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GATE – 2019
Questions with Detailed Solutions
CIVIL ENGINEERING
Afternoon Session

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Subject wise weightage

S. No.	Name of the Subject	1 Mark (Q)	2 Marks (Q)
1	Verbal Ability	3	2
2	Numerical Ability	2	3
3	Engineering Mathematics	5	3
4	Engineering Mechanics	0	0
5	Solid Mechanics (Strength of Materials)	2	1
6	Structural Analysis	1	2
7	Construction Material & Management	1	1
8	Reinforced Cement Concrete	1	1
9	Steel Structures	1	2
10	Geotechnical Engineering	4	5
11	Fluid Mechanics & Hydraulic Machines	2	3
12	Hydrology	1	2
13	Irrigation	1	0
14	Environmental Engineering	2	4
15	Transportation Engineering	3	4
16	Geomatics Engineering (Surveying)	1	2
	TOTAL	**30**	**35**

Subject Experts,
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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°C.
(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 = $\frac{0.6 \times 3000 \times 1200 \times 600}{8 \times 6 \times 6}$

= 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 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 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

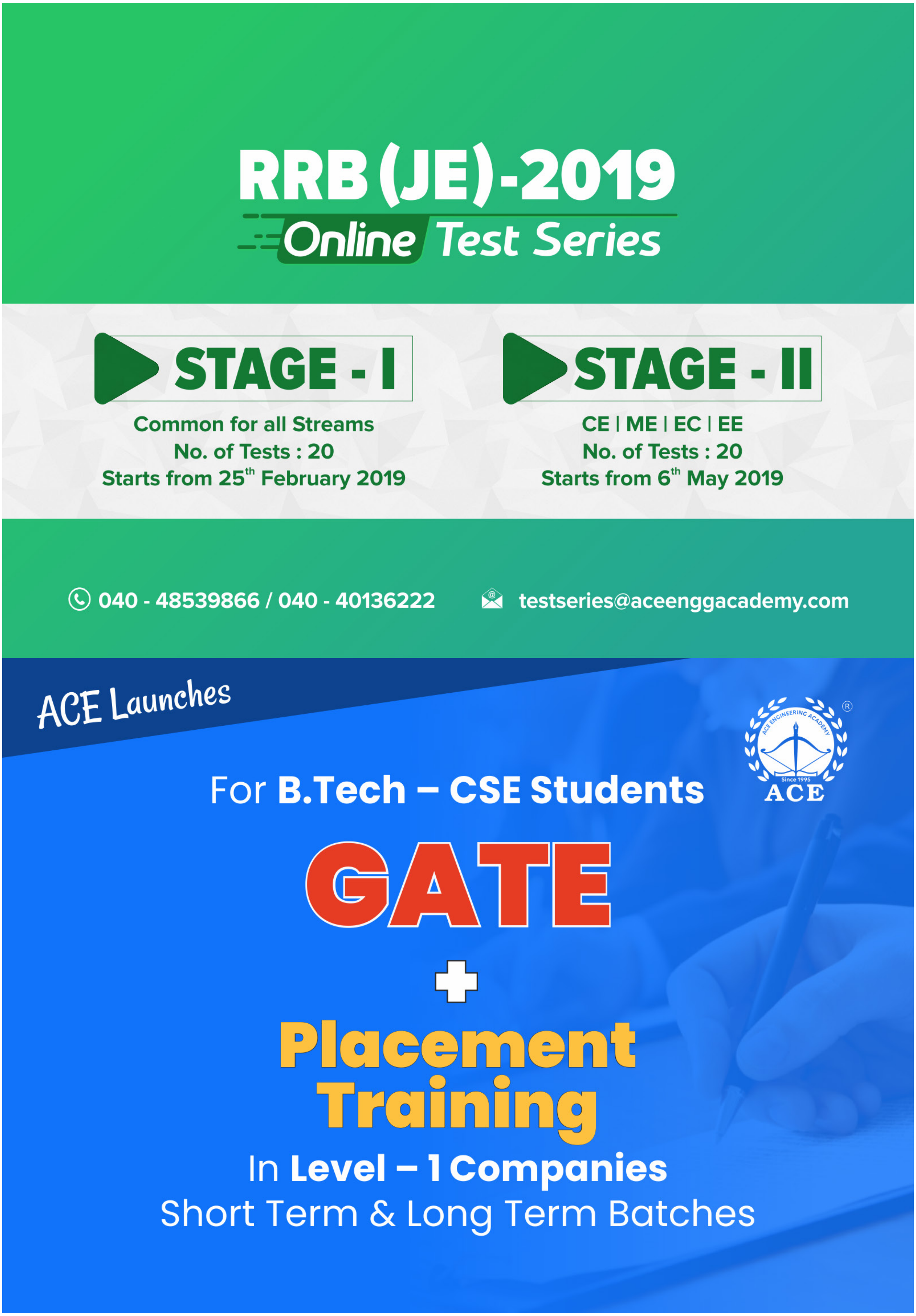
10. Ans: (b)

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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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, $\nu_1 = 20$ 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), $\nu_2 = 10$ m/s

$$\text{Breaking distance , } S_b = \frac{\left(\nu_1^2 - \nu_2^2\right)}{2g(f+G)}$$

$$= \frac{\left(20^2 - 10^2\right)}{2\times 10(0.46+0.04)} = 30 \text{ m}$$

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: $\mathop{Lt}\limits_{x\to 0}\dfrac{x\sin x}{1-\cos x}$

$= \mathop{Lt}\limits_{x\to 0}\dfrac{\dfrac{\sin x}{x}}{\dfrac{1-\cos x}{x^2}}$

$= \dfrac{1}{\dfrac{1}{2}}$

= 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)

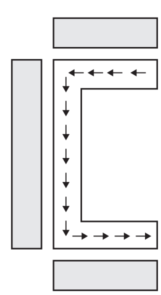
Sol: Mechanistic empirical method for flexible pavement design consider the following structural failures

1. Fatigue 2. Rutting

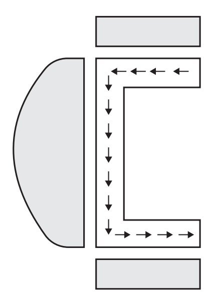
End of Solution

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?

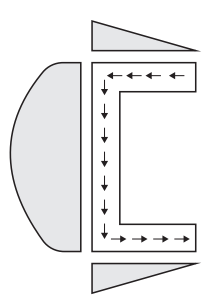
a.



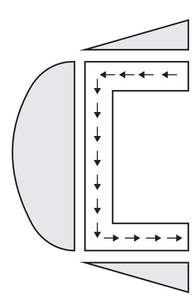
b.



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

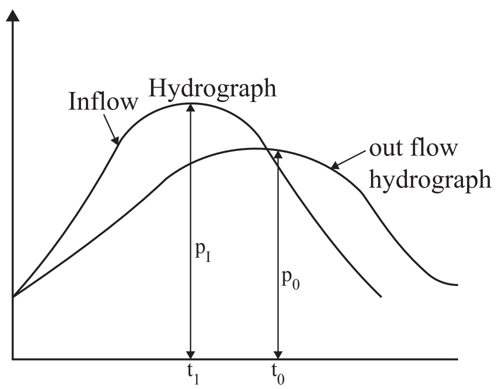
11. An inflow hydrograph is routed through a reservoir to produce an outflow hydrograph. The peak flow of the inflow hydrograph is P_I and the time of occurrence of the peak is t_I. The peak flow of the outflow hydrograph is P_o and the time of occurrence of the peak is t_o. Which one of the following 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 = $(2n-4)\times 90^o = (2\times 4) - 4\times 90^o = 360^o$

angles = $(2n-4)\times 90^o = (2\times 4) - 4\times 90^o = 360^o$

$\angle P + \angle Q + \angle R + \angle S = 88 + 92 + 94 + 89 = 363^\circ$

$\therefore$ Angular correction = -3^o

Angular error = $+3^o$

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,

Δ = 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

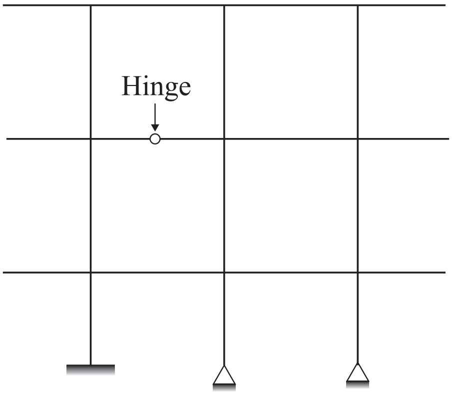
(d) Nitrogen oxides and peroxyacetyl nitrate

15. Ans: (c)

Sol: Hydrocarbon's and oxides of nitrogen are primary air pollutants.

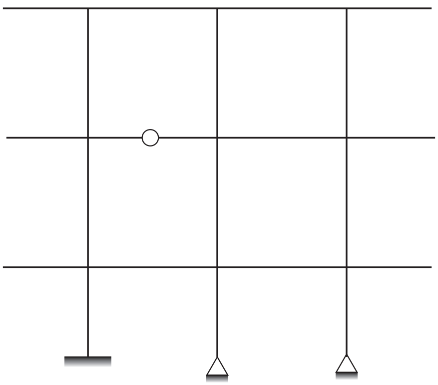
End of Solution

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

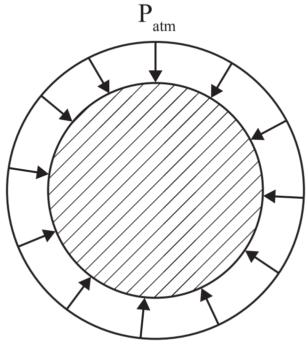
End of Solution

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

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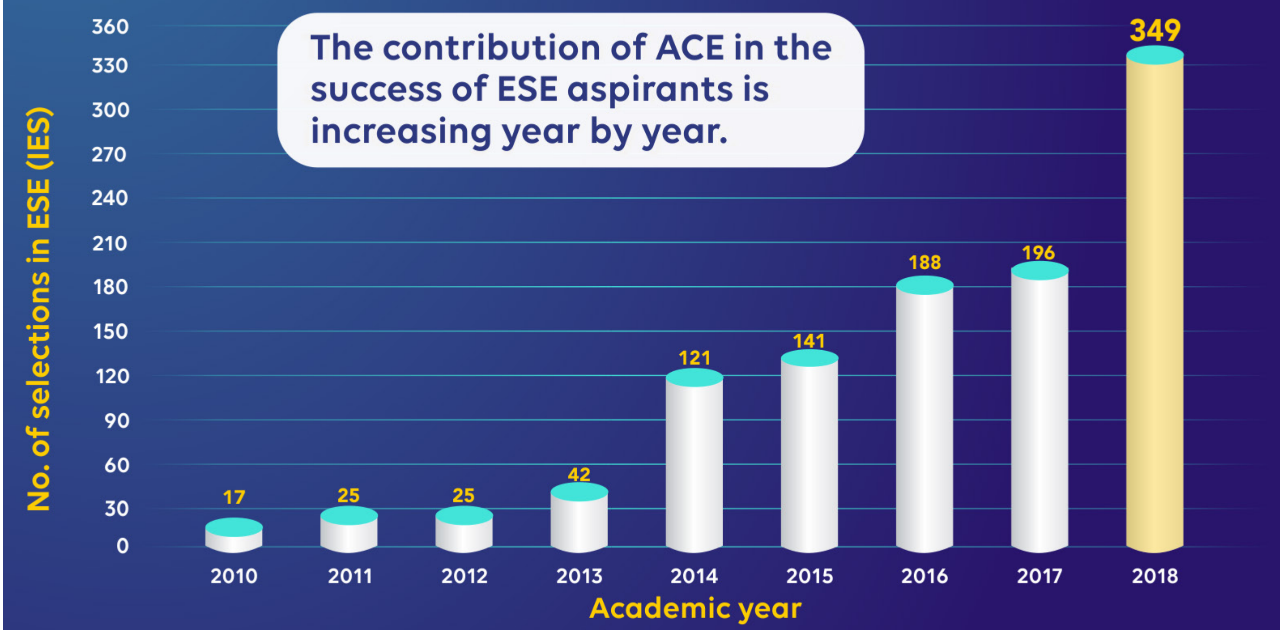

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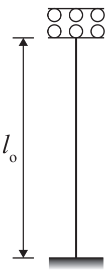
19. A steel column is restrained against both translation and rotation at one end and is restrained only against rotation but free to translate at the other end. Theoretical and design (IS: 800-2007) values, respectively, of effective length factor of the column are

(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 $T_{v2} < 0.28$

$0.11044 = \frac{\pi}{4}\left(\frac{U_2}{100}\right)^2$

$U_2 = 37.5\ \%$

$U_2 = \frac{S_2}{S_f} \times 100$

$37.5 = \frac{S_2}{40} \times 100$

$S_2 = 14.99$ 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: $\vec{V} = 2x^2y\,\vec{i} + 5z^2\,\vec{j} - 4yz\,\vec{k}$

$$\text{curl}\ \vec{V} = \nabla \times \vec{V} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 2x^2y & 5z^2 & -4yz \end{vmatrix}$$

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

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

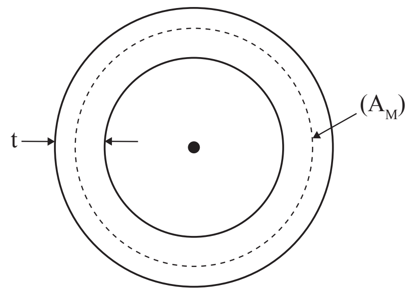
End of Solution

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:

$$\vec{V} = 2\hat{i} + (x+y)\hat{j} + (xyz)\hat{k}$$

$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} + \frac{\partial u}{\partial t} = 0$$

$$a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} + \frac{\partial v}{\partial t} = 2(1) + (x+y)(1) + xyz(0) + 0$$

$$= x + y + 2 = 1 + 1 + 2 = 4$$

$$a_z = u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} + \frac{\partial w}{\partial t} = 2(yz) + (x+y)(xz) + xyz(xy) + 0$$

$$= 2yz + x^2z + xyz + x^2y^2z$$

$$= 2(1)(2) + 1^2(2) + 1(1)(2) + 1^2 \times 1^2 \times 2$$

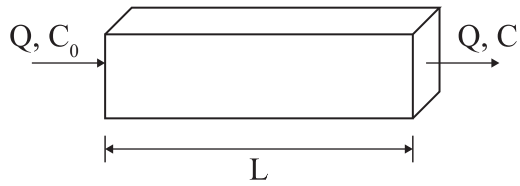
$$= 4 + 2 + 2 + 2 \quad = 10$$

$$\therefore \vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k} = o\hat{i} + 4\hat{j} + 10\hat{k}$$

$$= 4\hat{j} + 10\hat{k}$$

End of Solution

26. Consider the reactor shown in the figure. The flow rate through the reactor is Q m^3/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: $\frac{C}{C_0} = 0.8$

For CMFR	For PFR
$Q(C_o - C) = kC.V$ $\frac{Vk}{Q} = \left(\frac{C}{C_o - C}\right)^{-1}$ $= \frac{C_o - C}{C}$ $= \frac{C_o}{C} - 1$ $= \frac{1}{0.8} - 1$ $= \frac{0.2}{0.8}$ $= \frac{1}{4} = 0.25$	$U_z \frac{dC}{dZ} = -kC$ Multiply with area, A $Q\frac{dC}{dZ} = -kC.A$ $Q\int_{C_o}^{C} \frac{dC}{C} = -kA\int_{o}^{L} dZ$ $Q\ln\left(\frac{C}{C_o}\right) = -kAL = -kV$ $\therefore \frac{Vk}{Q} = -\ln(0.8) = 0.223$

$$\therefore \frac{\left(\frac{Vk}{Q}\right)_{CMFR}}{\left(\frac{Vk}{Q}\right)_{PFR}} = \frac{0.25}{0.2231} = 1.12 = \frac{L_{CMFR}}{L_{PFR}}$$

End of Solution

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

(a) $\frac{1}{y-x}$ (b) $\frac{1}{x-y}$ (c) x - y (d) y -x

27. Ans: (a)

Sol: We know that the probability density functions of uniform distributions in [x, y] is

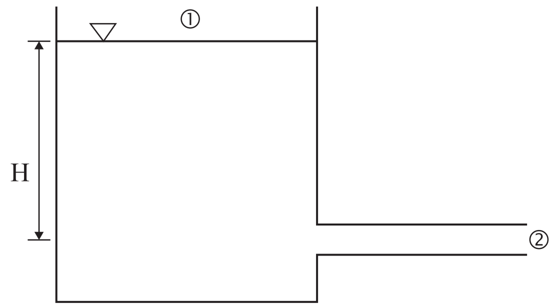
$$f(t) = \frac{1}{y-x} \qquad x \le t \le y$$
$$= 0 \qquad \text{otherwise}$$

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

$$H = h_f \text{ ------ } (1)$$

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

$$h_f = h_{f1} = h_{f2} \quad \& \quad Q_1 = Q_2 = \left(\frac{Q_p}{2}\right)$$

$$\text{i.e} \quad H = \frac{fL\left(\frac{Q_p}{2}\right)^2}{12.1\,D^5}$$

$$H = \frac{fLQ_p^2}{4 \times 12.1 \quad D^5} \text{ ------- } (3)$$

from 2 & 3

$$\frac{2\,fLQ_s^2}{12.1 \quad D^5} = \frac{fLQ_p^2}{4 \times 12.1 \quad D^5}$$

$$\text{i.e } \frac{Q_p}{Q_S} = \sqrt{8} = 2.83$$

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 $k = 0$, $u = u_{max}$

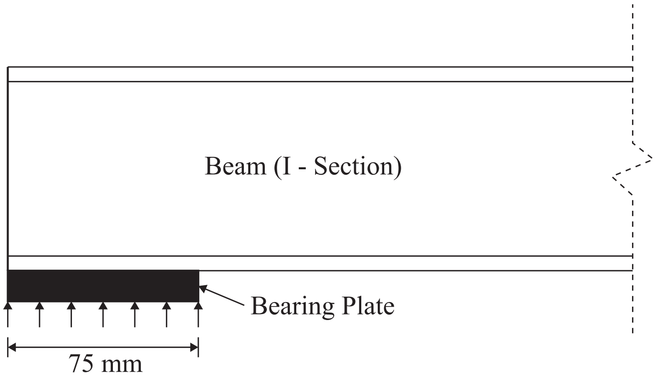
$u_{max} = 100$ kmph

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

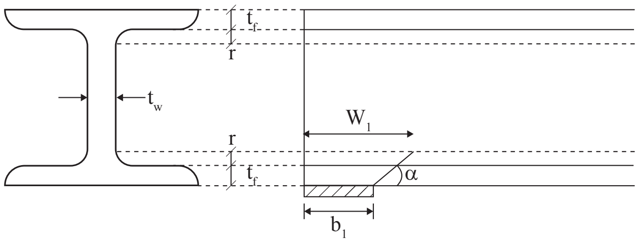
30. A rolled I-section beam is supported on a 75 mm wide bearing plate as shown in figure. Thickness of flange and web of the I-section are 20 mm and 8 mm, respectively. Root radius of the I-section is 10 mm. Assume: material yield stress, $f_y = 250$ MPa and partial safety factor for material, $\gamma_{mo}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



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 = $\frac{f_y}{\gamma_{mo}} = \frac{250}{1.1}$ MPa

⇒ 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

⇒ Total load carrying capacity of web with respect to web crippling = $w_1 \times t_w \times \frac{f_y}{\gamma_{mo}}$

= 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

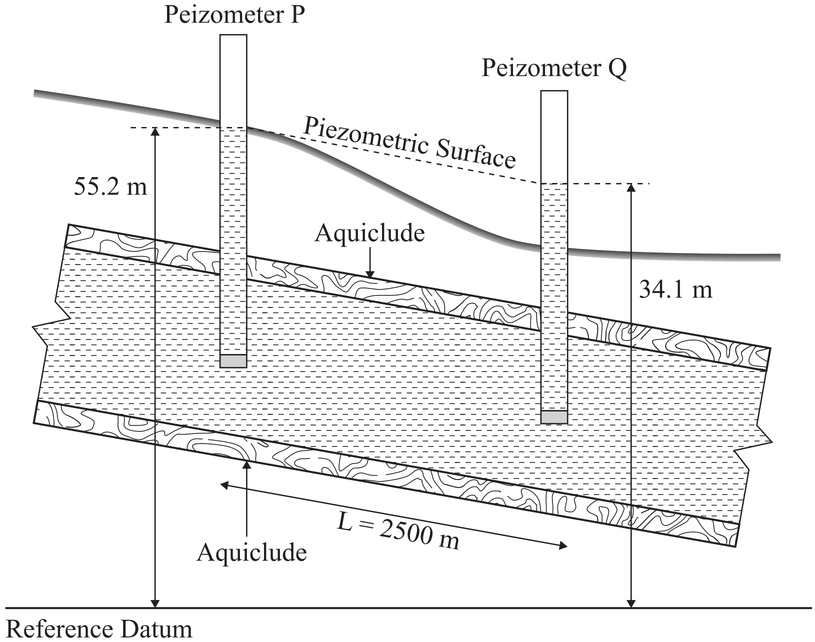
Critical bending compressive stress in the extreme fiber $f_{cr,b}$ = 1000 N/mm²

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, $V_s = \dfrac{V}{n}$

$$= \frac{0.6752}{0.25} = 2.7008 \text{ m/day}$$

$$\text{Time taken} = \frac{L}{V_s} = \frac{2500}{2.7008} = 925.65 \text{ days say } 925.7 \text{ days}$$

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 $E_{ce} = \dfrac{E_c}{1+\theta}$

$$E_c = 5000\sqrt{f_{ck}} = 5000\sqrt{25} = 25000 \text{ MPa}$$

$$\text{Creep coefficient } (\theta) = \frac{\text{creep strain}}{\text{elastic strain}}$$

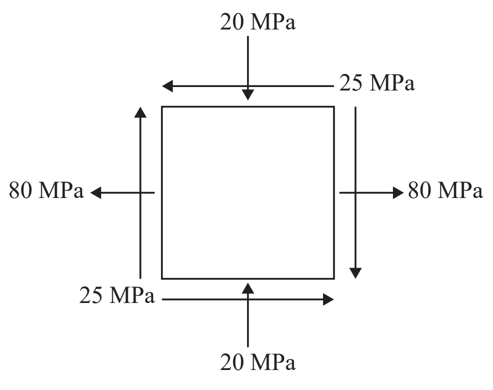
$$= \frac{\text{longterm strain} - \text{elastic strain}}{\text{elastic strain}}$$

$$= \frac{(1000\times10^{-6})-(500\times10^{-6})}{(500\times10^{-6})} = 1$$

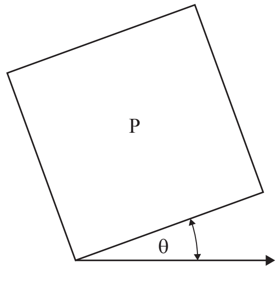
$$\therefore\ E_{ce} = \frac{25000}{1+1} = 12500 \text{ MPa}$$

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 :

$$\tan 2\theta_p = \frac{2\,\tau_{xy}}{(\sigma_x - \sigma_y)} = \frac{2(-25)}{80-(-20)}$$

$\theta_p = -13.28^o$

Angle of maximum shear stress plane

$= \theta_p + 45 = -13.28 + 45 = 31.7^o$

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: $Q = k\ i\,A$

$$= k \times \frac{h}{L} \times \frac{\pi}{4} D^2$$

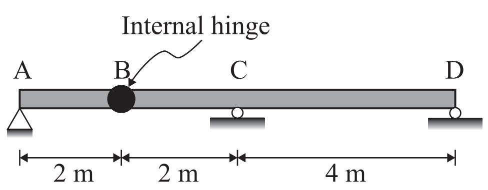
$$\frac{Q_1}{Q_2} = \frac{k_1}{k_2}\frac{h_1}{h_2}\frac{L_2}{L_1}\left(\frac{D_1}{D_2}\right)^2$$

$$1 = \frac{k_1}{k_2} \times 2 \times \frac{1}{1.5} \times 0.5^2$$

$$\frac{k_1}{k_2} = 3$$

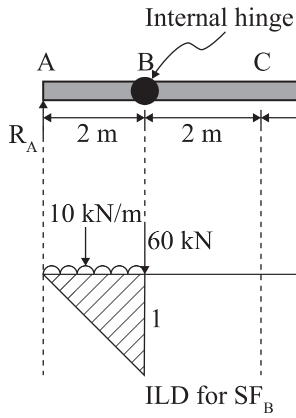
End of Solution

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

$$\eta_1 = [1 - e^{-k\times t_1}]\times 100$$

$$50 = [1 - e^{-k\times 3}]\times 100$$

$k = 0.231\ \text{min}^{-1}$

$\eta_2 = 99\ \%$, $t_2 = \ ?$

$$\eta_2 = [1 - e^{-k\times t_2}]\times 100$$

$$99 = [1 - e^{-0.231\times t_2}]\times 100$$

$t_2 = 19.93$ 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 $= \frac{187.2}{1233.2}$ parts of CH_4 gas

1 kg of MSW produce $= \frac{187.2}{1233.2} \times 1$ 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

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

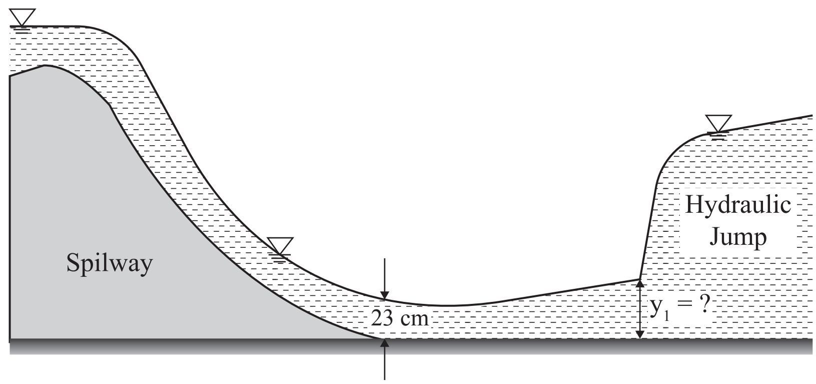
A 6-hour storm occurs over the catchment such that the effective rainfall intensity is 1 cm/hour for the first two hours, zero for the next two hours, and 0.5 cm/hour for the last two hours. If the base flow is constant at 5 m^3/s. The peak flow due to this storm (in m^3/s round off to 1 decimal place) 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	

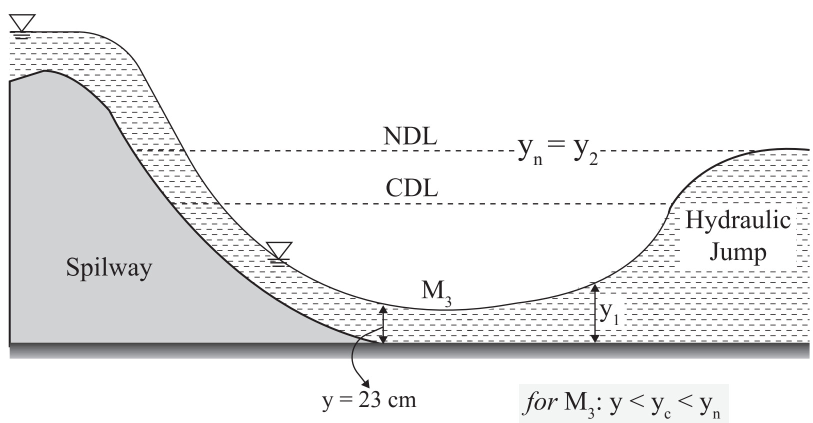
43. At the foot of a spillway, water flows at a depth of 23 cm with a velocity of 8.1 m/s, as shown in the figure.



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

$$= (N_1 + N_2)\left[\frac{40}{80}\right]^4 + N_3\left[\frac{80}{80}\right]^4$$

$$= (160 + 160)\left[\frac{40}{80}\right]^4 + 160\left[\frac{80}{80}\right]^4 = 180 \quad \text{(Standard axles)}$$

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 $\phi = 25^o$ and unit weight γ 18 kN/m^3. Terzaghi's bearing capacity factors for $\phi = 25^o$ 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 $e_{th} = e_a + e_d$ ∴ 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, $\eta_h = 100$ %

$$Q_{safe} = \frac{20 \times 150 \times 1}{6(0.8+2.5)}$$

$= 151.5152$ kN say 151.52 kN

End of Solution

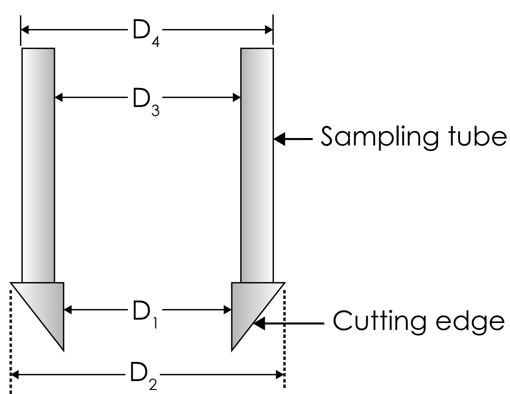
48. The dimensions of a soil sample are given in the table.

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, $D_1 = 80$, $D_2 = 100$, $D_3 = 86$, $D_4 = 90$

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

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

$= 11.1111$ % 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

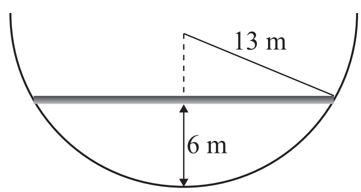
Scale of map = S = $\frac{f}{(H-h)}$

$$\frac{1}{800} = \frac{0.2}{H-1200}$$

$\Rightarrow$ H = 2800 m

End of Solution

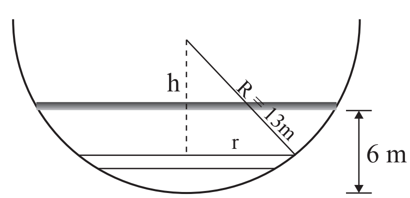
50. Consider the hemi-spherical tank of radius 13 m as shown in the figure (not drawn to scale). What is the volume of water (in m^3) when the depth of water at the centre of the tank is 6 m?



(a) 156 π (b) 468 π (c) 78 π (d) 396 π

50. Ans: (d)

Sol:



$$v = \int_7^{13} \pi r^2 dh = \pi \int_7^{13} (R^2 - h^2) dh$$

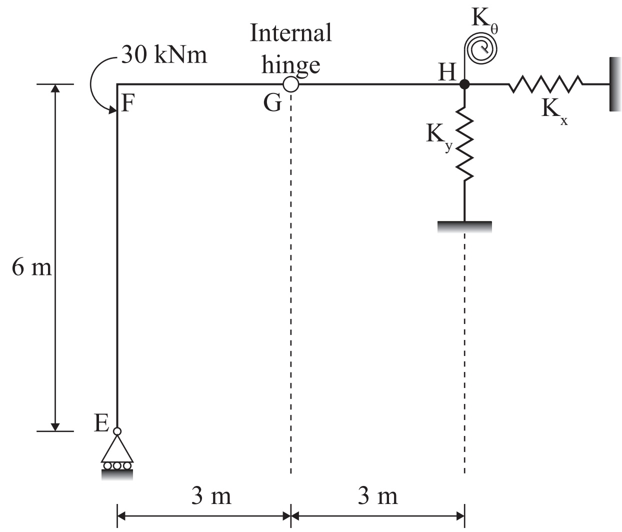
$$= \pi \left[R^2 h - \frac{h^3}{3}\right]_7^{13}$$

$$= \left\{\left[13^2 \times 13 - \frac{13^3}{3}\right] - \left[13^2 \times 7 - \frac{7^3}{3}\right]\right\} \times \pi$$

$$= 396\pi$$

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.



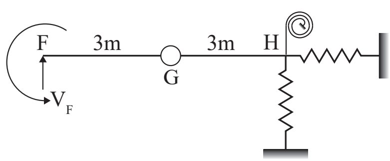
For the externally applied moment of 30 kNm at node F, the rotation (in degrees, round off to 3 decimals) observed in the rotational spring at node H is ____.

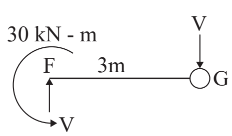
51. Ans: 0.006 degree

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

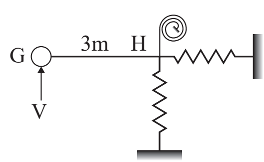




FBD of FG

$\Sigma m_F = 0$

v = 10 kN



FBD of FG

$v \times 3 = k_\theta \times \theta$

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: $Q = 6000\ m^3/\text{day} = \ = \frac{6000}{24} = 250\ m^3/hr$

$v_0 = 1.5$ 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:

$$\sigma_z = \frac{Q}{(B+Z)(L+Z)} \quad \text{for 2V to 1 H load dispersion}$$

$$= \frac{2\times4\times120}{(2+2)(4+2)} = 40 \text{ kPa}$$

End of Solution

ESE / GATE / PSUs - 2020
ADMISSIONS OPEN

CENTER	COURSE	BATCH TYPE	DATE
HYDERABAD - DSNR	GATE + PSUS – 2020	Regular Batches	26th April, 11th, 25th May, 09th, 24th June, 8th July 2019
HYDERABAD - DSNR	ESE + GATE + PSUs - 2020	Regular Batches	21st March, 26th April, 11th, 25th May, 09th, 24th June, 8th July 2019
HYDERABAD - DSNR	GATE + PSUs - 2020	Short Term Batches	29th April, 6th, 11th, 18th May 26th May, 2nd June, 2019
HYDERABAD - DSNR	GATE + PSUs - 2020	Morning/Evening Batch	24th February 2019
HYDERABAD - DSNR	ESE – 2019 STAGE-II (MAINS)	Regular Batch	17th Feb 2019
HYDERABAD - Abids	GATE + PSUS – 2020	Regular Batches	26th April, 11th, 25th May, 09th, 24th June, 8th July 2019
HYDERABAD - Abids	GATE + PSUs - 2020	Short Term Batches	29th April, 6th, 11th, 18th May 26th May, 2nd June, 2019
HYDERABAD - Abids	ESE + GATE + PSUs - 2020	Morning Batch	24th February 2019
HYDERABAD - Abids	ESE – 2019 STAGE-II (MAINS)	Regular Batch	17th Feb 2019
HYDERABAD - Abids	GATE + PSUs - 2020	Weekend Batch	24th February 2019
HYDERABAD - Abids	ESE+GATE + PSUs - 2020	Spark Batches	11th May, 09th June 2019
HYDERABAD - Kukatpally	GATE + PSUs - 2020	Morning/Evening Batch	24th February 2019
HYDERABAD - Kukatpally	GATE + PSUS – 2020	Regular Batches	17th May, 1st, 16th June, 1st July 2019
HYDERABAD - Kukatpally	GATE + PSUs - 2020	Short Term Batches	29th April, 6th, 11th, 18th May 26th May, 2nd June, 2019
HYDERABAD - Kothapet	ESE + GATE + PSUS – 2020	Regular Batches	21st March, 26th April, 11th, 25th May, 09th, 24th June, 8th July 2019
HYDERABAD - Kothapet	ESE+GATE + PSUs - 2020	Spark Batches	11th May, 09th June 2019
DELHI	ESE+GATE+PSUs - 2020	Weekend Batches	9th Mar 2019
DELHI	ESE+GATE+PSUs - 2020	Regular Evening Batch	18th Feb 2019
DELHI	ESE+GATE+PSUs - 2020	Regular Day Batch	11th May 2019
DELHI	ESE+GATE+PSUs - 2020	Spark Batch	11th May 2019
DELHI	GATE+PSUs - 2020	Short Term Batches	11th, 23rd May 2019
BHOPAL	ESE+GATE+PSUs - 2020	Regular Day Batch	01st Week of June 2019
BHUBANESWAR	GATE+PSUs - 2020	Weekend Batch	16th Feb 2019
BHUBANESWAR	GATE+PSUs - 2020	Regular Batch	02nd Week of May 2019
CHENNAI	GATE+PSUs - 2020 & 21	Weekend Batch	16th Feb 2019
CHENNAI	GATE+PSUs - 2020	Regular Batch	02nd Week of May 2019
BANGALORE	GATE+PSUs - 2020 & 21	Weekend Batch	23rd Feb 2019
BANGALORE	GATE+PSUs - 2020	Regular Batch	17th June 2019