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GATE 2019

CIVIL ENGINEERING

Detailed Solution

EXAM DATE: 10-02-2019

AFTERNOON SESSION (02:30 PM-05:30 PM)

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SECTION: GENERAL APTITUDE

1. Daytime temperature in Delhi can ___ 40°C

(a) Peak (b) reach
(c) get (d) stand

Ans. (b)

2. The growth rate of ABC Motors in 2017 was the same ___ XYZ Motors in 2016.

(a) As those of (b) As that off
(c) As that of (d) As off

Ans. (c)

Sol. "As that of"

3. 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) Rs. 1,92,500
(c) Rs. 1,27,500 (d) Rs. 2,75,000

Ans. (a)

Sol. Area of mansion = $70 \times 55 = 3850\ m^2$

Area for flower pots = $550\ m^2$

$\therefore$ Area left for carpet = $3850 - 550 = 3300 m^2$

$\therefore$ Cost = $3300 \times 50 = 165000$

4. A retaining wall with measurements 30 m × 12 m × 6m was constructed with bricks of dimensions 8 cm × 6cm. If 60% of the wall consists of bricks used for the construction is ___ lakhs.

(a) 45 (b) 30
(c) 40 (d) 75

Ans. (a)

Sol. Volume of wall = $30 \times 12 \times 6 = 2160\ m^3$

$= 2160 \times 10^6\ cm^3$

Total volume of bricks required = $2160 \times 10^6 \times 0.6\ cm^3 = 1296 \times 10^6\ cm^3$

Volume of one brick = $8 \times 6 \times 6 = 288\ cm^3$

$\therefore$ No. of bricks required = $\dfrac{1296 \times 10^6}{288}$

$= 4.5 \times 10^6 = 45$ lakhs

5. Hima Das was ___ only Indian athlete to win___ gold for India.

(a) the, many (b) an, the
(c) an, a (d) the, a

Ans. (d)

Sol. the, a

6. 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) $x - y$ (b) $\dfrac{100(x-y)}{100+x}$

(c) $\dfrac{100(x-y)}{100+y}$ (d) $\dfrac{x}{y}$

Ans. (c)

Sol. Let population of X is 'A' in 2001

and Population of Y is 'B' in 2001

$\therefore$ Population of A in 2011 = $A\left(1+\dfrac{x}{100}\right)$

& Population of B in 2011 = $B\left(1+\frac{y}{100}\right)$

Given, $\frac{A}{B} = P$

% increase in P = $\dfrac{\dfrac{A\left(1+\frac{x}{100}\right)}{B\left(1+\frac{y}{100}\right)} - \dfrac{A}{B}}{\dfrac{A}{B}} \times 100$

$= \dfrac{\left[\dfrac{P\left(1+\frac{x}{100}\right)}{\left(1+\frac{y}{100}\right)} - P\right]}{P} \times 100$

$= \left[\dfrac{1+\frac{x}{100}}{1+\frac{y}{100}} - 1\right] \times 100 = \dfrac{(x-y)\,100}{100+y}$

7. The Newspaper report that over 500 hectares of tribal land spread across 28 tribal seetlements in Mohinitampuram 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 enroach further into the forests".

On the basis of the information available in the paragraph, ___ is/are responsible for duping the tribals.

(a) The newspaper
(b) Landless families
(c) forest officials
(d) it cannot be inferred who

Ans. **(d)**

Sol. "it cannot be inferred who"

From given information, nobody can be held responsible.

8. 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 tak for the tank to be filled? (Assume that the rate of drainage is independent of the head)

(a) 2.50 (b) 1.50
(c) 2.00 (d) 4.00

Ans. **(a)**

Sol. Pipe X will fill how much in one hour = $\frac{1}{5}$ tank

Pipe Y will fill how much in one hour = $\frac{1}{4}$ tank

Drainage will drain out how much water in 1 hour = $\frac{1}{20}$ tank

$\therefore$ Total tank filled in one hour

$= \left(\frac{1}{5}+\frac{1}{4}-\frac{1}{20}\right)$ tank $= \frac{2}{5}$ tank

$\frac{2}{5}$ tank gets filled in = 1 hour

$\therefore$ Full (i) tank gets filled in = $\dfrac{1}{\left(\frac{2}{5}\right)} \times 1$

$= \frac{5}{2} = 2.5$ hr

9. Mohan, the manager, wants his foru workers to work in pairs. No paper should work for more than 5 hours. Ram and Johan have worked together for 5 hours. Krishna and Amir have worked as a team for 2 hours. Krishan does not want to work with Ram whom should

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mohan allot to work with Johan, if we wants all the workers to continue working?

(a) Amir (b) Krishna
(c) Ram (d) None of the three

Ans. (b)

Sol. Conditions given:

(i) Ram & John have worked for 5 hours.

(ii) Krishna doesn't want to work with Ram.

(iii) No pair should work beyond 5 hours.

Hence, Krishna should work with John to satisfy the above conditions.

10. "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 protagonisits usually read books of apsirational 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 apsirational value, but not popular Hindi fiction

(b) People do not look up to writers of textbooks, English book or high value litrature

(c) Though popular hindi fiction was wide readh, it often does not appear in the movies

(d) Protagonists in Hindi movies, being ideals for viewers, read only books of aspirational value.

Ans. (b)

SECTION : CIVIL ENGINEERING

1. What is curl of the vector field $2x^2yi + 5z^2j - 4yzk$?

(a) $-14zi - 2x^2k$ (b) $6zi + 4xj - 2x^2k$
(c) $6zi + 8xyj + 2x^2yk$ (d) $-14zi + 6yj + 2x^2k$

Ans. (a)

Sol.

$$\text{Curl} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 2x^2y & 5z^2 & -4yz \end{vmatrix}$$

$$= \hat{i}(-4z - 10z) - \hat{j}(0-0) + \hat{k}(0 - 2x^2)$$

$$= -14z\hat{i} - 2x^2\hat{k}$$

2. 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) $CO_3^{2-}, H^+, HCO_3^-, OH^-$

(b) $H^+, H_2CO_3, HCO_3^-, OH^-$

(c) $CO_3^{2-}, H_2CO_3, HCO_3^-, OH^-$

(d) $CO_3^{2-}, H^+, H_2CO_3, HCO_3^-$

Ans. (a)

Sol. H_2CO_3 and HCO_3^- never come together

3. 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 is always greater than I_N

(b) No definite relation exists between I_L and I_N.

(c) I_L is alway less than I_N

(d) I_L and I_N are always equal

Ans. **(b)**

Sol. Lagrange's form is more efficient when you have to interpolate several data sets on the same data point.

Newton's form is more efficient when you have to interpolate data incrementally. So no relationship between both.

4. If the fineness modulus of a sample of the fine aggregates is 4.3, the mean size of the particles in the sample is between

(a) 150μm and 300 μm

(b) 2.36 mm and 4.75 mm

(c) 300 μm and 600 μm

(d) 1.18 mm and 2.36 mm

Ans. **(d)**

Sol.

150μm, 300μm, 600μm, 1.18mm, 2.36mm, 4.75mm, 10mm, 20mm, 40mm, 80mm

150 – 1

300 – 2

600 – 3

$$\left.\begin{matrix}1.18-4\\2.36-5\end{matrix}\right]\rightarrow 4.3$$

.
.
.
.

5. 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 ____

Ans. **(5184)**

Sol.

B = 120 days

Δ = 0.4 m

and $D\Delta$ = 8.64B

$\Rightarrow$ D = 2592 has per (m^3/s)

$\therefore$ For 2m^3/sec water, area will be 5184 ha

6. The characteristic compressive strength of concrete required is a project is 25 MPa and 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, round off to the lower integer) to be used in the mix is______

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Ans. (46)

Sol. $f_{ck} = 25$; $\sigma = 4$ MPa

$f_m = f_{ck} + 1.65\sigma = 31.6$ MPa

Using interpolation

$$\text{w/c req.} = 50 - \frac{(50-45)}{(35-25)} \times (31.6 - 25)$$

= 46.7 (Rounded off to the lowest integer).

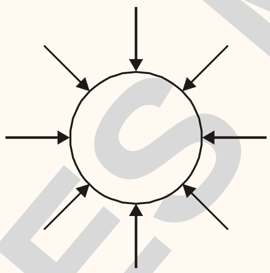
7. A solid sphere of radius, r, and made of material with density ρ_s, is moving through the atmosphere (constant pressure, p) with a velocity, v. The net force ONLY due to atmospheric pressure (F_p) acting on the sphere at any time, t, is

(a) $\frac{4}{3}\pi r^3 \rho_s \frac{dv}{dt}$ (b) Zero

(c) $\pi r^2 p$ (d) $4\pi r^2 p$

Ans. (b)

Sol. Force = area × P



Net force will be zero as pressure acts from all sides.

8. 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

(a) $\frac{\gamma H}{cF_c}$ (b) $\frac{F_c \gamma H}{c}$

(c) $\frac{c}{F_c \gamma H}$ (d) $\frac{cF_c}{\gamma H}$

Ans. (c)

Sol.

$$S_n = \frac{C}{F_c\,\gamma H}$$

9. A closed thin walled tube has thickness, t, mean enclosed area within the boundary of the centrline 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) $\tau A_m t$

(c) $0.5\tau A_m t$ (d) $4\tau A_m t$

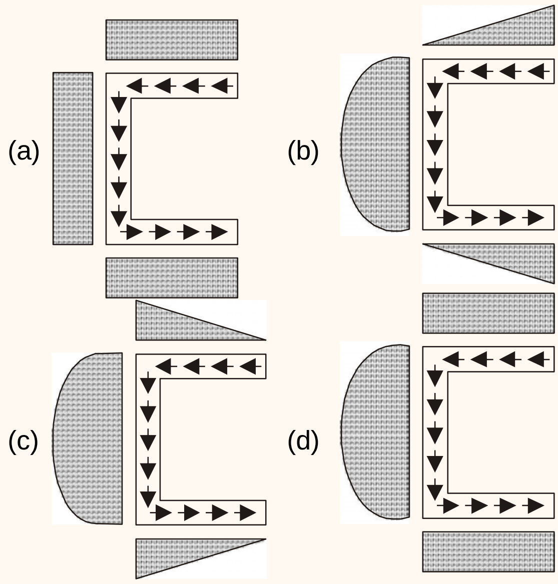
Ans. (a)

Sol.

$$\tau t = \frac{T}{2A_m}$$

$$\Rightarrow \boxed{T = 2A_m \tau t}$$

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?



Ans. (c)

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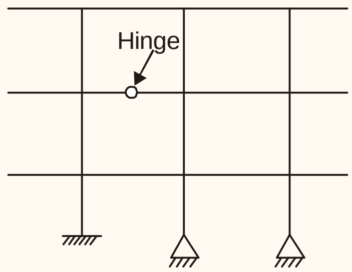
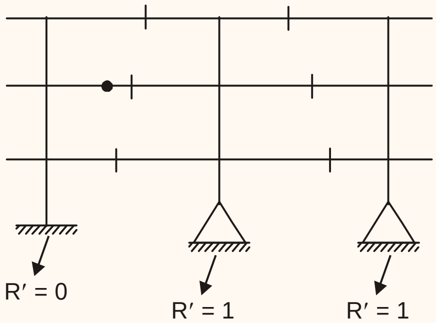
Sol. Standard result

11. The degree of static indeterminancy of the plane frame is shown in the figure is____



Ans. **(15)**

Sol.



(Total R′ = 2)

D_s = 3C – R'

C = 6

D_s = (3 × 6 – 2) – 1 (due to hinge)

= 15

12. Structural failures considered in the mechanistic method of bituminous pavement design are

(a) Shear and slippage

(b) Fatique and Rutting

(c) Fatique and shear

(d) Rutting and shear

Ans. **(b)**

Sol. As per IRC66:2012

13. Which one of the options contains ONLY primary air pollutants?

(a) Ozone and peroxyacetyl nitrate

(b) Nitrogen oxides and peroxyacetyl nitrate

(c) Hydrocarbons and nitrogen oxides

(d) Hydrocarbons and ozone

Ans. **(c)**

Sol. Ozone PAN are secondary air pollutants.

14. The following inequality is true for all x close to 0.

$$2-\frac{x^2}{3}<\frac{x\sin x}{1-\cos x}<2$$

What is the value of $\lim\limits_{x\to 0}\frac{x\sin x}{1-\cos x}$?

(a) 2 (b) 1/2

(c) 0 (d) 1

Ans. **(a)**

Sol.

$$\lim_{x\to 0}\frac{x\sin x}{1-\cos x}$$

It is $\frac{0}{0}$ form

L's hospital rule (differentiate)

$$\Rightarrow \lim_{x\to 0}\frac{x\cos x+\sin x}{-(-\sin x)}$$

Putting 0 everywhere $\Rightarrow$ still $\frac{0}{0}$ form. Differentiating numerator and denominator again,

$$\lim_{x\to 0}\frac{x(-\sin x)+\cos x+\cos x}{\cos x} = 2$$

15. The velocity field in a flow system is given by $v = 2i+(x+y)j+(xyz)k$. The acceleration of the fluid at (1, 1, 2) is

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(a) j + k (b) 2i + 10 k
(c) 4j + 10k (d) 4i + 12 k

Ans. **(c)**

Sol.

$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} + \frac{\partial u}{\partial t}$$

$$\Rightarrow \quad a_x = \frac{2 \times \partial(2)}{\partial x} + (x+y)\frac{\partial(2)}{\partial y} + (xyz)\frac{\partial(2)}{\partial z} + \frac{\partial(2)}{\partial t}$$

$$\boxed{a_x = 0}$$

$$\text{and} \quad a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} + \frac{\partial v}{\partial t}$$

$$= \frac{2\partial(x+y)}{\partial x} + (x+y)\frac{\partial(x+y)}{\partial y} + (xyz)\frac{\partial(x+y)}{\partial z} + \frac{\partial(x+y)}{\partial t}$$

$$= 2 + (x + y) + (xyz)(0) + 0$$

$$\boxed{a_y = 2 + x + y}$$

$$\Rightarrow \quad a_y = 2 + 1 + 1$$

$$\Rightarrow \quad \boxed{\vec{a}_y = 4\hat{j}}$$

$$\text{and} \quad a_z = u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} + \frac{\partial w}{\partial t}$$

$$= 2(yz) + (x + y)(xz) + (xyz)(xy) + 0$$

$$a_z = 2(1\times2) + (1+1)(1\times2) + (1\times1 \times 2)(1\times1)$$

$$\vec{a}_z = (4+4+2)\hat{k} = 10\hat{k}$$

$$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$$

$$\boxed{\vec{a} = 4\hat{j} + 10\hat{k}}$$

16. 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 1.0 (b) 1.2 and 1.0
(c) 1.2 and 1.2 (d) 1.0 and 1.2

Ans. **(d)**

Sol. As per IS:800-2007

17. Euclindean norm (length) of the vector $[4\ -2\ -\ 6]^T$ is

(a) $\sqrt{48}$ (b) $\sqrt{24}$
(c) $\sqrt{12}$ (d) $\sqrt{56}$

Ans. **(d)**

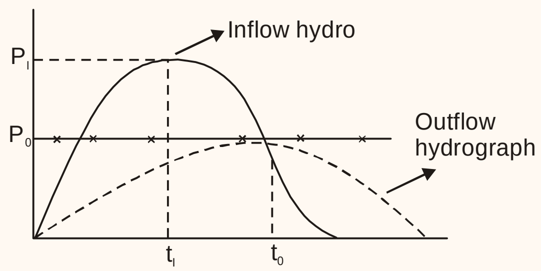
Sol. Length = $\sqrt{4^2 + (-2)^2 + (-6)^2} = \sqrt{56}$

18. 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_0 and the time of occurance of the peak is t_0. Which one of the following statements is correct?

(a) $P_I < P_0$ and $t_I > t_0$
(b) $P_I > P_0$ and $t_I > t_0$
(c) $P_I < P_0$ and $t_I < t_0$
(d) $P_I > P_0$ and $t_I < t_0$

Ans. **(d)**

Sol.



$P_l > P_o$; $t_l < t_o$

19. 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____

Ans. **(15)**

Sol.

Ultimate consolidation = 40 mm

Recorded consolidation = 10 mm

$$\therefore \quad U\% = \frac{10}{40}\times 100 = 25\%$$

$$\therefore \quad \boxed{U = 0.25}$$

$$T_V = \frac{\pi}{4}U^2 = \frac{C_V t}{H^2}$$

$$\therefore \quad U^2 \propto t \qquad \begin{bmatrix} t_1 = 4\text{ yrs}\,;\, U_1 = 0.25 \\ t_2 = 9\text{ yrs}\,;\, U_2 = ? \end{bmatrix}$$

$$\frac{U_1^2}{U_2^2} = \frac{t_1}{t_2}$$

$$\Rightarrow \quad \frac{(0.25)^2}{U_2^2} = \frac{4}{9}$$

$$\Rightarrow \quad \frac{0.25}{U_2} = \frac{2}{3} \Rightarrow U_2 = 0.375$$

$\therefore$ Total recorded consolidation

$\Rightarrow$ 40 × 0.375

$$\Rightarrow \quad \boxed{15\text{ mm}}$$

20. The notation “SC” as per Indian standard Soil Classification System refers to

(a) Clayey silt (b) Sandy clay

(c) Calyey sand (d) Silty clay

Ans. **(c)**

Sol.

SC : clayey sand

21. 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 ection is

(a) $\frac{v_f k_j}{2}$ (b) $\frac{v_f k_j}{8}$

(c) $v_f k_j$ (d) $\frac{v_f k_j}{4}$

Ans. **(d)**

Sol.

$$Q = \left[\frac{-V_f}{K_j}K + V_f\right]K \qquad \text{... (1)}$$

$$\frac{dQ}{dK} = \frac{-V_f}{K_j}\times 2K + V_f = 0$$

$$\Rightarrow \quad K = \frac{K_j}{2}$$

$$\therefore \quad Q = \left[\frac{-V_f}{K_j}\times\frac{K_j}{2} + V_f\right]\frac{K_j}{2} = \frac{V_f K_j}{4}$$

22. 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) $\frac{k_x}{k_z}$

(c) $\sqrt{\frac{k_z}{k_x}}$ (d) $\sqrt{\frac{k_x}{k_z}}$

Ans. (c)

Sol. Flow net for anisotropic soil.

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

$$\Rightarrow \quad \frac{k_x}{k_z}\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial z^2} = 0 \quad \text{...(i)}$$

If we transformed geometry in x direction let x cordinate be transformed to the new cordinate x_t by the transformation.

$$x_t = x\sqrt{\frac{k_z}{k_x}}$$

$$\Rightarrow \quad x = x_t\sqrt{\frac{k_x}{k_z}} \quad \text{...(ii)}$$

From eq. (i) & (ii),

$$\Rightarrow \quad \frac{k_x}{k_z}\frac{\partial^2 h}{\partial\left(x_t\sqrt{\frac{k_x}{k_z}}\right)^2} + \frac{\partial^2 h}{\partial z^2} = 0$$

$$\Rightarrow \quad \boxed{\frac{\partial^2 h}{\partial x_t^2} + \frac{\partial^2 h}{\partial z^2} = 0} \quad \text{Hence prove}$$

So, multiplied factor = $\sqrt{\frac{k_z}{k_x}}$

23. The Laplace transform of sinh (at) is

(a) $\frac{s}{s^2 - a^2}$ (b) $\frac{s}{s^2 + a^2}$

(c) $\frac{a}{s^2 - a^2}$ (d) $\frac{a}{s^2 + a^2}$

Ans. (c)

Sol. Laplace transform of sinh (at) = $\frac{a}{s^2 - a^2}$

24. 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_____

Ans. (3°)

Sol. n = 4 (number of sides of closed traverse)

(2n – 4) × 90° = 360°

so, error in included angle

= (88 + 92 + 94 + 89) – 360 = +3°

25. 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/s². 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 ______.

Ans. (30)

Sol. Given: grade = +4%

V_1 = 20 m/sec.

f = 0.46

g = 10 m/sec.

V_1 = 10 m/sec.

We know,

$$V_2^2 = V_1^2 + 2as$$

$$(10)^2 = (20)^2 + 2s\left[-g\left(f + \frac{n\%}{100}\right)\right]$$

$$\Rightarrow \quad \boxed{s = 30\text{ m}}$$

26. A broad gauge railway line passes through a horizontal curved section (radius = 875 m) of length 200 m. The allowable speed on this

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ESE-2019 Conventional Test Schedule, Civil Engineering

Date	Topic
17th Mar 2019	**N.T.** : M-1, M-3, M-4, SM-1, SM-3, SM-8
	R.T. :
24th Mar 2019	**N.T.** : SA-1, SA-2, SA-5, HY-1, HY-4, HY-5, M-5
	R.T. : SM-1, M-1
31st Mar 2019	**N.T.** : DSS-4, DSS-5, FM-1, FM-4, FM-6
	R.T. : M-3, SA-1, SA-2
07th Apr 2019	**N.T.** : SA-6, SA-4, SA-3, EE-6, EE-5, EE-4
	R.T. : FM-4, FM-6, M-1, M-4, M-3, HY-1
14th Apr 2019	**N.T.** : FM-7, RCC-1, RCC-2, RCC-3, HY-2
	R.T. : SA-1, SA-2, SM-3, FM-6, EE-6
21st Apr 2019	**N.T.** : SM-4, DSS-1, DSS-2, DSS-3, RCC-4, RCC-5, RCC-6
	R.T. : SM-1, SA-3, EE-5
28th Apr 2019	**N.T.** : SU-1, SU-2, SU-3, SM-2, SM-5, SM-6, SM-7, HY-3, SU-5
	R.T. : FM-7, RCC-1, RCC-2, RCC-3, HY-1, EE-6
05th May 2019	**N.T.** : TF-1, TF-2, TF-3, TF-4, FM-5, M-2
	R.T. : RCC-5, DSS-1, DSS-2, SM-4, M-1, M-3, M-4, FM-4, SA-1
12th May 2019	**N.T.** : IR-1, IR-2, IR-3, IR-4, EE-7
	R.T. : SM-5, SM-6, FM-1, EE-5, DSS-3, DSS-4, HY-3, HY-4, HY-5, SU-1, SU-2
19th May 2019	**N.T.** : CPM-1, CPM-2, EE-1, EE-2, EE-3, SU-4 (Railway & Airport)
	R.T. : SM-4, FM-5, TF-1, TF-2, FM-7, SA-3, SU-3, SU-5, RCC-5
26th May 2019	**N.T.** : FM-2, FM-3, FM-8, Building Material, Ports & Harbors/Tunneling
	R.T. IR-1, IR-2, HY-2, DSS-4, DSS-2, SA-1, SA-2, SA-3, RCC-6, EE-2, FM-6
02nd Jun 2019	Full Length-1 (Test Paper-1 + Test Paper-2)
09th Jun 2019	Full Length-2 (Test Paper-1 + Test Paper-2)
16th Jun 2019	Full Length-3 (Test Paper-1 + Test Paper-2)

Test Type	Timing	Day
Conventional Test	10:00 A.M. to 1:00 P.M.	Sunday
Conventional Full Length Test Paper-1	10:00 A.M. to 1:00 P.M.	Sunday
Conventional Full Length Test Paper-2	02:00 P.M. to 5:00 P.M.	Sunday

Note : The timing of the test may change on certain dates. Prior information will be given in this regard.

***N.T. :** New Topic. ***R.T. :** Revision Topic

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Subject Code Details

Structural Analysis (SA)

SA-1	SA-2	SA-3	SA-4	SA-5	SA-6
Slope Deflection Method	Moment Distribution Method	Truss, Cables, Arches	Force Method, • Consistent Deformation Method • Method of Least work • Castigliano's Method	Determinacy/ indeterminacy/ stability	Stiffness Matrix Method, Influence Line Diagram/Moving Load , Free and Forced Vibrations , Concepts and use of computer aided design

SOM (M)

M-1	M-2	M-3	M-4	M-5
Concept of Stress and Strain	Shear Force & Bending Moment, Deflection of Beams	Transformation of Stress & Strains, Theory of Failure, Combined Bending & Torsion/ Combined bending & Transverse shear stress/ combined bending & Axial stress, Torsion	Bending Stress, Shear Stress	Columns, Springs, Thick & Thin Shells, Moment of inertia

RCC & PSC (RCC)

RCC-1	RCC-2	RCC-3	RCC-4	RCC-5		RCC-6
Working stress Method of RCC Design	Limit State Method	Earthquake resistant structures, Beams (LS, WS), Lintels	Slab-One way, (LS, WS) Staircase	Column, (LS, WS) Water Tanks	Fooling (LS, WS), Retaining Wall	Cement & Concrete, Masonry Structures, PSC-Pre stressed Concrete

Design of Steel Structure (DSS)

DSS-1	DSS-2	DSS-3	DSS-4	DSS-5	DSS-6
Compression member	Plastic Analysis	Beams	Connections (Direct, Eccentric)	Tension Member	Plate girders, Industrial building

Pert & CPM (CPM)

CPM-1	CPM-2
Network analysis, Pert, CPM, Crashing, Resource allogaction, Levelling,Smoothing, Rate Analysis	Construction equipments, Engineering Economy,Tendering Process and Contract , Management Estimation and costing, Quality control, Productivity, Opration cost, Land Aquisition

Building Material (BM)

BM-1	BM-2
Cement, Concrete, Stone, Lime, Glass, Steel	Brick Mortar Timber, Plastics, FRP, Ceramics, Aluminium

Environmental (EE)

EE-1	EE-2	EE-3	EE-4	EE-5	EE-6	EE-7
Characteristics of water, Treatment of water	Distribution of water	Characteristics of Sewage	Disposal of Sewage	Sewer design	Treatment of Sewage	Air Pollution, Noise Pollution, Solid Waste Management, Miscellaneous topics

Fluid Mechanics (FM)

FM-1	FM-2	FM-3	FM-4	FM-5	FM-6	FM-7	FM-8
Fluid properties, Hydrostatic Pressure, Liquid in relative equilibrium, Buoyancy & Flotation	Fluid Kinematics	Fluid Dynamics, Weirs & Notches	Laminar flow, Turbulent flow, Boundary layer theory, Drag & lift	Flow through Pipes	Open channel flow	Hydraulic Machines, Power House	Modal Analysis & Dimensional Analysis

Soil Mechanics (SM)

SM-1	SM-2	SM-3	SM-4	SM-5	SM-6	SM-7	SM-8
Classification of Soil, Soil water relationships, index properties of Soil, Compaction of Soil	Effective stress, Seepage, Permeability	Consolidation	Shear Stress/ Vertical Stress	Earth Pressure, Stability of Slopes	Bearing capacity- Shallow Foundation	Deep foundation - Piles	Exploration of Soil, Expansive Soil, Geosynthetics, Ground Modification Techniques

Transportation (TF)

TF-1	TF-2	TF-3	TF-4
Geometric Design	Pavement Design	Materials, Construction, Maintenance, Hill roads etc.	Traffic Engineering

Surveying (SU)

SU-1	SU-2	SU-3	SU-4	SU-5
Scale/ Accuracy, Measurements of horizontal distances, Theory of Errors	Angular Measurements, Theodolite	Levelling, Contouring, Curve setting, Measurment of Area & Volume	Triangulation & Traversing Plane tabling, Geology	Photogrammetry, Field Astronomy, GPS, Remote Sensing

Irrigation (IR)

IR-1	IR-2	IR-3	IR-4
Soil water relationships, irrigation requirements of crops (Duty, Delta)	Design of Canals (Lacey & Kennedy)	Gravity dams	Cross drainage works, Weirs & Barrages, Seepage theory, Canal Falls/ Canal Regulators, Energy dissipators, River training works

Hydrology (HY)

HY-1	HY-2	HY-3	HY-4	HY-5
Hydrographs	Flood Routing	Ground Water	Evapo-transpiration, Run off	Abstraction from Precipitation, Hydrological Cycle, Precipitation, Stream flow measurement

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portion is 100 km/h. For calculating the cant, consider the gauge as centre-to-centre distance between the rail heads, equal to 1750mm, 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 ______.

Ans. **(157.5)**

Sol. Given data:

$$R = 875 \text{ mm}$$

Allowable speed = 100 kmph

Gauge length G = 1750 mm

$$\text{Allowable cant} = \frac{GV_{all}^2}{127R}$$

$$= \frac{1750 \times 100^2}{127 \times 875} = 157.6 \text{ mm}$$

27. 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 provisions of IS: 456-2000, considering the long-term effects, the effective modulus of elasticity of the concrete (in MPa) is ________

Ans. **(12500)**

Sol. Short term strain = 500×10^{-6}

Long term strain = 1000×10^{-6}

So, creep coefficient, $\theta = \dfrac{(1000-500)\times 10^{-6}}{500 \times 10^{-6}}$

$\theta = 1$

Long-term effective modulus

$$= \frac{E_s}{1+\theta} = \frac{5000\sqrt{25}}{1+1}$$

$= 12500 \text{ N/mm}^2 = 12500 \text{ MPa}$

or

$$E_{cc} = \frac{\text{Stress}}{\text{Long term strain}}$$

$$= \frac{12.5}{1000 \times 10^{-6}} = 12500 \text{ MPa}$$

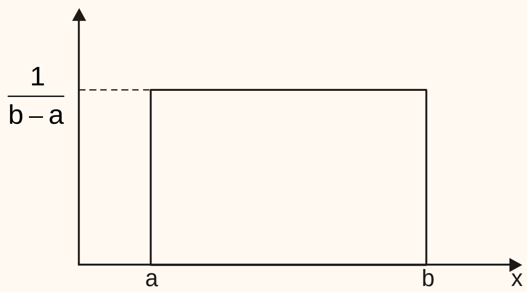
28. The probability density function of a continuous random variable distributed uniformly between x and y (for y > x) is

(a) $\dfrac{1}{x-y}$ (b) $x - y$

(c) $y - x$ (d) $\dfrac{1}{y-x}$

Ans. **(d)**

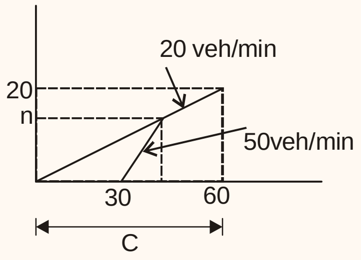
Sol. Probability density function of a uniformly distributed random variable.



29. The uniform arrival and uniform service rates observed on an approach road to a signalized intersection are 20 and 50 vehicles/minutes, respectively. For this signal, the red time is 30 s, the effective green time is 30 s, and the cycle length is 60s. Assuming that initially there are no vehicles in the queue, the average delay per vehicle using the approach road during a cycle length (in s, round off to 2 decimal places) is _______

Ans. **(12.5)**

Sol.



C $\rightarrow$ Cycle time

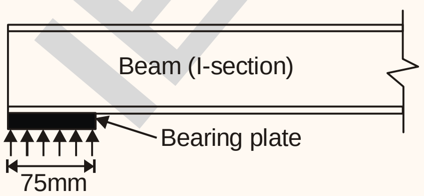
Average delay per vehicle

$$= \frac{C\left(1-\frac{g}{C}\right)^2}{2\left(1-\frac{v}{s}\right)}$$

$$= \frac{60}{2}\frac{\left(1-\frac{30}{60}\right)^2}{\left(1-\frac{20}{50}\right)} = \frac{60}{2}\frac{\left(1-\frac{30}{60}\right)^2}{\left(1-\frac{20}{50}\right)} = \frac{50}{4}$$

= 12.5 sec

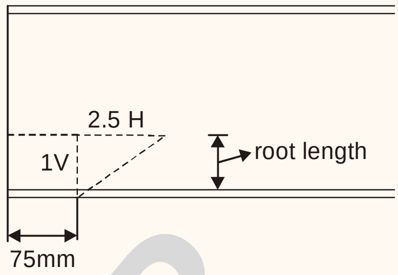
30. A rolled I-section beam is supported on a 75 mm wide bearing plate as shown in the figure. Thickness of flange and web of the I-section are 20 mm and 8mm, respectively. Root radius of the I-section is 10mm. Assuming: material yield stress, f_y = 250 MPa and partial safety factor for material, γ_{mo} = 1.10



As per IS: 800-2007, the web bearing strength (in kN, round off to 2 decimal places) of the beam is ________

Ans. **(272.73)**

Sol.



Effective area in bearing = [75 + 2.5 (flange thickness + root radius)] × 8

= [75 + 2.5 (20 + 10)] × 8

= 1200 mm^2

so, web bearing strength = $A_g \frac{f_y}{1.1}$

$$= 1200 \times \frac{250}{1.1} \times 10^{-3}$$

= 272.73 kN

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) 0.50 (b) 2.00

(c) 0.25 (d) 0.75

Ans. **(a)**

Sol. Non-dimensional slenderness ratio

$$\lambda = \sqrt{\frac{f_y}{f_{cc}}} = \sqrt{\frac{250}{1000}} = 0.50$$

32. 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.

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02-03-19	Full Length Test-02	3 Hrs	Objective	English	02:30 PM-05:30 PM
03-03-19	Full Length Test-03	3 Hrs	Objective	General Studies	11:00 AM-02:00 PM
03-03-19	Full Length Test-04	1 Hr	Objective	General Engineering	02:30 PM-03:30 PM
03-03-19	Full Length Test-05	2 Hrs	Subjective	General Engineering	03:30 PM-05:30 PM
09-03-19	Full Length Test-06	1 Hr	Objective	Civil Engineering Paper-I	02:00 AM-03:00 PM
09-03-19	Full Length Test-07	2 Hrs	Subjective	Civil Engineering Paper-I	03:30 PM-05:30 PM
10-03-19	Full Length Test-08	1 Hr	Objective	Civil Engineering Paper-II	02:00 AM-03:00 PM
10-03-19	Full Length Test-09	2 Hrs	Subjective	Civil Engineering Paper-II	03:30 PM-05:30 PM
16-03-19	Full Length Test-10	3 Hrs	Objective	Hindi	11:00 AM-02:00 PM
16-03-19	Full Length Test-11	3 Hrs	Objective	English	02:30 PM-05:30 PM
17-03-19	Full Length Test-12	3 Hrs	Objective	General Studies	11:00 AM-02:00 PM
17-03-19	Full Length Test-13	1 Hr	Objective	General Engineering	02:30 PM-03:30 PM
17-03-19	Full Length Test-14	2 Hrs	Subjective	General Engineering	03:30 PM-05:30 PM
23-03-19	Full Length Test-15	1 Hr	Objective	Civil Engineering Paper-I	02:00 AM-03:00 PM
23-03-19	Full Length Test-16	2 Hrs	Subjective	Civil Engineering Paper-I	03:30 PM-05:30 PM
24-03-19	Full Length Test-17	1 Hr	Objective	Civil Engineering Paper-II	02:00 AM-03:00 PM
24-03-19	Full Length Test-18	2 Hrs	Subjective	Civil Engineering Paper-II	03:30 PM-05:30 PM

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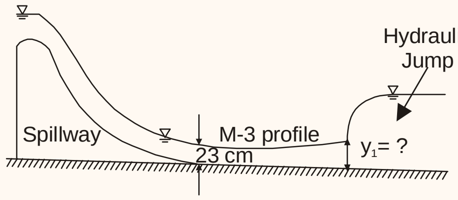


The flow enters as an M-3 profile in the long wide rectangular channel with bed slope = $\frac{1}{1800}$ and Manning's n = 0.015. A hydraulic jump is formed at a certain distance from the foot of the spillway. Assume the acceleration due to gravity, g = 9.81 m/s^2. Just before the hydraulic jump, the depth of flow y_1 (in m, round off to 2 decimal places) is _____

Ans. **(0.417)**

Sol. Given data:

$$y = 0.23 \text{ m}$$
$$V = 8.1 \text{ m/sec.}$$
$$\text{Slope, } s = \frac{1}{1800}$$
$$h = 0.015$$
$$g = 9.81 \text{ m/sec}^2$$
$$q = yV = 8.1 \times 0.23$$
$$= 1.863 \text{ m}^3\text{/sec/m}$$

It is given that flow enters as an M-3 profile in the long wide rectangular channel with bed slope = $\frac{1}{1800}$

From manning equation at M_3 profile section.

$$Q = \frac{1}{n}R^{\frac{2}{3}}\sqrt{s}\,A$$
$$q\cdot B = \frac{1}{n}y^{2/3}\sqrt{s}\cdot y\cdot B$$

[for wide channel R = y]

$$1.863 = \frac{1}{0.015}\sqrt{\frac{1}{1800}}\,y^{5/3}$$
$$\Rightarrow \quad y_n = 1.11 \text{ m}$$

The flow profile will follow normal depth (y_n) after jump.

For wide rectangular channel,

$$y_c = \left(\frac{q^2}{g}\right)^{1/3}$$
$$\therefore \quad y_c = \left(\frac{1.863^2}{9.81}\right)^{1/3} = 0.707 \text{ m}$$

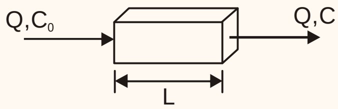
Here, $y_n = y_2 = 1.11$ m

$$F_2^2 = \frac{q^2}{gy_2^3}$$
$$\Rightarrow \quad F_2 = \sqrt{\frac{1.863^2}{9.81\times 1.11^3}} = 0.508$$

Again, $\frac{y_1}{y_2} = \frac{1}{2}\left[\sqrt{1+8F_2^2}-1\right]$

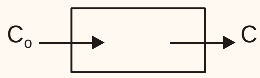
$$\Rightarrow \quad \frac{y_1}{y_2} = \frac{1}{2}\left[\sqrt{1+8\times 0.508^2}-1\right]$$
$$\Rightarrow \quad y_1 = 0.417 \text{ m} < y_c \text{ [supercritical]}$$

33. Consider the reactor shown in the figure. The concentration (in mg/l) of a compound in the influent and effluent are C_0 and C, flow rate through the reactor is Q m^3/h respectively. The compound is degraded in the reactor following the first order reactions. The mixing condition of the reactor Complete Mix 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_{PER} while keeping the cross-section of the reactor constant. Assuming steady state and for C/C_0 = 0.8, the value of L_{CMFR}/L_{PER} (round off to 2 decimal places) is _______



Ans. **(1.12)**

Sol.



A = constant

Q = AL

For plug flow = $C = C_o e^{-kt_{d_1}}$

[t_{d_1} = detention time for plug flow reaction]

For completely mix = $C = \dfrac{C_o}{1+kt_{d_2}}$

[t_{d_2} = detention time for completely mix reaction]

$\Rightarrow \quad 0.8 = e^{-kt_{d_1}}$

$\Rightarrow \quad kt_{d_1} = 0.223 = k\cdot\dfrac{AL_{plug}}{Q}$

Also, $0.8 = \dfrac{1}{1+kt_{d_2}}$

$\Rightarrow \quad kt_{d_2} = 0.25 = k.\dfrac{AL_{com}}{Q}$

$\Rightarrow \quad \dfrac{kt_{d_1}}{kt_{d_2}} = \dfrac{L_{plug}}{L_{com}} = \dfrac{0.223}{0.25} = 0.892 \simeq 0.89$

$\Rightarrow \quad \dfrac{L_{com}}{L_{plug}} = \dfrac{1}{0.89} = 1.12$

34. 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) boundary by the survey line, curved boundary wall, the first and the last offsets, determined using Simpson's rule, is _______.

Ans. **(68.50)**

Sol. Area by simpson's rule = $\dfrac{h}{3}$ [$(y_1 + y_n)$ + $4(y_2 + y_4 + ...y_{n-1}) + 2(y_3 + y_5 + ... + y_{n-2})$]

$= \dfrac{6}{3}$ [(1.22 + 1.15) + 4 (1.67 + 2.34 + 1.87) + 2 (2.04 + 2.14)]

= 68.50 m^2

35. 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 removal of particles through settling 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

Ans. **(500)**

Sol. Given data:

Flow rate = 6000 m^3/day

Over flow rate = 1.5 m/hour

= 1.5 × 24 m/day = 36 m/day

Flow area = $\dfrac{\text{Flow rate}}{\text{over flow rate}} = \dfrac{6000}{36}$

= 166.67 m^2

Volume required for clarifier = Flow area × depth

= 166.67 × 3 = 500 m^3

36. A flexible pavement has the following class of 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 (front 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

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(a) 320 (b) 250
(c) 240 (d) 180

Ans. (d)

Sol.

$$\text{ESAL} = 80\times\left(\frac{40}{80}\right)^4 + 80\times\left(\frac{40}{80}\right)^4 + 160\times\left(\frac{40}{80}\right)^4 + 160\times\left(\frac{80}{80}\right)^4$$

$$= 5 + 5 + 10 + 160$$

$$= 180$$

37. 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 ________

Ans. (3)

Sol. For constant head permeability test,

$$k = \frac{QL}{ah}$$

$Q \rightarrow$ discharge

$L \rightarrow$ length of specimen

$a \rightarrow$ area of cross-section of specimen

$h \rightarrow$ constant head

Given,

$$\frac{L_{s_1}}{L_{s_2}} = \frac{3}{2}$$

$$\frac{D_{s_1}}{D_{s_2}} = 0.5$$

$$\Rightarrow \quad \frac{a_{s_1}}{a_{s_2}} = \left(\frac{D_{s_1}}{D_{s_2}}\right)^2 = (0.5)^2$$

$$\frac{h_{s_1}}{h_{s_2}} = 2$$

$$Q_{s_1} = Q_{s_2}$$

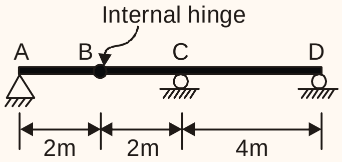
$$\therefore \quad \frac{k_{s_1}}{k_{s_2}} = \frac{\left(\dfrac{Q_{s_1}L_{s_1}}{a_{s_1}h_{s_1}}\right)}{\left(\dfrac{Q_{s_2}L_{s_2}}{a_{s_2}h_{s_2}}\right)}$$

$$= \frac{Q_{s_1}}{Q_{s_2}}\times\frac{L_{s_1}}{L_{s_2}}\times\frac{h_{s_2}}{h_{s_1}}\times\frac{a_{s_2}}{a_{s_1}}$$

$$= 1\times\frac{3}{2}\times\frac{1}{2}\times\frac{1}{(0.5)^2}$$

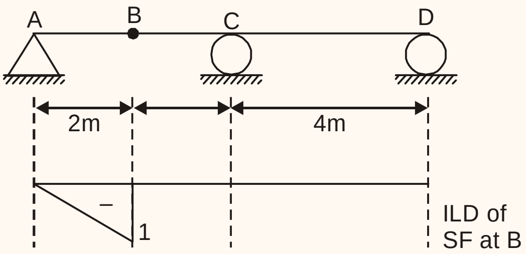
$$= \frac{3}{2^2}\times 2^2 = 3$$

38. 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 the 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 ________



Ans. (70 kN)

Sol.



$$\text{Maximum SF} = 60 \times 1 + \left(\frac{1}{2}\times 1\times 2\right) \times 10$$

$$= 60 + 10 = \boxed{70\ \text{kN}}$$

39. A square footing of 2m 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/m^3. Terzaghi's bearing capacity factor ϕ = 25° are N_c = 25.1, N_q = 12.7, N_γ = 9.7, N'_c = 14.8, N'_q = 5.6, and N'_γ = 3.2. The ultimate bearing capacity of the foundation (in kPa, round off to 2 decimal places) is ______.

Ans. **(353.92)**

Sol. $$Q_{ultimate} = 1.3c'N'_c + qN'_q + 0.4B\gamma N'_\gamma$$

$$= 1.3\times\left(\frac{2}{3}\times 24\right)\times 14.8 + 0 + 0.4 \times 2 \times 18 \times 3.2$$

$$= 353.92\ \text{kPa}$$

Here, $\phi < 29°$

Footing rests on the ground

Hence, q = 0

so, $c' = \frac{2}{3}c$

use, N'_q, N'_c, N'_γ accordingly.

40. The dimensions of a soil sampler 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 (in percent, round off to 2 decimal places) is ________.

Ans. **(11.11%)**

Sol. Given:

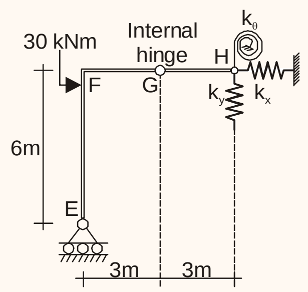
$$D_4 = 90\ \text{mm}$$

$$D_2 = 100\ \text{mm}$$

$\therefore$ $$\text{Outside clearance} = \frac{D_2 - D_4}{D_4}\times 100$$

$$= \frac{100-90}{90}\times 100 = 11.11\%$$

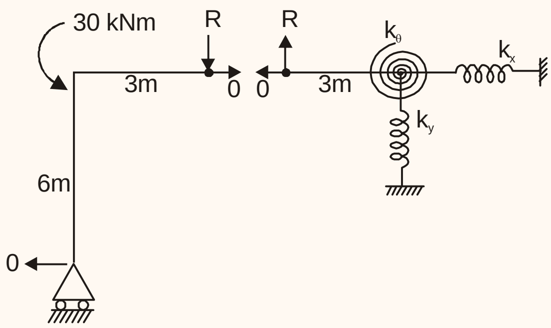
41. A plane frame shown in the figure (not to scale) has linear elastic springs at node H. The spring constants are $k_x = k_y = 5 \times 10^5$ kN/m^3 and k_θ = 3 × 10^5 kNm/rad.



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 ________

Ans. **(0.006 degree)**

Sol.



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$R \times 3 = 30$

$\Rightarrow$ $R = 10$ kN

From right side of FBD

$R \times 3 = K_\theta \cdot \theta$

$$\theta = \frac{3R}{K_\theta} = \frac{3 \times 10 \text{ kNm}}{3 \times 10^5 \text{ kNm/rad}}$$

$= 10^{-4}$ rad $= 0.0057$

$= 0.006$ degree

42. Chlorine is used as the disinfectant in a municipal water treatment plant. It achieves 50 percent of disinfection efficiency measured in terms of killing the indicator microorganisms (E-Coli) 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) 19.93 minutes

Ans. **(d)**

Sol. Disinfection eff. $= \dfrac{N_o - N}{N_o}$

$$= \frac{N_o - N_o e^{-kt}}{N_o} = (1 - e^{-kt})$$

$0.5 = 1 - e^{-k \times 3}$

$\Rightarrow$ $k = \dfrac{\ell n 2}{3}$

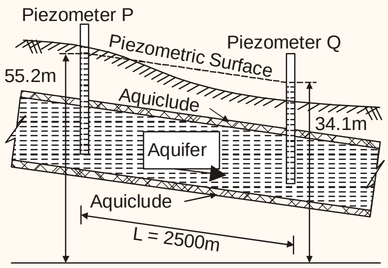
Again, $0.99 = 1 - e^{-\frac{\ell n 2}{3} \times t}$

$\Rightarrow$ $0.01 = e^{-\frac{\ell n 2}{3} \times t}$

$\Rightarrow$ $-4.605 = -\dfrac{\ell n 2}{3} \times t$

$\Rightarrow$ $t = 19.93$ min.

43. 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 ______.

Ans. **(925.9)**

Sol. Given,

$k = 80$ m/day $= \dfrac{80}{24 \times 3600}$ m/s

$= 9.259 \times 10^{-4}$ m/s

$h = 55.2 - 34.1 = 21.1$ m

$L = 2500$ m

$n = 0.25$

$B = 15$ m

As per Darcy's law,

$V = ki$

$= 9.259 \times 10^{-4} \times \dfrac{h}{L}$

$= 9.259 \times 10^{-4} \times \dfrac{21.1}{2500}$

$= 7.814 \times 10^{-6}$ m/s

Seepage velocity $V_s = \dfrac{V}{n}$

$= \dfrac{7.814 \times 10^{-6}}{0.25} = 3.125 \times 10^{-5}$ m/s

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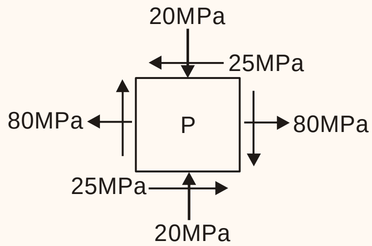
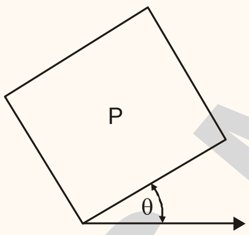
$\therefore$ Time taken (t) $= \dfrac{L}{V_s} = \dfrac{2500}{3.125 \times 10^{-5}}$

$= 800 \times 10^5$ sec. $= \dfrac{800 \times 10^5}{24 \times 3600} = 925.9$ days

44. For a plane stress problem, the state of stress at a point P is represented by the stress element as shown in the figure.



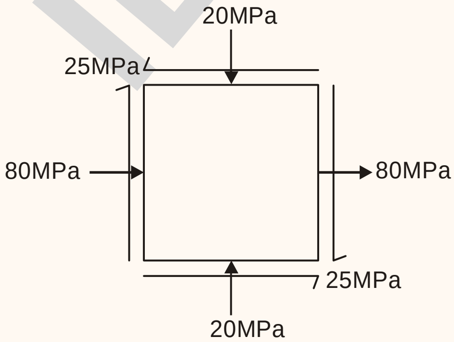
By how much angle (θ) in degrees the stress element should be rotated in order to get the planes of maximum shear stress?

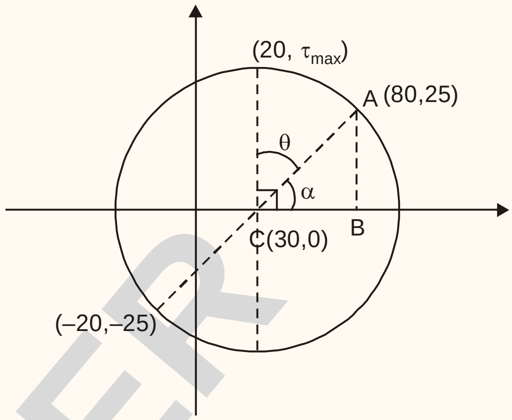


(a) 26.6 (b) 48.3
(c) 31.7 (d) 13.3

Ans. **(c)**

Sol.





Coordinates of C $= \left(\dfrac{80-20}{2}, \dfrac{25-25}{2}\right)$

$= (30, 0)$

In ΔABC,

BC = 80 – 30 = 50 MPa

AB = 25 MPa

$$\alpha = \tan^{-1}\left(\frac{25}{50}\right) = 26.56°$$

$$\therefore \quad \theta = 90° - \alpha = 63.44°$$

Angle to be rotated $= \dfrac{\theta}{2} = \dfrac{63.44}{2} = 31.7°$

45. The inverse of the matix $\begin{bmatrix} 2 & 3 & 4 \\ 4 & 3 & 1 \\ 1 & 2 & 4 \end{bmatrix}$ is

(a) $\begin{bmatrix} 2 & -\frac{4}{5} & -\frac{9}{5} \\ -3 & \frac{4}{5} & \frac{14}{5} \\ 1 & -\frac{1}{5} & -\frac{6}{5} \end{bmatrix}$ (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) $\begin{bmatrix} 10 & -4 & -9 \\ -15 & 4 & 14 \\ 5 & -1 & -6 \end{bmatrix}$ (d) $\begin{bmatrix} -10 & 4 & 9 \\ 15 & -4 & -14 \\ -5 & 1 & 6 \end{bmatrix}$

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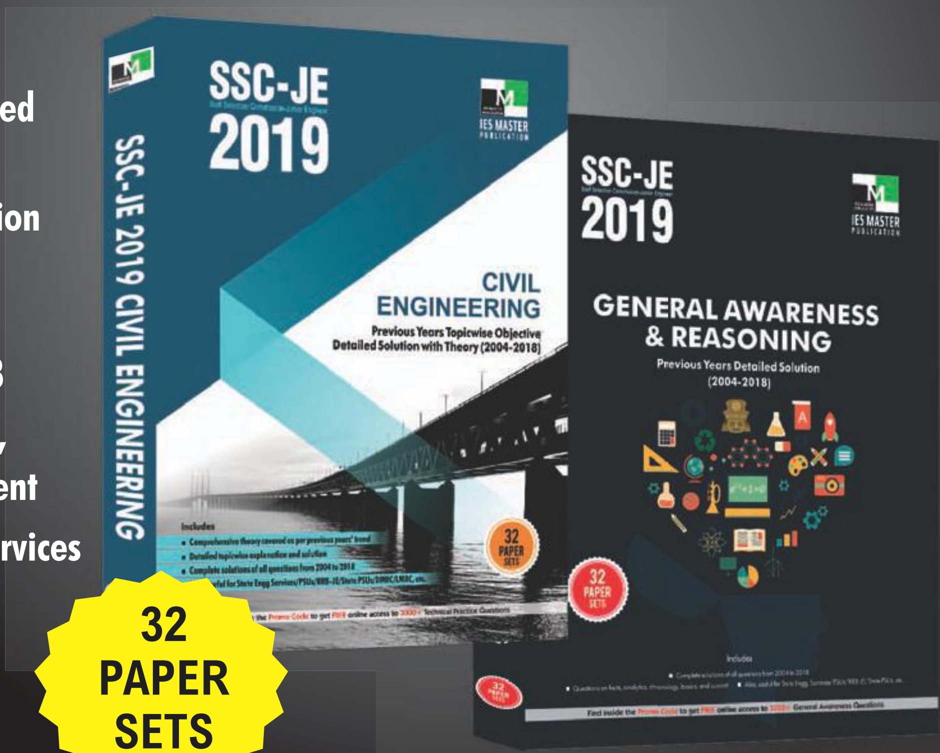

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Ans. **(b)**

Sol.

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

Det. of matrix, $|A| = 2(12-2) - 3(16-1) + 4(8-3)$

$$= 20 - 45 + 20$$

$$= -5$$

$$A^{-1} = \frac{1}{|A|}(\text{adj} \cdot A)$$

$$(\text{adj } A) = (\text{cof } A)'$$

$$\text{cof of } A_{11} = 12 - 2 = 10$$

$$\text{cof of } A_{12} = -(16-1) = -15$$

$$\text{cof of } A_{13} = 8 - 3 = 5$$

$$\text{cof of } A_{21} = -(12-8) = -4$$

$$\text{cof of } A_{22} = (8-4) = 4$$

$$\text{cof of } A_{23} = -(4-3) = -1$$

$$\text{cof of } A_{31} = (3-12) = -9$$

$$\text{cof of } A_{32} = -(2-16) = 14$$

$$\text{cof of } A_{33} = (6-12) = -6$$

$$\text{cof } A = \begin{bmatrix} 10 & -15 & 5 \\ -4 & 4 & -1 \\ -9 & 14 & -6 \end{bmatrix}$$

$$\text{adj } A = (\text{cof } A)'$$

$$= \begin{bmatrix} 10 & -4 & -9 \\ -15 & 4 & 14 \\ 5 & -1 & -6 \end{bmatrix}$$

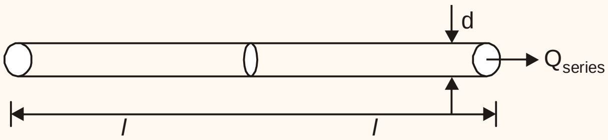
$$A^{-1} = -\frac{1}{5}\begin{bmatrix} 10 & -4 & -9 \\ -15 & 4 & 14 \\ 5 & -1 & -6 \end{bmatrix}$$

$$= \begin{bmatrix} -2 & 4/5 & 9/5 \\ 3 & -4/5 & -14/5 \\ -1 & 1/5 & 6/5 \end{bmatrix}$$

46. 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 also discharge freely into the atmosphere. In the second case, they are attached in parallel and friction factor is same in both the cases, the ratio of the discharge in the parallel arrangement to that in the series arrangement (round off to 2 decimal places) is _____

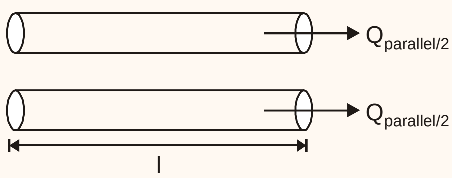
Ans. **(2.828)**

Sol. Case (1): Series connection,



then $$\Delta h = \frac{f \times (2\ell)\, Q_{series}^2}{12.1\, d^5} \quad \text{...(i)}$$

Case (ii) : parallel connection



then, $$\Delta h = \frac{f \times \ell \times (Q_{parallel}/2)^2}{12.1\, d^5} \quad \text{...(ii)}$$

then from equation (i) and (ii)

$$\frac{f(2\ell) \times Q_{series}^2}{12.1\, d^5} = \frac{f \times \ell \times (Q_{parallel}/2)^2}{12.1\, d^5}$$

$$\Rightarrow 2Q_{series}^2 = \frac{Q_{parallel}^2}{4}$$

$$\Rightarrow \frac{Q_{parallel}}{Q_{series}} = (8)^{1/2} = 2\sqrt{2}$$

$$\boxed{\frac{Q_{parallel}}{Q_{series}} = 2.828}$$

47. 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) 3200 m (b) 2800 m

(c) 2600 m (d) 3000 m

Ans. **(b)**

Sol. Given that

$$f = 0.2 \text{ m}$$

$$h = 1200 \text{ m}$$

$$s = \frac{1}{8000}$$

then, $$s = \left(\frac{f}{H-h}\right)$$

$$\Rightarrow \quad \frac{1}{8000} = \frac{0.2}{H-1200}$$

$$H = 2800 \text{ m}$$

48. 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 elemental anlysis of the decomposable material yields the following mass percent.

C : H : O: N : other = 44 : 6 : 43 : 0.8 : 6.2

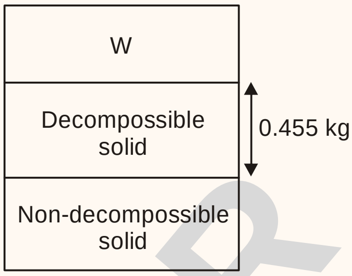
The methane production of the decomposable material is governed by the following stoichiometric relation

$$C_aH_bO_cN_d + nH_2O \rightarrow mCH_4 + sCO_2 + dNH_3$$

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 _______

Ans. **(137.6 g)**

Sol. For the MSW, the phase diagram is as follows



Moisture content = 35%
For 1 kg of Raw MSW
wt. of water = 0.35 kg
wt. of solid = 0.65 kg
wt. of decomposable solid = 0.65 × 0.7
= 0.455 kg

From the mass percent given,

$$12a = 44x$$

$$b = 6x$$

$$16c = 43x$$

$$14d = 0.8x$$

$$\Sigma = 100x$$

$$100x = \text{wt of decomposable waste} = 0.455 \text{ kg}$$

$$\Rightarrow \quad x = \frac{0.455}{100} \text{kg} = 4.55 \text{ g}$$

$$\Rightarrow \quad a = 16.683,\ b = 27.3,\ c = 12.228,\ d = 0.26$$

From the balance of reaction we have

$$a = m + s \quad \text{...(A)}$$

$$b + 2n = 4m + 3d \quad \text{...(B)}$$

$$c + n = 2s \quad \text{...(C)}$$

$$\Rightarrow \quad 2c + 2n = 4s \quad \text{...(D)}$$

$$\Rightarrow \quad b - 2c = 4m - 4s + 3d$$

$$\Rightarrow \quad \frac{b-2c-3d}{4} = m - s$$

$$\Rightarrow \quad m - s = 0.516$$

$$\Rightarrow \quad m + s = 16.683$$

$$\Rightarrow \quad m = 8.6$$

$\Rightarrow$ Methane produced = 8.6 × 16 g = 137.6 g

49. In the context of provisions relating to durability of concrete, consider the following assertion:

Assertion (1): As per IS 456-2000, air entrainment to the extent of 3% to 6% is required for concrete exposed to marine environment.

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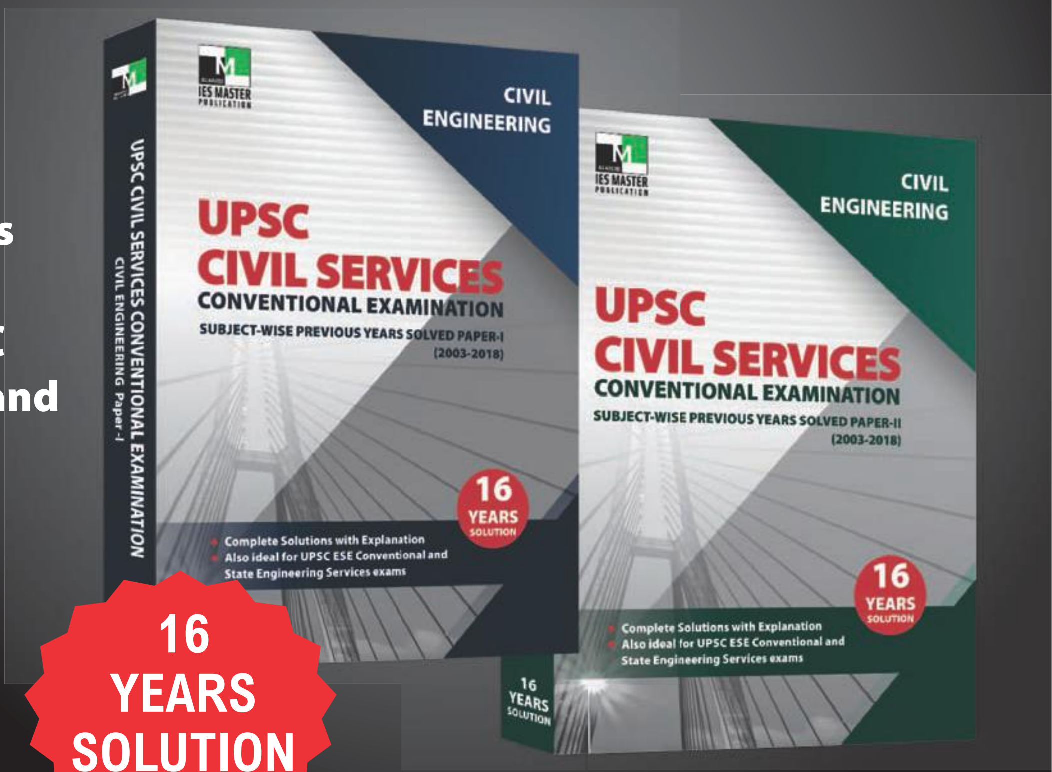

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Assertion (2): The equivalent alkali content (in terms of Na_2O equivalent) for a cement containing 1% and 0.6% of Na_2O and K_2O, respectively, is approximately 1.4% (rounded to 1 decimal place).

Which one of the following statements is correct?

(a) Assertion (1) is true and Assertion (2) is FALSE

(b) Both Assertion (1) and Assertion (2) are TRUE

(c) Both Assertion (1) and Assertion 2) are FALSE

(d) Assertion (1) is false and Assertion (2) is TRUE

Ans. **(b)**

Sol. As per IS-456, where freezing and thawing actions under wet conditions exit, inhance durability can be obtained by the use of suitable air entraining admixture.

The entrained air percentage can vary from 4 ± 1 to 5 ± 1 (i.e. 3 to 6%) depending on size of aggregate. Hence, Assertion (1) is correct.

Equivalent alkali content (in terms of Na_2O equivalent)

$= Na_2O + 0.658 \times K_2O$

Molecular ratio of Na_2O to K_2O = 0.658

$= 1\% + 0.658 \times 0.6\% = 1.39$

$\simeq$ 1.4 (rounded to 1 decimal place).

50. 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.

t(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 ________

Ans. **(97)**

Sol.

0–2 hr — total rainfall = 1 × 2 = 2 cm

2–4 hr — total rainfall = 0 cm

4–6 hr — total rainfall = 2 × 0.5 = 1 cm

Time hour	u m^3/sec	$u \times 2cm$	$a \times u$ lagged by 2hr	$1 \times u$ lagged by 1hr.	sum $=1+2+3$
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
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

Maximum ordinate is 92 m^3/sec.

Maximum flood discharge = 92 + 5

= 97 m^3/sec

51. The speed-density relationship of a highway is given as

$u = 100 - 0.5\ k$

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 ______

Ans. **(5000)**

Sol. Given that,

$u = 100 - 0.5\ k$

Maximum flow = $\dfrac{u_f\, k_{jam}}{4}$

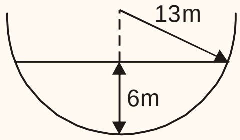
at k = 0, u = u_f = 100 km/hr

and u = 0, then k = k_{jam} = 200 Veh/km.

so, maximum flow = $\dfrac{200 \times 100}{4}$

= 5000 vehicles/hr

52. 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?

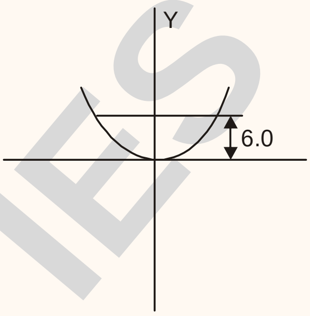


(a) 78π (b) 468π

(c) 156π (d) 396π

Ans. **(d)**

Sol. Volume generated by the Y axis revolution equaton of circle



$\Rightarrow$ $(x-0)^2 + (y-13)^2 = 13^2$

$$\text{Volume} = \pi \int_{y_1}^{y_2} x^2\, dy$$

$$= \pi \int_0^6 (169 - (y-13)^2\, dy$$

$$= 396\,\pi$$

53. A timber pile of length 8m and diameter of 0.2m is driven with a 20 kN drop hammer, falling freely from a height of 1.5m. The total penetration of the pile in the last 5 blows is 40mm. Use the engineering news record expression. Assume a factor of safety of 6 and empirical factor (allowing reducing 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 ______

Ans. **(151.515)**

Sol. Engineering news record expression

$$Q_u = \left(\frac{wh}{s+c}\right)$$

s = Penetration of pile per hammer blow.

$$= \frac{40 \text{ mm}}{8} = 8 \text{ mm} = 0.008 \text{ m}$$

C = 2.5 cm = 0.025 m

so, $Q_u = \dfrac{20 \times 1.5}{(0.025 + 0.008)}$ = 909.09 kN

then safe load carrying capacity

$$= \frac{909.09}{6} = 151.515 \text{ kN}$$

54. 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 _______.

Ans. **(40)**

Sol. Increment in the vertical stress

$$= \frac{120 \times 2 \times 4}{(2+h)(4+h)}$$

$$= \frac{120 \times 2 \times 4}{(2+2)(4+2)} = 40 \text{ kPa}$$

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55. 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) $y = K \ln x$ (b) $y = Kx \ln x$

(c) $y = Kxe^{x}$ (d) $y = Kxe^{-x}$

Ans. (a)

Sol. $\frac{dy}{dx} x \ell nx = y$

$$\Rightarrow \int \frac{dy}{y} = \int \frac{dx}{x \ell nx}$$

taking $\ell nx = t$

$$\Rightarrow \frac{1}{x}dx = dt$$

$$\Rightarrow \int \frac{dy}{y} = \int \frac{dt}{t}$$

$$\Rightarrow \ell nx = \ell nt + \ell nk$$

$$\Rightarrow y = kt$$

$$\Rightarrow \boxed{y = k\ \ell nx}$$