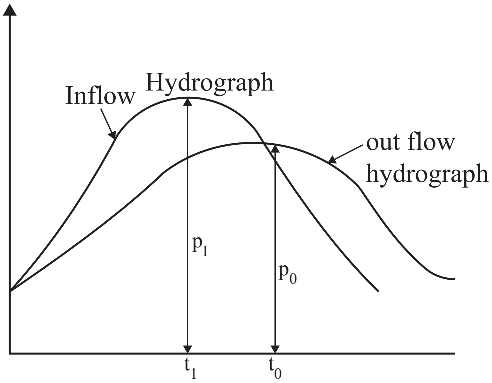
11. An inflow hydrograph is routed through a reservoir to produce an outflow hydrograph. The peak flow of the inflow hydrograph is P_I and the time of occurrence of the peak is t_I. The peak flow of the outflow hydrograph is P_o and the time of occurrence of the peak is t_o. Which one of the following statements is correct?

(a) $P_I > P_o$ and $t_I > t_o$ (b) $P_I > P_o$ and $t_I < t_o$

(c) $P_I < P_o$ and $t_I > t_o$ (d) $P_I < P_o$ and $t_I < t_o$

11. Ans: (b)

Sol:



$P_I > P_O$

$t_I < t_O$

End of Solution

12. The data from a closed traverse survey PQRS (run in the clockwise direction) are given in the table

Line	Included angle (in degree)
PQ	88
QR	92
RS	94
SP	89

The closing error for the traverse PQRS (in degrees) is ________

12. Ans: 3

Sol: In a closed triangle sum of interior angles = $(2n-4)\times 90^\circ = (2\times 4)-4\times 90^\circ = 360^\circ$

angles = $(2n-4)\times 90^\circ = (2\times 4)-4\times 90^\circ = 360^\circ$

$\angle P + \angle Q + \angle R + \angle S = 88 + 92 + 94 + 89 = 363^\circ$

$\therefore$ Angular correction = -3°

Angular error = $+3^\circ$

End of Solution

13. The command area of a canal grows only one crop, i.e., wheat. The base period of wheat is 120 days and its total water requirement. Δ, is 40 cm. If the canal discharge is 2 m^3/s, the area, in hectares, rounded off to the nearest integer, which could be irrigated (neglecting all losses) is _______

13. Ans: 5184

Sol: Wheat,

B = 120 days,

$\Delta = 40$ m,

$Q = 2\ m^3/s$

A = ?

$$Q = \frac{A}{D}$$

$$Q = \frac{A}{8.64\times\frac{B}{\Delta}}$$

$$2 = \frac{A}{8.64\times\frac{120}{0.4}}$$

A = 5184 ha

End of Solution

14. An earthen dam of height H is made of cohesive soil whose cohesion and unit weight are c and γ, respectively. If the factor of safety against cohesion is F_c, the Taylor's stability number (S_n) is

(a) $\frac{\gamma H}{cF_c}$ (b) $\frac{c}{F_c\gamma H}$ (c) $\frac{F_c\gamma H}{c}$ (d) $\frac{cF_c}{\gamma H}$

14. Ans: (b)

Sol: Stability number, $S_n = \frac{C}{F_c\,\gamma\,H}$

End of Solution

15. Which one of the following options contains ONLY primary air pollutants?

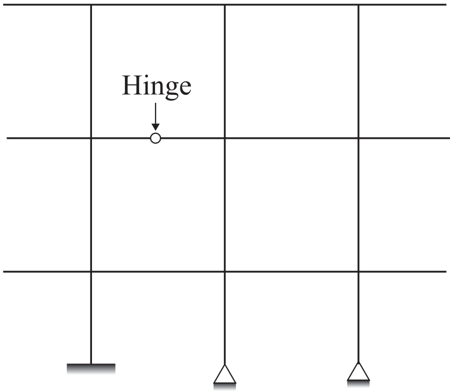
(a) Hydrocarbons and ozone
(b) Ozone and peroxyacetyl nitrate
(c) Hydrocarbons and nitrogen oxides
(d) Nitrogen oxides and peroxyacetyl nitrate

15. Ans: (c)

Sol: Hydrocarbon's and oxides of nitrogen are primary air pollutants.

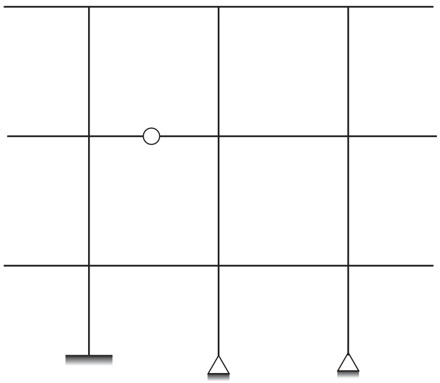
End of Solution

16. The degree of static indeterminacy of the plane frame as shown in figure is ________



16. Ans: 15

Sol:



Static indeterminacy $D_s = D_{se} + D_{si} -$ Force releases

External indeterminacy, $D_{se} = r - s$

No. of support reactions, $r = 7$

Number of equilibrium equations, $s = 3$

$D_{se} = 7 - 3 = 4$

Internal indeterminacy $D_{si} = 3\times$ No of closed boxes

$= 3\times 4 = 12$

Force releases $= 1$[At the internal hinge]

$D_S = 4 + 12 - 1 = 15$

17. The speed-density relationship in a mid-block section of a highway follows the Greenshield's model. If the free flow speed is V_f and the jam density is k_j, the maximum flow observed on this section is

(a) $\frac{v_f k_j}{8}$ (b) $v_f k_j$ (c) $\frac{v_f k_j}{4}$ (d) $\frac{v_f k_j}{2}$

17. Ans: (c)

Sol: From Green shield's linear model

Maximum flow, $q_{max} = \frac{k_j}{2} \times \frac{V_f}{2} = \frac{k_j V_f}{4} = \frac{V_f k_j}{4}$

Where, $V_f \rightarrow$ Free flow (maximum) velocity

$k_j \rightarrow$ Jam (maximum) density

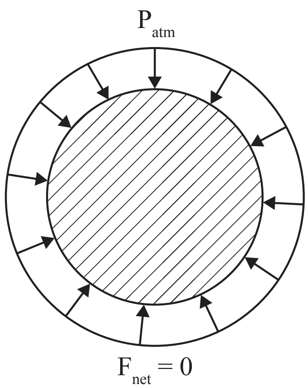
End of Solution

18. A solid sphere of radius, r, and made of material with density, ρ_s, is moving through the atmosphere (constant pressure, P) with a velocity, v. The net force ONLY due to atmosphere pressure (F_p) acting on the sphere at any time, t, is

(a) $4\pi r^2 p$ (b) zero (c) $\frac{4}{3}\pi r^3 \rho_s \frac{dv}{dt}$ (d) $\pi r^2 p$

18. Ans: (b)

Sol:



When object of any shape (not only sphere) is subjected to uniform pressure over entire surface, the net force is zero because pressure force at any point is balanced by an equal and opposite force on opposite point.

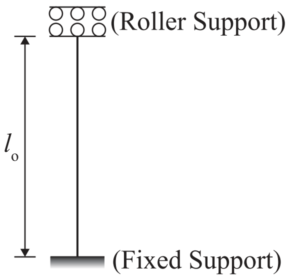
End of Solution

19. A steel column is restrained against both translation and rotation at one end and is restrained only against rotation but free to translate at the other end. Theoretical and design (IS: 800-2007) values, respectively, of effective length factor of the column are

(a) 1.0 and 1.2 (b) 1.2 and 1.2 (c) 1.2 and 1.0 (d) 1.0 and 1.0

19. Ans: (a)

Sol: The given support conditions indicates the following support/ end conditions of column



l_{eff} as per theoretical conditions = 1.0 l_o

l_{eff} as per IS 800 : 2007 = 1.2 l_o

Considering the errors that may occur due to construction of supports on site.

End of Solution

20. Construction of a new building founded on a clayey soil was completed in January 2010. In January 2014, the average consolidation settlement of the foundation in clay was recorded as 10 mm. The ultimate consolidation settlement was estimated in design as 40 mm. Considering double drainage to occur at the clayey soil site, the expected consolidation settlement in January 2019 (in mm, round off to the nearest integer) will be ________

20. Ans: 15

Sol: Time, t_1 = 2014 - 2010 = 4 years

Settlement, S_1 = 10 mm,

S_f = 40 mm,

$$U_1 = \frac{S_1}{S_f} \times 100 = \frac{10}{40} \times 100 = 25\%$$

$$T_{v1} = \frac{\pi}{4}\left(\frac{U_1}{100}\right)^2 = \frac{\pi}{4}\left(\frac{25}{100}\right)^2 = 0.0491$$

For time, t_2 = 2019 - 2010 = 9 years

S_2 = ?

$$T_v = \frac{C_v\, t}{d^2}$$

Since $\frac{C_v}{d^2}$ remains same for both the times,

$T_v \propto t$

$\frac{T_{v2}}{T_{v1}} = \frac{t_2}{t_1}$

$\frac{T_{v2}}{0.0491} = \frac{9}{4}$

$\therefore\ T_{v2} = 0.11044$

$T_{v2} = \frac{\pi}{4}\left(\frac{U_2}{100}\right)^2$ since $T_{v_2} < 0.28$

$0.11044 = \frac{\pi}{4}\left(\frac{U_2}{100}\right)^2$

$U_2 = 37.5\ \%$

$U_2 = \frac{S_2}{S_f} \times 100$

$37.5 = \frac{S_2}{40} \times 100$

$S_2 = 14.99$ mm say 15 mm

End of Solution

21. What is curl of the vector field $2x^2 y\mathbf{i} + 5z^2\mathbf{j} - 4yz\mathbf{k}$?

(a) $-14z\mathbf{i} + 6y\mathbf{j} + 2x^2\mathbf{k}$
(b) $6z\mathbf{i} + 4x\mathbf{j} - 2x^2\mathbf{k}$
(c) $6z\mathbf{i} - 8xy\mathbf{j} + 2x^2y\mathbf{k}$
(d) $-14z\mathbf{i} - 2x^2\mathbf{k}$

21. Ans: (d)

Sol: Given: $\vec{V} = 2x^2y\,\vec{i} + 5z^2\,\vec{j} - 4yz\,\vec{k}$

$$\text{curl}\,\vec{V} = \nabla\times\vec{V} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 2x^2y & 5z^2 & -4yz \end{vmatrix}$$

$= \vec{i}(-4z - 10z) - \vec{j}(0-0) + \vec{k}(0 - 2x^2)$

$= -14z\,\vec{i} - 2x^2\,\vec{k}$

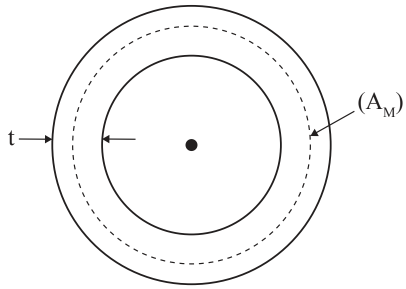
End of Solution

22. A closed thin-walled tube has thickness, t, mean enclosed area within the boundary of the centerline of tube's thickness, A_m and shear stress, τ. Torsional moment of resistance, T, of the section would be

(a) $2\tau A_m t$ (b) $4\tau A_m t$ (c) $\tau A_m t$ (d) $0.5\tau A_m t$

22. Ans: (a)

Sol:



For thin walled circular tubes,

Torsional moment of resistance = $2\tau A_m t$

where, τ = shear stress,

A_m = Area enclosed by median line,

t = thickness of tube.

End of Solution

23. The notation "SC" as per Indian Standard Soil Classification System refers to

(a) Clayey sand (b) Silty clay (c) Clayey silt (d) Sandy clay

23. Ans: (a)

Sol: The symbol SC refers to Clayey Sand.

End of Solution

24. Analysis of a water sample revealed that the sample contains the following species.

CO_3^{2-}, Na^+ , H^+ , PO_4^{3-} , Al^{3+} , H_2CO_3, Cl^-, Ca^{2+} , Mg^{2+} , HCO_3^-, Fe^{2+} , OH^-

Concentrations of which of the species will be required to compute alkalinity?

(a) H^+, H_2CO_3, HCO_3^-, OH^- (b) CO_3^{2-}, H^+, HCO_3^-, OH^-

(c) CO_3^{2-}, H^+, H_2CO_3, HCO_3^- (d) CO_3^{2-}, H_2CO_3, HCO_3^-, OH^-

24. Ans: (b)

Sol: At $p^H < 4.3$ there is no alkalinity present there is only free mineral acidity and dissolved carbon dioxide expressed as carbonic acid $H_2CO_3^-$. Therefore $H_2CO_3^-$ doesn't contribute alkalinity remaining substances CO_3^{2-}, HCO_3^-, OH^- directly cause alkalinity and it also require H^+ ions to calculate OH^-.

End of Solution

25. The velocity field in a flow system is given by v = 2**i** + (x + y) **j** + (xyz)**k**. The acceleration of the fluid at (1, 1, 2) is

(a) **j** + **k** (b) 4**j** + 10**k** (c) 2 **i** + 10 **k** (d) 4**i** + 12 **k**

25. Ans: (b)

Sol:

$$\vec{V} = 2\hat{i} + (x+y)\hat{j} + (xyz)\hat{k}$$

$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} + \frac{\partial u}{\partial t} = 0$$

$$a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} + \frac{\partial v}{\partial t} = 2(1) + (x+y)(1) + xyz(0) + 0$$

$$= x + y + 2 = 1 + 1 + 2 = 4$$

$$a_z = u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} + \frac{\partial w}{\partial t} = 2(yz) + (x+y)(xz) + xyz(xy) + 0$$

$$= 2yz + x^2z + xyz + x^2y^2z$$

$$= 2(1)(2) + 1^2(2) + 1(1)(2) + 1^2 \times 1^2 \times 2$$

$$= 4 + 2 + 2 + 2 \quad = 10$$

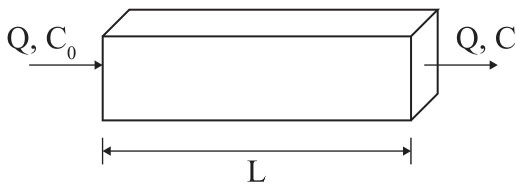
$$\therefore \vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k} = o\hat{i} + 4\hat{j} + 10\hat{k}$$

$$= 4\hat{j} + 10\hat{k}$$

End of Solution

26. Consider the reactor shown in the figure. The flow rate through the reactor is Q m³/h. The concentrations (in mg/L) of a compound in the influent and effluent are C_o and C, respectively. The compound is degraded in the reactor following the first order reaction. The mixing condition of the reactor can be varied such that the reactor becomes either a completely mixed flow reactor (CMFR) or a plug-flow reactor (PFR). The length of the reactor can be adjusted in these two mixing conditions to L_{CMFR} and L_{PFR} while keeping the cross-section of the reactor constant. Assuming steady state and for $C/C_o = 0.8$, the value of L_{CMFR}/L_{PFR} (round off to 2 decimal places) is

___



26. Ans: 1.12

Sol: $\dfrac{C}{C_0} = 0.8$

For CMFR	For PFR
$Q\,(C_o - C) = kC.V$ $\dfrac{Vk}{Q} = \left(\dfrac{C}{C_o - C}\right)^{-1}$ $= \dfrac{C_o - C}{C}$ $= \dfrac{C_o}{C} - 1$ $= \dfrac{1}{0.8} - 1$ $= \dfrac{0.2}{0.8}$ $= \dfrac{1}{4} = 0.25$	$U_z \dfrac{dC}{dZ} = -kC$ Multiply with area, A $Q\dfrac{dC}{dZ} = -kC.A$ $Q\int_{C_o}^{C} \dfrac{dC}{C} = -kA\int_{o}^{L} dZ$ $Q\ell n\left(\dfrac{C}{C_o}\right) = -kAL = -kV$ $\therefore \dfrac{Vk}{Q} = -\ell n(0.8) = 0.223$

$$\therefore \frac{\left(\frac{Vk}{Q}\right)_{CMFR}}{\left(\frac{Vk}{Q}\right)_{PFR}} = \frac{0.25}{0.2231} = 1.12 = \frac{L_{CMFR}}{L_{PFR}}$$

End of Solution

27. The probability density function of a continuous random variable distributed uniformly between x and y (for y > x) is

(a) $\dfrac{1}{y - x}$ (b) $\dfrac{1}{x - y}$ (c) $x - y$ (d) $y - x$

27. Ans: (a)

Sol: We know that the probability density functions of uniform distributions in [x, y] is

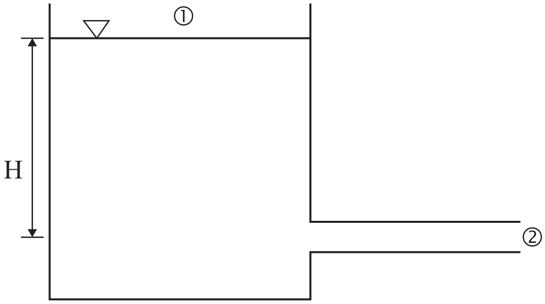
$$f(t) = \frac{1}{y - x} \qquad x \le t \le y$$
$$= 0 \qquad \text{otherwise}$$

End of Solution

28. Two identical pipes (i.e., having the same length, same diameter, and same roughness) are used to withdraw water from a reservoir. In the first case, they are attached in series and discharge freely into the atmosphere. In the second case, they are attached in parallel and also discharge freely into the atmosphere. Neglecting all minor losses, and assuming that the friction factor is same in both the cases,t eh ratio of the discharge in the parallel arrangement to that in the series arrangement (round off to 2 decimal places) is ________.

28. Ans: 2.83

Sol:



Applying Bernoulli's equation between free surface and exit we get

$$H = h_f + \frac{v^2}{2g}$$

Neglecting kinetic energy head at exit

$H = h_f$ ------ (1)

for series combination

$h_f = h_{f1} + h_{f2}$

$$= \frac{fLQ_s^2}{12.1D^5} + \frac{fLQ_s^2}{12.1D^5}$$

$$\text{i.e } H = \frac{2fLQ_s^2}{12.1D^5} \text{ ------- (2)}$$

for parallel combination

$$h_f = h_{f1} = h_{f2} \quad \& \quad Q_1 = Q_2 = \left(\frac{Q_p}{2}\right)$$

$$\text{i.e} \quad H = \frac{fL\left(\frac{Q_p}{2}\right)^2}{12.1\,D^5}$$

$$H = \frac{fLQ_p^2}{4 \times 12.1\ \ D^5} \text{ ------- (3)}$$

from 2 & 3

$$\frac{2\,fLQ_s^2}{12.1\ \ D^5} = \frac{fLQ_p^2}{4 \times 12.1\ \ D^5}$$

$$\text{i.e } \frac{Q_p}{Q_S} = \sqrt{8} = 2.83$$

End of Solution

29. The speed-density relationship of a highway is given as

$$u = 100 - 0.5k$$

where, u = speed in km per hour, k = density in vehicles per km. The maximum flow (in vehicles per hour, round off to the nearest integer is) ________

29. Ans: 5000 veh/hr

Sol: Given speed (u) - density (k) relation

$u = 100 - 0.5k$

when $u = 0$, $k = k_{max}$

$\therefore\ 0 = 100 - 0.5\,k_{max}$

$k_{max} = 200$ veh/km

when $k = 0$, $u = u_{max}$

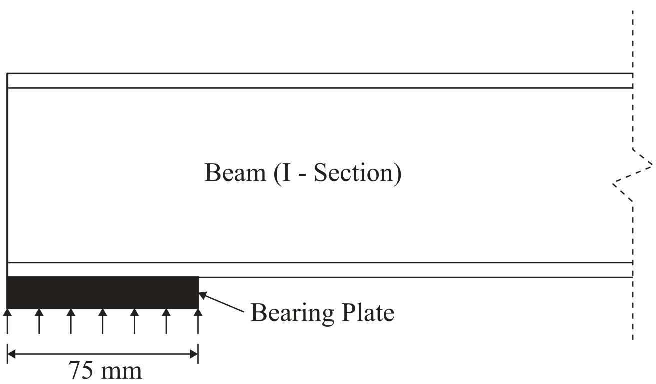
$u_{max} = 100$ kmph

For Greenshield's linear speed - density model

$$q_{max} = \frac{k_{max}}{2} \times \frac{V_{max}}{2} = \frac{200}{2} \times \frac{100}{2} = 5000 \text{ veh/hr}$$

End of Solution

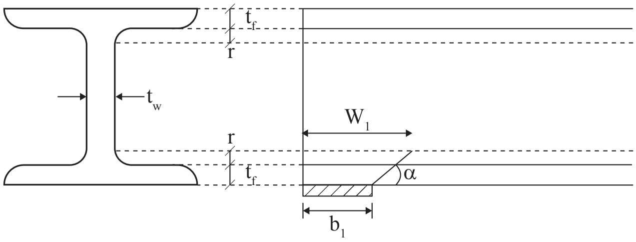
30. A rolled I-section beam is supported on a 75 mm wide bearing plate as shown in figure. Thickness of flange and web of the I-section are 20 mm and 8 mm, respectively. Root radius of the I-section is 10 mm. Assume: material yield stress, $f_y = 250$ MPa and partial safety factor for material, $\gamma_{mo} = 1.10$



As per IS : 800-2007, the web bearing strength (in kN, round off to 2 decimal places) of the beam is ___

30. Ans: 272.72

Sol:



Thickness of web (t_w) = 8 mm

Thickness of flange (t_f) = 20 mm

Radius of roof (r) = 10 m

width of support (b_1) (or support reaction) = 75 mm

As per IS 800:2007

Load distribution angle (α) = 21.8° [1V : 2.5H]

Design bearing strength of steel $= \dfrac{f_y}{\gamma_{mo}} = \dfrac{250}{1.1}$ MPa

$\Rightarrow$ Width of critical section @ root resisting web crippling due to high bearing stress $(w_1) = b_1 + 2.5(t_f + r)$

$= 75 + 2.5\,(20 + 10)$

$= 150$ mm

$\Rightarrow$ Total load carrying capacity of web with respect to web crippling $= w_1 \times t_w \times \dfrac{f_y}{\gamma_{mo}}$

$= 272.72$ kN

End of Solution

31. The critical bending compressive stress in the extreme fibre of a structural steel section is 1000 MPa. It is given that the yield strength of the steel is 250 MPa, width of flange is 250 mm and thickness of flange is 15 mm. As per the provisions of IS : 800 -2007, the non-dimensional slenderness ratio of the steel cross-section is

(a) 0.25 (b) 0.75 (c) 2.00 (d) 0.50

31. Ans: (d)

Sol: Yield stress of steel $f_y = 250$ N/mm²

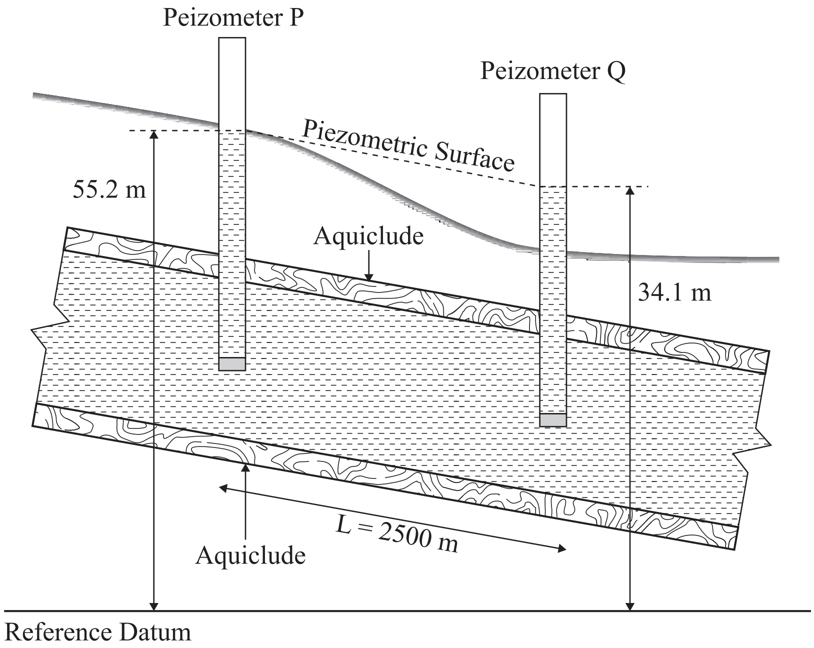
Critical bending compressive stress in the extreme fiber $f_{cr,b} = 1000$ N/mm²

Non dimensional effective slenderness ratio of the steel cross section as per IS800:2007 (λ_{LT})

$$\lambda_{LT} = \sqrt{\frac{f_y}{f_{cr,b}}} = \sqrt{\frac{250}{1000}} = 0.5$$

End of Solution

32. A confined aquifer of 15 m constant thickness is sandwiched between two aquicludes as shown in the figure (not drawn to scale)



The heads indicated by two piezometers P and Q are 55.2 m and 34.1 m, respectively. The aquifer has a hydraulic conductivity of 80 m/day and its effective porosity is 0.25. If the distance between the piezometers is 2500 m, the time taken by the water to travel through the aquifer from piezometer location P to Q (in days, round off to 1 decimal place) is ____

32. Ans: 925.7

Sol: Discharge velocity, V = k i

$$V = k\left(\frac{h_1 - h_2}{L}\right)$$

$$= 80\left(\frac{55.2 - 34.1}{2500}\right) = 0.6752 \text{ m/day}$$

Porosity, n = 0.25

$\therefore$ Seepage velocity, $V_s = \frac{V}{n}$

$$= \frac{0.6752}{0.25} = 2.7008 \text{ m/day}$$

Time taken $= \frac{L}{V_s} = \frac{2500}{2.7008} = 925.65$ days say 925.7 days

End of Solution

33. When a specimen of M25 concrete is loaded to a stress level of 12.5 MPa, a strain of 500×10^{-6} is recorded. If this load is allowed to stand for a long time, the strain increases to 1000×10^{-6}. In accordance with the provisions of IS:456-2000, considering the long-term effects, the effective modulus of elasticity of the concrete (in MPa) is _______

33. Ans: 12500

Effective modulus of elastic $E_{ce} = \dfrac{E_c}{1+\theta}$

$$E_c = 5000\sqrt{f_{ck}} = 5000\sqrt{25} = 25000 \text{ MPa}$$

Creep coefficient $(\theta) = \dfrac{\text{creep strain}}{\text{elastic strain}}$

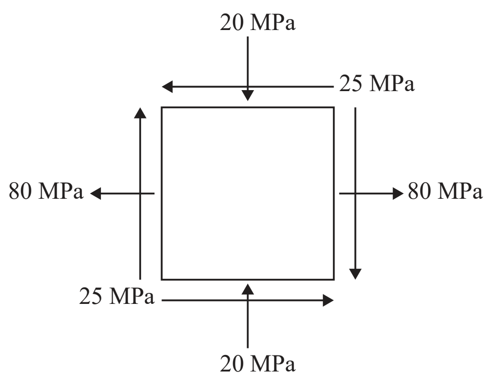
$$= \frac{\text{longterm strain} - \text{elastic strain}}{\text{elastic strain}}$$

$$= \frac{(1000 \times 10^{-6}) - (500 \times 10^{-6})}{(500 \times 10^{-6})} = 1$$

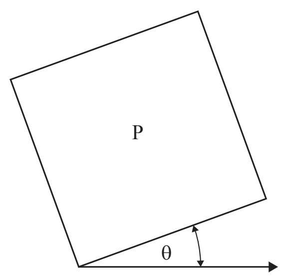
$$\therefore\ E_{ce} = \frac{25000}{1+1} = 12500 \text{ MPa}$$

End of Solution

34. For a plane stress problem, the state of stress at a point P is represented by the stress element as shown in figure.



By how much angle (θ) in degrees the stress element should be rotated in order to get the planes of maximum shear stress?



(a) 48.3 (b) 31.7 (c) 26.6 (d) 13.3

34. Ans: (b)

Sol: $\sigma_x = 80$ MPa, $\sigma_y = -20$ MPa, $\tau_{xy} = -25$ MPa,

Angle of major principal plane :

$$\tan 2\theta_p = \frac{2\,\tau_{xy}}{(\sigma_x - \sigma_y)} = \frac{2(-25)}{80-(-20)}$$

$$\theta_p = -13.28^\circ$$

Angle of maximum shear stress plane

$$= \theta_p + 45 = -13.28 + 45 = 31.7^\circ$$

End of Solution

35. Constant head permeability tests were performed on two soil specimens. S1 and S2. The ratio of height of the two specimens ($L_{S1} : L_{S2}$) is 1.5, the ratio of the diameter of specimens ($D_{S1} : D_{S2}$) is 0.5, and the ratio of the constant head ($h_{s1}: h_{S2}$) applied on the specimens is 2.0. If the discharge from both the specimens is equal, the ratio of the permeability of the soil specimens ($k_{s1}: k_{S2}$) is ______

35. Ans: 3

Sol: $Q = k\ i\,A$

$$= k \times \frac{h}{L} \times \frac{\pi}{4} D^2$$

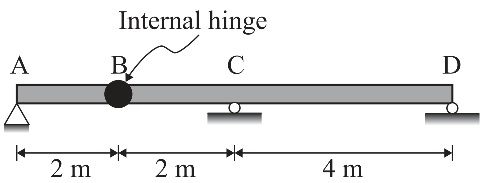
$$\frac{Q_1}{Q_2} = \frac{k_1}{k_2}\frac{h_1}{h_2}\frac{L_2}{L_1}\left(\frac{D_1}{D_2}\right)^2$$

$$1 = \frac{k_1}{k_2} \times 2 \times \frac{1}{1.5} \times 0.5^2$$

$$\frac{k_1}{k_2} = 3$$

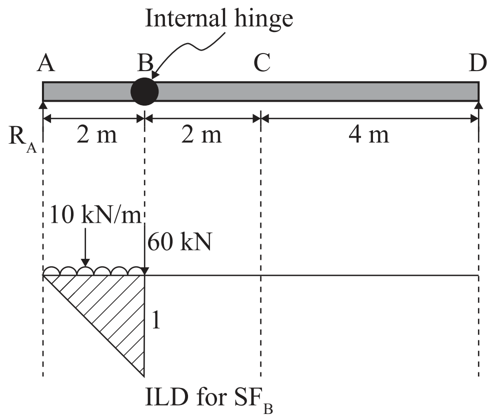
End of Solution

36. A long uniformly distributed load of 10 kN/m and a concentrated load of 60 kN are moving together on the beam ABCD shown in figure (not drawn to scale). The relative positions of the two loads are not fixed. The maximum shear force (in kN, round off to the nearest integer) caused at the internal hinge B due to the two loads is _______.



36. Ans: 70

Sol:



$$\text{Maximum SF at B} = 10\left[\frac{1}{2} \times 2 \times 1\right] + 60 \times 1$$

$$= 70 \text{ kN}$$

End of Solution

37. Chlorine is used as the disinfectant in a municipal water treatment plant. It achieves 50 percent of disinfection efficiency measure in terms of killing the indicator microorganisms (E-coil) in 3 minutes. The minimum time required to achieve 99 percent disinfection efficiency would be

(a) 9.93 minutes (b) 11.93 minutes (c) 21.93 minutes (d) 19.39 minutes

37. Ans: (d)

Sol: $\eta_1 = 50$ %, $t_1 = 3$ min

$$\eta_1 = [1 - e^{-k \times t_1}] \times 100$$

$$50 = [1 - e^{-k \times 3}] \times 100$$

$k = 0.231$ min^{-1}

$\eta_2 = 99$ %, $t_2 =$?

$$\eta_2 = [1 - e^{-k \times t_2}] \times 100$$

$$99 = [1 - e^{-0.231 \times t_2}] \times 100$$

$t_2 = 19.93$ min

End of Solution

38. In the context of provisions relating to durability of concrete, consider the following assertions:

Assertion (1): As per is 456-2000, air entrainment to the extent of 3% to 6% is required for concrete exposed to marine environment.

Assertion (2): The equipment alkali content (in terms of Na_2O equivalent) for a cement containing 1% and 0.6% of Na_2O and K_2O, respectively is approximately 1.4% (rounded to 1 decimal place)

Which one of the following statements is CORRECT?

(a) Assertion (1) is FALSE and Assertion (2) is TRUE

(b) Assertion (1) is TRUE and Assertion (2) is FALSE

(c) Both Assertion (1) and Assertion (2) are FALSE

(d) Both Assertion (1) and Assertion (2) are TRUE

38. Ans: (a)

Sol: As per clause 8.2.2.3 of IS 456-2000, entrained air percentage of 3 to 6% is required to resist freezing and thawing, i.e. not for marine environment.

Hence, Assertion (1) is wrong

Equivalent alkali content is terms of Na_2O

$$= [Na_2O] + 0.685\,[K_2O]$$

$$= 1 + 0.685 \times 0.6 = 1.41\%$$

Hence, Assertion (2) is correct.

End of Solution

39. Raw municipal solid waste (MSW) collected from a city contains 70% decomposable material that can be converted to methane. The water content of the decomposable material is 35°. An elementj analysis of the decomposable material yields the following mass percent?

C : H : O : N : other = 44 : 6 : 43 : 0.8 : 6.2

The methane production of the decomposable material is governed by the following stoichiometric relation.

$C_aH_bO_cN_d + nH_2O \rightarrow mCH_4 + sCO_{\_2} + dNH_3$

Given atomic weights : C = 12, H = 1, O = 16, N = 14. The mass of methane produced (in grams, round off to 1 decimal place) per kg of raw MSW will be_____

39. Ans: 151.8

Sol:

C: H : O : N = 44 : 6 : 43 :0.8

$\Rightarrow$ a = 44 , b = 6, c = 43 , d = 0.8

$$C_a H_b O_c N_d + n\,H_2O \rightarrow m\,CH_4 + s\,CO_2 + d\,NH_3$$

By balancing the equation,

m + s = 44 ------(1)

4m - 2n = 3.6 -----(2)

2s - n = 43 ------(3)

By solving m = 11.7

Molecular weight of $C_{44} H_6 O_{43} N_{0.8}$ = 44×12 + 6×1 + 43×16 + 0.8×14 = 1233.2

Molecular weight of 11.7 CH_4 = 11.7 × (12 + 4 ×1) = 187.2

1233.2 parts of MSW produce = 187.2 parts of CH_4 gas

1 part of MSW produce $= \dfrac{187.2}{1233.2}$ parts of CH_4 gas

1 kg of MSW produce $= \dfrac{187.2}{1233.2} \times 1$ kg of CH_4 gas

Mass of methane gas produced = 0.1518 kg = 151.8 gm

End of Solution

40. A series of perpendicular offsets taken from a curved boundary wall to a straight survey line at an interval of 6 m are 1.22, 1.67, 2.04, 2.34, 2.14, 1.87 and 1.15 m. The area (in m^2, round off to 2 decimal places) bounded by the survey line, curved boundary wall, the first and the last offsets, determined using Simpson's rule is _______.

40. Ans: 68.5

Sol: By using Simpson's rule:

$$A = \frac{d}{3}\left[(\text{first} + \text{last}) + 2(\text{odd}) + 4(\text{Even})\right]$$

$$= \frac{6}{3}\left[(1.22 + 1.15) + 2(2.04 + 2.14) + 4(1.67 + 2.34 + 1.87)\right]$$

$= 68.5\ m^2$

Simpson's rule is applicable for odd number of ordinates and also for curved boundaries.

End of Solution

41. The inverse of the matrix $\begin{bmatrix} 2 & 3 & 4 \\ 4 & 3 & 1 \\ 1 & 2 & 4 \end{bmatrix}$ is

(a) $\begin{bmatrix} -10 & 4 & 9 \\ 15 & -4 & -14 \\ -5 & 1 & 6 \end{bmatrix}$

(b) $\begin{bmatrix} 2 & -\frac{4}{5} & -\frac{9}{5} \\ -3 & \frac{4}{5} & \frac{14}{5} \\ 1 & -\frac{1}{5} & -\frac{6}{5} \end{bmatrix}$

(c) $\begin{bmatrix} -2 & \frac{4}{5} & \frac{9}{5} \\ 3 & -\frac{4}{5} & -\frac{14}{5} \\ -1 & \frac{1}{5} & \frac{6}{5} \end{bmatrix}$

(d) $\begin{bmatrix} 10 & -4 & -9 \\ -15 & 4 & 14 \\ 5 & -1 & -6 \end{bmatrix}$

41. Ans: (c)

Sol: Let $A = \begin{bmatrix} 2 & 3 & 4 \\ 4 & 3 & 1 \\ 1 & 2 & 4 \end{bmatrix}$

det (A) = 2(12 – 2) – 3 (16 – 1) + 4 (8 –3)

= 2(10) – 3 (15) + 4(5)

det (A) = – 5

Minor of 2 = 12 – 2 = 10

Minor of 3 = 16 – 1 = 15

Minor of 4 = 8– 3 = 5

Minor of 4 = 12 – 8 = 4

Minor of 3 = 8 – 4 = 4

Minor of 1 = 4 – 3 = 1

Minor of 1 = 3 – 12 = –9

Minor of 2 = 2 – 16 = –14

Minor of 4 = 6 – 12 = –6

$$\text{Cofactors of } A = \begin{bmatrix} 10 & -15 & 5 \\ -4 & 4 & -1 \\ -9 & 14 & -6 \end{bmatrix}$$

adj A = (cofactors of A)^T

$$\text{adj } A = \begin{bmatrix} 10 & -4 & -9 \\ -15 & 4 & 14 \\ 5 & -1 & -6 \end{bmatrix}$$

$$\therefore A^{-1} = \frac{\text{adj}A}{|A|} = \frac{-1}{5}\begin{bmatrix} 10 & -4 & -9 \\ -15 & 4 & 14 \\ 5 & -1 & -6 \end{bmatrix}$$

$$A^{-1} = \begin{bmatrix} -2 & \frac{4}{5} & \frac{9}{5} \\ 3 & \frac{-4}{5} & \frac{-14}{5} \\ -1 & \frac{1}{5} & \frac{6}{5} \end{bmatrix}$$

Option (c) is correct

End of Solution

42. The ordinates, u, of a 2-hour unit hydrograph (i.e., for 1 cm of effective rain), for a catchment are shown in the table.

r(hour)	0	1	2	3	4	5	6	7	8	9	10	11	12
u(m^3/s)	0	2	8	18	32	45	30	19	12	7	3	1	0

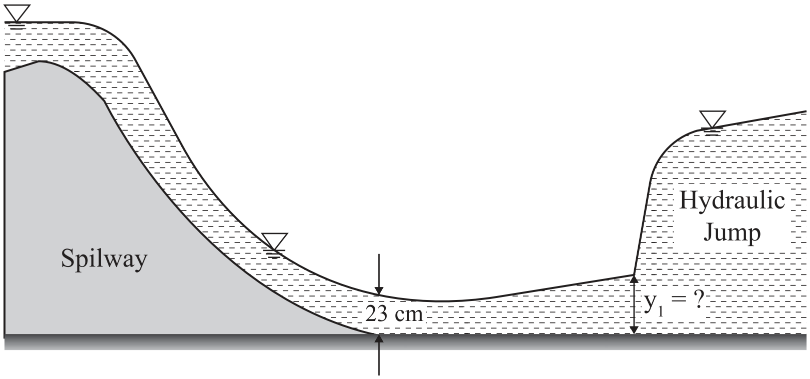
A 6-hour storm occurs over the catchment such that the effective rainfall intensity is 1 cm/hour for the first two hours, zero for the next two hours, and 0.5 cm/hour for the last two hours. If the base flow is constant at 5 m^3/s. The peak flow due to this storm (in m^3/s round off to 1 decimal place) will be _______

42. Ans: 97

Sol:

			log 2h	log 4 hu		
Time	2h UH	1st DRH, $R_1 = 2$ cm	2nd DRH, $R_2 = 0$	3rd DRH, $R_3 = 1$ cm	Total DRH	B F
0	0	0	-	-	0	
1	2	4	-	-	4	
2	8	16	0	-	16	
3	18	36	0	-	36	
4	32	64	0	0	64	
5	45	90	0	2	92	5 **(97 m^3/s)**
6	30	60	0	8	68	
7	19	38	0	18	56	
8	12	24	0	32	56	
9	7	14	0	45	59	
10	3	6	0	30	36	
11	1	2	0	19	21	
12	0	0	0	12	12	

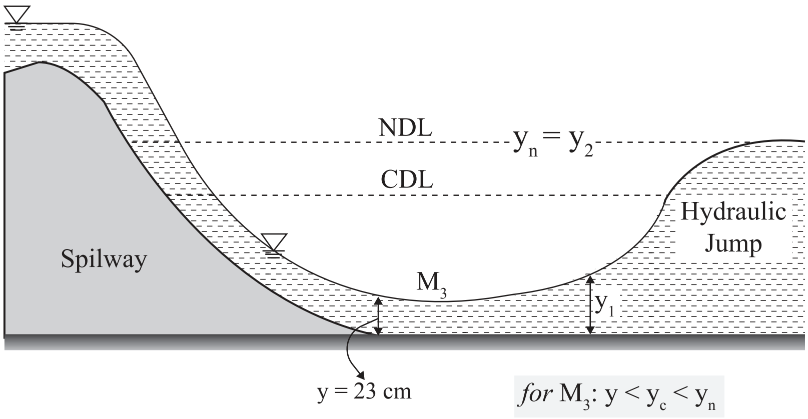
43. At the foot of a spillway, water flows at a depth of 23 cm with a velocity of 8.1 m/s, as shown in the figure.



The flow enters as an M-3 profile in the long wide rectangular channel with bed slope = $\frac{1}{1800}$ and Manning's n = 0.015. A hydraulic jump is formed at a certain distance from the foot of the spillway. Assume the acceleration due to gravity, g = 9.81 m/s^2. Just before the hydraulic jump, the depth of flow y_1 (in m, round off to 2 decimal places is _______

43. Ans: 0.42 m

Sol:



$q = V \times y = 8.1 \times 0.23 = 1.863$ m^2/s

Hydraulic jump will be formed when depth of water changes from super critical depth to subcritical depth.

For mild slopes, normal depth is more than the critical depth ($y_n > y_c$)

$\Rightarrow$The flow after the jump is considered as uniform flow for which the depth is y_n.

Consider post jump depth $y_2 = y_n$

Calculation of y_n :

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

$$q = \frac{1.863}{y_n} = \frac{1}{0.015}\left(y_n^{2/3}\right)\left(\frac{1}{1800}\right)^{1/2}$$

$$\Rightarrow y_n = 1.11 \text{ m} = y_2$$

$$F_{r_2}^2 = \frac{q^2}{gy_2^3}$$

$$= \frac{1.863^2}{9.81 \times 1.11^3}$$

$$F_{r_2} = 0.508$$

$$y_1 = \frac{y_2}{2}\left[-1 + \sqrt{1 + 8F_{r_2}^2}\right]$$

$$= \frac{1.11}{2}\left[-1 + \sqrt{1 + 8 \times 0.508^2}\right]$$

$$= 0.417$$

End of Solution

44. A flexible pavement has the following class loads during a particular hour of the day.

i. 80 buses with 2-axles (each axle load of 40 kN);

ii. 160 trucks with 2-axles (from and rear axle loads of 40 kN and 80 kN, respectively)

The equivalent standard axle load repetitions for this vehicle combination as per IRC : 37-2012 would be

(a) 180 (b) 250 (c) 240 (d) 320

44. Ans: (a)

Sol: Given,

80 buses with 2 axles, each axle load is 40 kN

$\therefore$ No. of repetitions of 40 kN, $N_1 = 80 \times 2 = 160$

160 trucks,with, front axle local = 40 kN

No. of repetitions of 40 kN, $N_2 = 160$

Rear axle load of 80 kN, No. of trucks, $N_3 = 160$

$\therefore$ Equivalent standard axle repetitions, in terms of standard axle load 80 kN is

$$= (N_1 + N_2)\left[\frac{40}{80}\right]^4 + N_3\left[\frac{80}{80}\right]^4$$

$$= (160 + 160)\left[\frac{40}{80}\right]^4 + 160\left[\frac{80}{80}\right]^4 = 180 \qquad \text{(Standard axles)}$$

End of Solution

45. A square footing of 2 m sides rests on the surface of a homogeneous soil bed having the properties cohesion c = 24 kPa, angle of internal friction ϕ = 25° and unit weight γ 18 kN/m³. Terzaghi's bearing capacity factors for ϕ = 25° are $N_c = 25.1$. $N_q = 12.7$, $N_\gamma = 9.7$, $N'_c = 14.8$, $N'_q = 5.6$, and $N'_\gamma = 3.2$. The ultimate bearing capacity of the foundation (in kPa, round off to 2 decimal places is _______.

45. Ans: 353.92

Sol: For surface footing, $D_f = 0$

Since ϕ value given (25°) is less than 29°, the soil undergoes local shear failure.

For LSF, $q_u = 1.3\, C_m\, N_c' + \gamma\, D_f\, N_q' + 0.4\, \gamma B\, N\gamma'$ [square footing]

$$= 1.3 \times \frac{2}{3} \times C\, N_c' + 0 + 0.4\, \gamma\, B\, N\gamma'$$

$$= 1.3 \times \frac{2}{3} \times 24 \times 14.8 + 0 + 0.4 \times 18 \times 2 \times 3.2$$

$$= 353.92 \text{ kPa}$$

End of Solution

46. A broad gauge railway line passes through a horizontal curved section (radius = 875 m) of length 200 m. The allowable speed on this portion is 100 km/h. For calculating the cant, consider the gauge as centre-to-centre distance between the rail heads, equal to 1750 mm. The maximum permissible cant (in mm, round off to 1 decimal place) with respect to the centre-to-centre distance between the rail heads is _____

46. Ans: 82.5 mm

Sol: Given BG railway track, G = 1750 mm = 1.750 m (c/c)

Radius of curve, R = 875 m

Length of curve, l = 200 m

Allowable speed, V_{max} = 100 kmph

For normal speed, BG track cant deficiency allowed, $e_d = c_d = 75$ mm = 0.075 m

We've $e_{th} = e_a + e_d$ $\quad\therefore$ where = e_a = actual cant

e_{th} = theoritical cant with respect to V_{max}

$$\frac{GV^2_{max}}{127R} = e_a + e_d$$

$$\frac{1.750 \times 100^2}{127 \times 875} = e_a + 0.075$$

$e_a = 0.08248$ m = 82.48 mm ≈ 82.5 mm

End of Solution

47. A timber pile of length 8 m and diameter 0.2 m is driven with a 20 kN drop hammer, falling freely from a height of 1.5 m. The total penetration of the pile in the last 5 blows is 40 mm. Use the Engineering News Record expression. Assume a factor of safety of 6 and empirical factor (allowing reduction in the theoretical set, due to energy losses) of 2.5 cm, The safe load carrying capacity of the pile (in kN, round off to 2 decimal places) is _____.

47. Ans: 151.52

Sol:

$$Q_{safe} = \frac{w\,h\,\eta_h}{F(S+C)}$$

S = set value = $\frac{40}{5}$ = 8 mm = 0.8 cm

C = 2.5 cm, F = 6 , W = 20 kN,

h = 1.5 m = 150 cm

Take, η_h = 100 %

$$Q_{safe} = \frac{20 \times 150 \times 1}{6(0.8+2.5)}$$

$$= 151.5152 \text{ kN say } 151.52 \text{ kN}$$

End of Solution

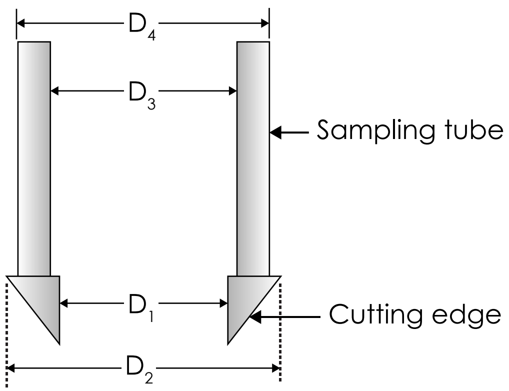
48. The dimensions of a soil sample are given in the table.

Parameter	Cutting edge	Sampling tube
Inside diameter (mm)	80	86
Outside diameter (mm)	100	90

For this sampler, the outside clearance ratio 9in percent, round off to 2 decimal places) is _______.

48. Ans: 11.11

Sol:



Sampler

Given, $D_1 = 80$, $D_2 = 100$, $D_3 = 86$, $D_4 = 90$

$$\text{Outside clearance} = \frac{D_2 - D_4}{D_4} \times 100$$

$$= \frac{100-90}{90} \times 100$$

$$= 11.1111\ \% \text{ say } 11.11\ \%$$

End of Solution

49. A camera with a focal length of 20 cm fitted in an aircraft is used for taking vertical aerial photographs of a terrain. The average elevation of the terrain is 1200 m above mean sea level (MSL). What is the height above MSL at which an aircraft must fly in order to get the aerial photographs at a scale of 1 : 8000?

(a) 2600 m (b) 3000 m (c) 3200 m (d) 2800 m

49. Ans: (d)

Sol: f = 20 cm, h = 1200 m, H = ?

S = 1:800

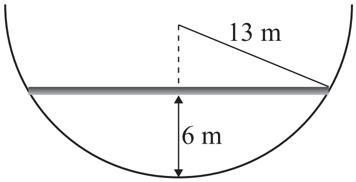
Scale of map = $S = \dfrac{f}{(H-h)}$

$$\frac{1}{800} = \frac{0.2}{H-1200}$$

$\Rightarrow$ H = 2800 m

End of Solution

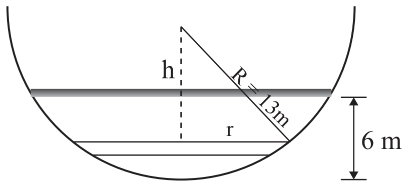
50. Consider the hemi-spherical tank of radius 13 m as shown in the figure (not drawn to scale). What is the volume of water (in m^3) when the depth of water at the centre of the tank is 6 m?



(a) 156 π (b) 468 π (c) 78 π (d) 396 π

50. Ans: (d)

Sol:



$$v = \int_7^{13} \pi r^2 dh = \pi \int_7^{13} (R^2 - h^2) dh$$

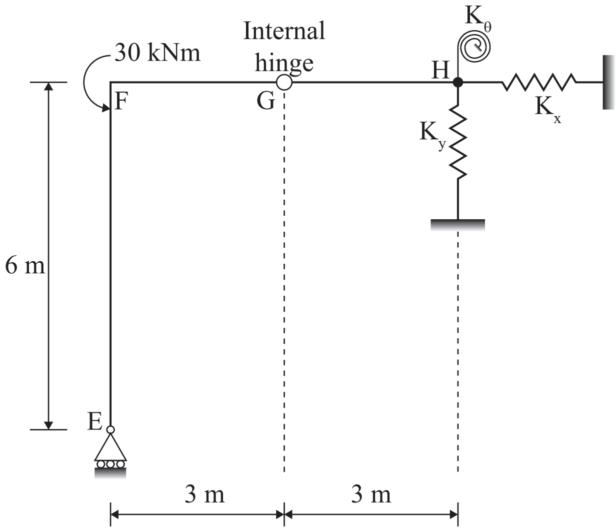
$$= \pi \left[R^2 h - \frac{h^3}{3}\right]_7^{13}$$

$$= \left\{\left[13^2 \times 13 - \frac{13^3}{3}\right] - \left[13^2 \times 7 - \frac{7^3}{3}\right]\right\} \times \pi$$

$$= 396\pi$$

End of Solution

51. A plane frame shown in the figure (not to scale) has linear elastic springs at node H. The spring constants are $k_x = k_y = 5 \times 10^5$ kN/m and $k\theta = 3 \times 10^5$ kNm/rad.



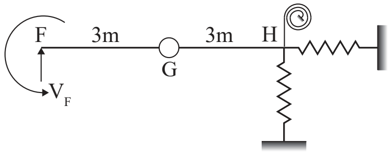
For the externally applied moment of 30 kNm at node F, the rotation (in degrees, round off to 3 decimals) observed in the rotational spring at node H is ____.

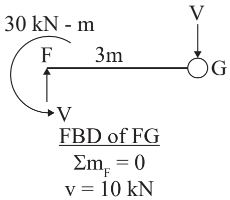
51. Ans: 0.006 degree

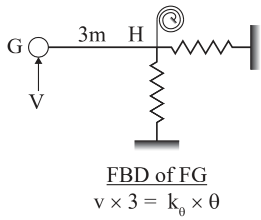
Sol: Since horizontal reaction at E = $H_c = 0$

Bending moment at F for member FE = $M_{FE} = 0$

Member FH behaves like propped cantilever beam







FBD OF GH

$$M_H = V \times 3 = k_\theta \times \theta$$

$$\theta = \frac{10 \times 3}{3 \times 10^5} = 10^{-4}\text{rad}$$

$= 0.0057$ deg

End of Solution

52. An ordinary differential equation is given below.

$$\left(\frac{dy}{dx}\right)(x \ln x) = y$$

The solution for the above equation is

(Note: K denotes a constant in the options)

(a) $y = Kxe^{-x}$ (b) $y = K \ln x$ (c) $y = Kx \ln x$ (d) $y = Kxe^{x}$

52. Ans: (B)

Sol: $\frac{dy}{dx}(x \log x) = y$

on separating the variables

$$\int \frac{1}{y}\, dy = \int \frac{1}{x \log x}\, dx \qquad \left(\text{let } \log x = t,\ \frac{1}{x} dx = dt\right)$$

$$\log y = \int \frac{1}{t} dt + \log k$$

logy = logt + logk

$\Rightarrow y = kt$

(or) y = k logx

End of Solution

53. A water treatment plant treats 6000 m^3 of water per day. As a part of the treatment process, discrete particles are required to be settled in a clarifier. A column test indicates that an overflow rate of 1.5 m per hour would produce the desired removed of particles through setting in the clarifier having a depth of 3.0 m. The volume of the required clarifier, (in m^3, round off to 1 decimal place) would be_______

53. Ans: 500

Sol: $Q = 6000\ m^3/\text{day} = \ = \frac{6000}{24} = 250\ m^3/\text{hr}$

$v_0 = 1.5$ m/hr

$$\text{Surface area} = \frac{Q}{v_0} = \frac{250}{1.5} = 166.66\ m^2$$

Depth , H = 3 m

Volume of clarifies = Surface area × depth

$= 166.66 \times 3 = 500\ m^3$

End of Solution

54. The uniform arrival and uniform service rates observed on an approach road to a signalized intersection are 20 and 50 vehicles/minute, respectively. For this signal, the red time is 30 x. the effective green time is 30 s and the cycle is length is 60 s. Assuming that initially there are no vehicles in the queue, the average delay per vehicle using the approach road during a cycle length (in x, round off to 2 decimal places) is____________.

54. Ans: 12.5

Sol: Effective green time, C_i = 30 sec,

Cycle length, C_o = 60 sec

Normal flow (uniform arrival), q_i = 20 veh/minute

Saturation flow (uniform service rate), s_i = 50 veh/minute

Webster's Delay

$$d_i = \frac{\frac{C_o}{2}\left[1 - \frac{G_i}{C_o}\right]^2}{\left[1 - \frac{q_i}{s_i}\right]}$$

$$d_i = \frac{\frac{60}{2}\left(1 - \frac{30}{60}\right)^2}{\left(1 - \frac{20}{50}\right)} = 12.5 \text{ sec}$$

End of Solution

55. A 2 m × 4 m rectangular footing has to carry a uniformly distributed load of 120 kPa, As per the 2 : 1 dispersion method of stress distribution, the increment in vertical stress (in kPa) at a depth of 2 m below the footing is ______

55. Ans: 40

Sol:

$$\sigma_z = \frac{Q}{(B+Z)(L+Z)} \quad \text{for 2V to 1 H load dispersion}$$

$$= \frac{2 \times 4 \times 120}{(2+2)(4+2)} = 40 \text{ kPa}$$

End of Solution