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Questions with Detailed Solutions

CIVIL ENGINEERING

(Afternoon Session)

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GATE - 2021

CIVIL ENGINEERING

Questions with Detailed Solutions

06/02/21

Afternoon Session

SUBJECTWISE WEIGHTAGE

S. No.	NAME OF THE SUBJECT	Number of Questions
01	Engineering Mechanics	2
02	Strength of Material	4
03	Structural Analysis	3
04	Construction Materials	2
05	Construction Planning & Management	3
06	Reinforced Cement Concrete	1
07	Design of Steel Structures	-
08	Geo-technical Engineering	8
09	Fluid Mechanics & Hydraulic Machines	5
10	Hydrology	2
11	Irrigation Engineering	1
12	Environmental Engineering	7
13	Transportation Engineering	6
14	Geomatics Engineering (Surveying)	2
15	Engineering Mathematics	9
16	Verbal Ability	2
17	Numerical Ability	8
Total No. of Questions		**65**

Section : General Aptitude

01. Four persons P, Q, R and S are to be seated in a row. R should not be seated at the second position from the left end of the row. The number of distinct seating arrangements possible is:
(a) 24 (b) 18
(c) 9 (d) 6

01. Ans: (b)

Sol: (3!) 3 = 18 chances
(∵ 'R' should not be seated at second position from the left end)
(__, (R), ____, ___)
×

02. (i) Arun and Aparna are here.
(ii) Arun and Aparna is here.
(iii) Arun's families is here.
(iv) Arun's family is here.
Which of the above sentences are grammatically CORRECT?
(a) (ii) and (iv) (b) (i) and (ii)
(c) (iii) and (iv) (d) (i) and (iv)

02. Ans: (d)

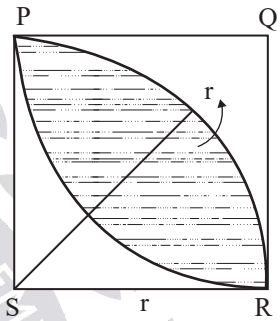
Sol: When two or more singular nouns joined by 'and' the verb should be plural.
Singular subject takes singular verb.

03. ⊕ and ⊙ are two operators on numbers p and q such that
$p \odot q = p - q$, and $p \oplus q = p \times q$
Then, $(9 \odot (6 \oplus 7)) \odot (7 \oplus (6 \odot 5))$=
(a) 40 (b) –26
(c) –33 (d) –40

03. Ans: (d)

Sol: $p \odot q = p - q$
$p \oplus q = p \times q$
Then, $(9 \odot (6 \oplus 7)) \odot (7 \oplus (6 \odot 5))$
$\Rightarrow (9 - (6 \times 7)) - (7 \times (6 - 5))$
$= 9 - 42 - 7$
$= -40$

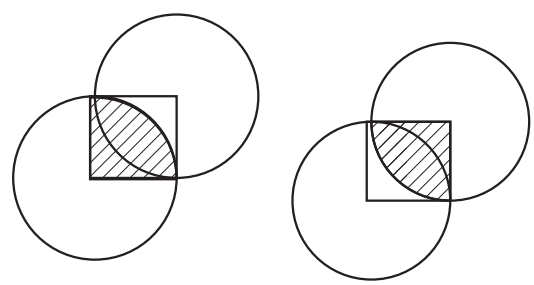
04.



In the figure shown above, PQRS is a square. The shaded portion is formed by the intersection of sectors of circles with radius equal to the side of the square and centers at S and Q.
The probability that any point picked randomly within the square falls in the shaded area is ———
(a) $\frac{\pi}{4}$ (b) $\frac{1}{2}$
(c) $4 - \frac{\pi}{2}$ (d) $\frac{\pi}{2} - 1$

04. Ans: (d)

Sol: Area of Shaded region from the figure is $\frac{\pi r^2}{4}$



Area of shaded region from the figure is $r^2 - \frac{\pi r^2}{4}$
Area of shaded part in the question

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$$= r^2 - 2\left(r^2 - \frac{\pi r^2}{4}\right)$$

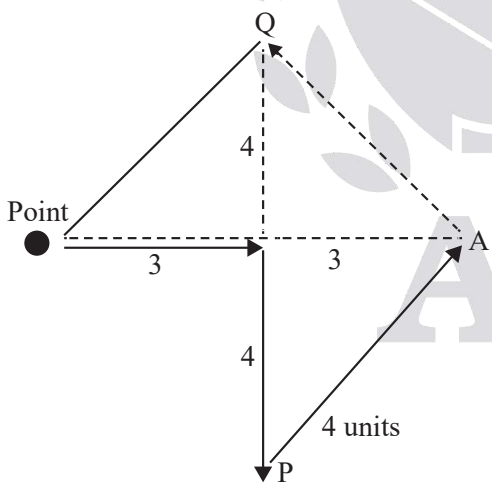
$$= \frac{\pi r^2}{2} - r^2$$

Required probability $= \dfrac{\frac{\pi r^2}{2} - r^2}{r^2} = \dfrac{\pi}{2} - 1$

05. On a planar field, you travelled 3 units East from a point O. Next you travelled 4 units South to arrive at point P. Then you travelled from P in the North-East direction such that you arrive at a point that is 6 units East of point O. Next, you travelled in the North-West direction, so that you arrive at point Q that is 8 units North of point P.
The distance of point Q to point O, in the same units, should be _____
(a) 4 (b) 3
(c) 5 (d) 6

05. Ans: (c)

Sol:



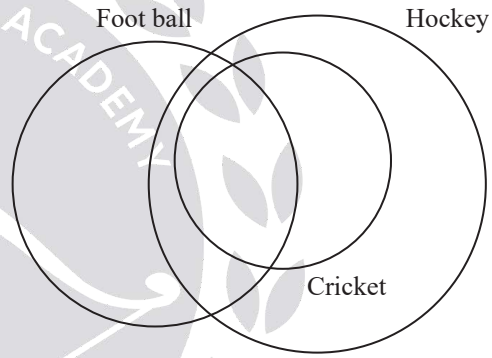
OA = 6 Units
PQ = 8

$(OQ)^2 = (OX)^2 + (OX)^2$
$= 3^2 + 4^2$
$(OQ)^2 = 25$
OQ = 5

06. 1. Some football players play cricket.
2. All cricket players play hockey.
Among the options given below, the statement that logically follows from the two statements 1 and 2 above, is:
(a) No football player plays hockey.
(b) All hockey players play football.
(c) All football players play hockey.
(d) Some football players play hockey.

06. Ans: (d)

Sol: Some foot ball players play cricket
All cricket players play hockey



Some football players play hockey is satisfied.

07. The author said. "Musicians rehearse before their concerts. Actors rehearse their roles before the opening of a new play. On the other hand, I find it strange that many public speakers think they can just walk on to the stage and start speaking. In my opinion, it is no less important for public speakers to rehearse their talks."
Based on the above passage, which one of the following is TRUE?
(a) The author is of the opinion that rehearsal is more important for actors than musicians.
(b) The author is of the opinion that rehearsing is important for musicians, actors and public speakers.

(c) The author is of the opinion that rehearsing is less important for public speakers than for musicians and actors.

(d) The author is of the opinion that rehearsing is more important only for musicians than public speakers.

07. Ans: (b)

Sol: The author states musicians rehearse, actors rehearse and likewise he states public speakers also should rehearse and this is stated in option (b).

08. Two identical cube shaped dice each with faces numbered 1 to 6 are rolled simultaneously. The probability that an even number is rolled out on each dice

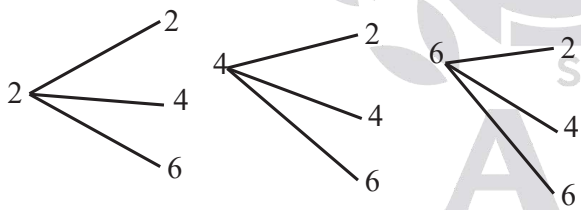
(a) $\frac{1}{36}$ (b) $\frac{1}{8}$ (c) $\frac{1}{4}$ (d) $\frac{1}{12}$

08. Ans: (c)

Sol: The even numbers on the dice are 2, 4, 6

The probability of even number on a dice = $\frac{3}{6}$

$\therefore$ The probability that an even number is rolled out on each dice is $\frac{3}{6}\times\frac{3}{6}=\frac{1}{4}$



09. In an equilateral triangle PQR, side PQ is divided into four equal parts, side QR is divided into six equal parts and side PR is divided into eight equal parts. The length of each subdivided part in cm is an integer.

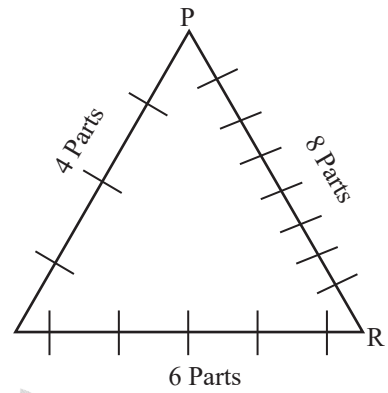
The minimum area of the triangle PQR possible, in cm , is

(a) 24 (b) $48\sqrt{3}$

(c) $144\sqrt{3}$ (d) 18

09. Ans: (c)

Sol:



Minimum area of triangle = L.C.M of (4,6, 8) = 24

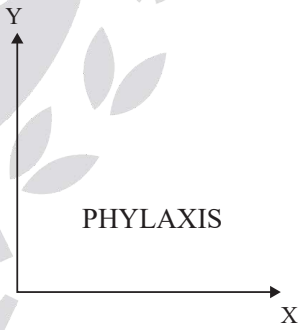
$$A=\frac{\sqrt{3}}{4}a^2=\frac{\sqrt{3}}{4}(24^2)$$

$$=\frac{\sqrt{3}}{4}(576)$$

$$=\sqrt{3}(144)$$

$$=144\sqrt{3}$$

10.



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

ƃHʎlΓ∀XIS

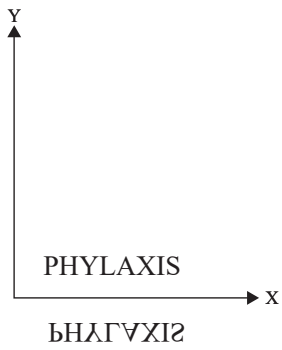
PHʎlΓ∀XIƧ

dHʎlΓ∀XIƧ

ƃHʎlΓ∀XIƧ

10. Ans: (d)

Sol:



With respect 'X' - axis

Section : Civil Engineering

01. From laboratory investigations, the liquid limit, plastic limit, natural moisture content and flow index of a soil specimen are obtained as 60%. 27%. 32% and 27, respectively. The corresponding toughness index and liquidity index of the soil specimen, respectively, are is

(a) 0.19 and 6.60 (b) 6.60 and 0.19

(c) 0.15 and 1.22 (d) 1.22 and 0.15

01. Ans: (d)

Sol: $w_L = 60\%$

$w_P = 27\%$

$w_n = 32\%$

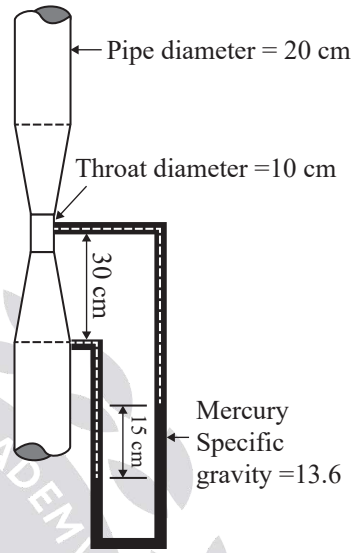
$I_f = 27$

$$I_T = \frac{I_P}{I_f} = \frac{w_L - w_P}{I_f}$$

$$I_T = \frac{60-27}{27} = 1.22$$

$$I_L = \frac{w_n - w_P}{I_p} = \frac{32-27}{60-27} = 0.15$$

02. A venturimeter as shown in the figure (not to scale) is connected to measure the flow of water in a vertical pipe of 20 cm diameter.



Assume g = 9.8 m/s^2. When the deflection in the mercury manometer is 15 cm, the flow rate (in lps, round off to two decimal places) considering no loss in the venturimeter is

02. Ans: 49.37

Sol: $$Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gxh}$$

$$= C_d \frac{a_2}{\sqrt{1 - \left(\frac{a_2}{a_1}\right)^2}} \sqrt{2gx\left(\frac{\rho_m}{\rho} - 1\right)}$$

$$= \frac{1 \times \frac{\pi}{4} \times 0.1^2}{\sqrt{1 - 0.5^4}} \times \sqrt{2 \times 9.8 \times (13.6 - 1) \times 0.15}$$

$$= 49.37 \text{ lit/s}$$

03. For a 2° curve on a high speed Broad Gauge (BG) rail section, the maximum sanctioned speed is 100 km/h and the equilibrium speed is 80 km/h. Consider dynamic gauge of BG rail as 1750 mm. The degree of curve is defined as the angle subtended at its center by a 30.5 m arc. The cant deficiency for the curve (in mm, round off to integer) is _____

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03. Ans: 57

Sol: $D^o = 2^o$

$V_{max} = 100$ kmph $\qquad e_d = ?$

$V_{equ} = 80$ kmph

$G = 1750$ mm

$D^o = \frac{1750}{R}(30.5\text{ m})$

$D^o = \frac{1750}{R}$

$\Rightarrow R = \frac{1750}{2} = 875$ m

Considering V_{max}, $e_{the} = \frac{GV_{max}^2}{127R}$

$= \frac{1.750 \times 100^2}{127 \times 875} = 157.480$ mm

Considering V_{equ}

$e_{equ} = \frac{GV_{equ}^2}{127R} = \frac{1.750 \times 80^2}{127 \times 875}$

$= 100.787$ mm

$e_{max} = \frac{1}{10}G$

$= \frac{1}{10}(1750\text{ mm}) = 175.0$ mm

$\therefore e_{actual} = e_{equ} = 100.787$ mm

$e_{the} = 157.480$ mm

$e_{equ} = 100.787$ mm

$\therefore e_d$ in field $= 157.480 - 100.787 = 56.693$ mm

Maximum allowable e_d for BG = 75 mm

$\therefore e_d = 56.693 \simeq 57$ mm is allowable

04. In an aggregate mix, the proportions of coarse aggregate, fine aggregate and mineral filler are 55%, 40% and 5%, respectively. The values of bulk specific gravity of the coarse aggregate, fine aggregate and mineral filler are 2.55. 2.65 and 2.70, respectively. The bulk specific gravity of the aggregate mix (round off to two decimal places) is

_____

04. Ans: 2.6

Sol: The proportion of mix is

Coarse aggregate = 55%

Fine aggregate = 40%

Mineral filler = 5%

Given Specific gravities are

Coarse aggregate, $SG_1 = 2.55$

Fine aggregate, $SG_2 = 2.65$

Mineral filler, $SG_3 = 2.70$

Bulk Specific gravity

$= \frac{X\% \times SG_1 + Y\% \times SG_2 + Z\% \times SG_3}{100}$

$= \frac{55\% \times 2.55 + 40\% \times 2.65 + 5\% \times 2.7}{100}$

$= 2.5975$

$\cong 2.6$

05. In a three-phase signal system design for a four-leg intersection, the critical flow ratios for each phase are 0.18, 0.32, and 0.22. The total loss time in each of the phases is 2 s. As per Webster's formula, the optimal cycle length (in s, round off to the nearest integer) is _____

05. Ans: 50

Sol: Three phase signal system

$y_1 = 0.18 \quad y_2 = 0.32;\ y_3 = 0.22$

Lost time per phase = 2 sec

Lost time per cycle = $2 \times 3 = 6$ sec

$y = y_1 + y_2 + y_3 = 0.18 + 0.32 + 0.22 = 0.72$

Cycle time as per Webster is

$C_o = \frac{1.5 \times L + 5}{1 - y} = \frac{1.5 \times 6 + 5}{1 - 0.72} = 50$ sec

06. The most appropriate triaxial test to assess the long-term stability of an excavated clay slope is

(a) unconsolidated undrained test

(b) consolidated drained test

(c) unconfined compression test

(d) consolidated undrained test

06. Ans: (b)

Sol: To assess the long term stability of clayey soil, the results of consolidated drained (CD) test are used.

07. A rectangular open channel of 6 m width is carrying a discharge of 20 m^3/s. Consider the acceleration due to gravity as 9.81 m/s^2 and assume water as incompressible and inviscid. The depth of flow in the channel at which the specific energy of the flowing water is minimum for the given discharge will then be

(a) 3.18 m (b) 0.82 m

(c) 1.04 m (d) 2.56 m

07. Ans: (c)

Sol: Rectangle, B = 6 m

$Q = 20\ m^3/s$

$g = 9.81\ m/s^2$

$\therefore q = \frac{Q}{B} = \frac{20}{6} = 3.33\ m^2/s$

Specific energy is minimum at critical flow, so, depth should be critical depth,

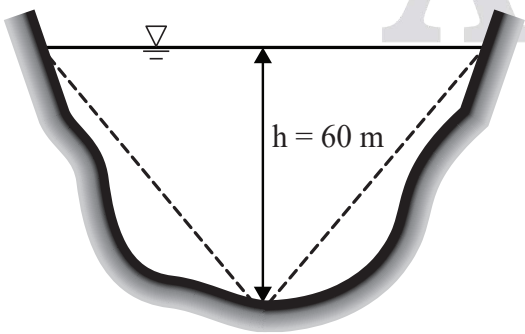
$$y_c = \left(\frac{q^2}{g}\right)^{1/3}$$

$$y_c = \left(\frac{3.33^2}{9.81}\right)^{1/3} = 1.04\ m$$

08. A lake has a maximum depth of 60 m. If the mean atmospheric pressure in the lake region is 91 kPa and the unit weight of the lake water is 9790 N/m^3, the absolute pressure (in kPa, round off to two decimal places) at the maximum depth of the lake is

08. Ans: 678.4

Sol:



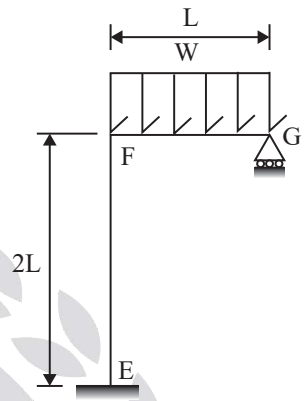
$\gamma_{water} = 9790\ N/m^3$

$P_{atm} = 91\ kPa \qquad (P_{\Delta})_{abs} = ?$

$P = P_{atm} + \gamma h$

$= 91 \times 10^3 + 9790 \times 60 = 678.4\ kPa$

09. A frame EFG is shown in the figure. All members are prismatic and have equal flexural rigidity. The member FG carries a uniformly distributed load w per unit length. Axial deformation of any member is neglected.



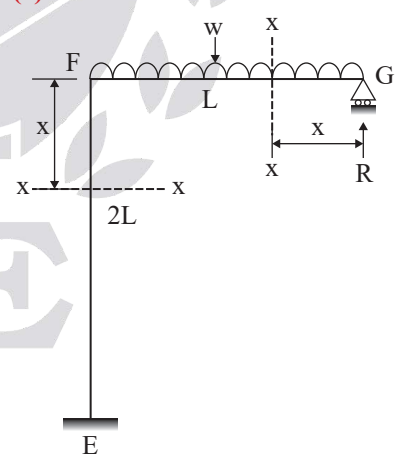
Considering the joint F being rigid, the support reaction at G is

(a) 0.375 wL (b) 0.453 wL

(c) 0.482 wL (d) 0.500 wL

09. Ans: (c)

Sol:



Sagging +ve

Hogging –ve

$$M_{x-x} = Rx - \frac{wx^2}{2}$$

$$M_{x-x} = RL - \frac{wL^2}{2}$$

Compatibility condition

$$\frac{\partial U}{\partial R} = 0$$

Strain energy (U) $= \int_0^{\ell} \frac{M_x^2}{2EI} dx$

$$\frac{\partial}{\partial R}\left[\int \frac{M_x^2}{2EI} dx\right] = 0$$

$$\frac{\partial}{\partial R}\left[\int_0^{\ell} \frac{\left(Rx - \frac{wx^2}{2}\right)^2}{2EI} dx + \int_0^{2L} \frac{\left(RL - \frac{wL^2}{2}\right)^2}{2EI} dx\right] = 0$$

$$\int_0^{L} \frac{2\left(Rx - \frac{wx^2}{2}\right)}{2EI} \times x dx + \int_0^{2L} \frac{2\left(RL - \frac{wL^2}{2}\right)}{2EI} dx = 0$$

$$\int_0^{L} \frac{2\left(Rx^2 - \frac{wx^3}{2}\right)}{EI} \times dx + \int_0^{2L} \frac{\left(RL^2 - \frac{wL^3}{2}\right)}{EI} = 0$$

$$\frac{RL^3}{3} - \frac{W}{2} \times \frac{L^4}{4} + RL^2(2L) - \frac{wL^3}{2}(2L) = 0$$

$$\frac{RL^3}{3} - \frac{wL^4}{8} + 2RL^3 - wL^4 = 0$$

$$\frac{7RL^3}{3} = \frac{9}{8} wL^4$$

$$R = \frac{27}{56} wL$$

$$R = 0.482\ wL$$

10. The smallest eigenvalue and the corresponding eigenvector of the matrix $\begin{bmatrix} 2 & -2 \\ -1 & 6 \end{bmatrix}$, respectively, are

(a) 2.00 and $\begin{Bmatrix} 1.00 \\ 1.00 \end{Bmatrix}$ (b) 1.55 and $\begin{Bmatrix} 2.00 \\ 0.45 \end{Bmatrix}$

(c) 1.55 and $\begin{Bmatrix} -2.55 \\ -0.45 \end{Bmatrix}$ (d) 1.55 and $\begin{Bmatrix} 2.00 \\ -0.45 \end{Bmatrix}$

10. Ans: (b)

Sol: Characteristic equation $= \begin{vmatrix} 2-\lambda & -2 \\ -1 & 6-\lambda \end{vmatrix} = 0$

$$(2-\lambda)(6-\lambda) - 2 = 0$$

$$\lambda^2 - 8\lambda + 12 - 2 = 0 \Rightarrow \lambda^2 - 8\lambda + 10 = 0$$

$$\lambda = \frac{8 \pm \sqrt{64-40}}{2} = \frac{8 \pm \sqrt{24}}{2} = 4 \pm \sqrt{6}$$

Smallest eigen value $= 4 - \sqrt{6} = 1.5505$

Consider $(A - \lambda I)\ X = 0$

$$\Rightarrow \begin{bmatrix} 2-\lambda & -2 \\ -1 & 6-\lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$\Rightarrow \begin{pmatrix} 2-(4-\sqrt{6}) & -2 \\ -1 & 6-(4-\sqrt{6}) \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$$\Rightarrow \begin{pmatrix} 2+\sqrt{6} & -2 \\ -1 & 2+\sqrt{6} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$$\Rightarrow \begin{pmatrix} -(2-\sqrt{6}) & -2 \\ 0 & 0 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$$\Rightarrow -(2-\sqrt{6})x_1 + (-2)x_2 = 0$$

Let $x_2 = K$

Then $x_1 = \frac{2K}{-2+\sqrt{6}}$

$$\therefore X_1 = \begin{bmatrix} \frac{2K}{-2+\sqrt{6}} \\ K \end{bmatrix} = K \begin{bmatrix} \frac{2}{-2+\sqrt{6}} \\ 1 \end{bmatrix} = \begin{bmatrix} 2+\sqrt{6} \\ 1 \end{bmatrix}$$

for K = 1

(or)

$$X_1 = \begin{bmatrix} 2 \\ -2+\sqrt{6} \end{bmatrix} = \begin{bmatrix} 2 \\ 0.45 \end{bmatrix} \text{ for } K = -2+\sqrt{6}$$

Verification of options for eigen vectors closest option that matches is (b)

11. For a given traverse, latitudes and departures are calculated and it is found that sum of latitudes is equal to +2.1 m and the sum of departures is equal to –2.8 m.

The length and bearing of the closing error, respectively, are

(a) 2.45 m and 53°7'48" NW

(b) 3.50 m and 53°7'48" NW

(c) 3.50 m and 53.13° SE

(d) 0.35 m and 53.13° SE

11. Ans: (b)

Sol: $\Sigma L = +2.1$ m

$\Sigma D = -2.8$ m

$$e = \sqrt{\Sigma L^2 + \Sigma D^2}$$

$$= \sqrt{(2.1)^2 + (-2.8)^2} = 3.5 \text{ m}$$

$$\alpha = \tan^{-1}\left(\frac{\Sigma D}{\Sigma L}\right) = N53.13^{\circ}W$$

UPCOMING BATCHES @ HYDERABAD

GATE + PSUs – 2022 (REGULAR BATCHES)

Batch Type	Timings	Batch Date	Duration	Venue & Streams
Regular	Daily 4 to 6 Hours	**2nd & 17th April 2021**	5 to 6 Months	Abids (CS&IT) Dilsukhnagar (EC, EE, IN) Kothapet (CE, ME, PI)
		1st & 17th May 2021		
		1st & 17th June 2021		

GATE + PSUs - 2022 (FLEXIBLE BATCHES)

Flexible Batches	Daily 6 to 8 Hours	**5th, 20th July 2021**	3 to 4 Months	Abids (CS&IT) Dilsukhnagar (EC, EE, IN) Kothapet (CE, ME, PI)
		4th, 18th August 2021		

GATE + PSUs – 2022 (SPARK BATCHES)

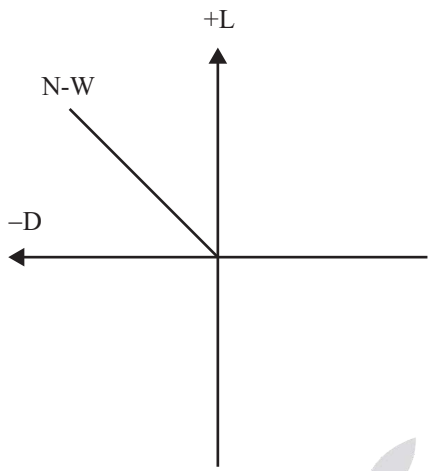
Spark	Daily 5 to 8 Hours	**17th May 2021**	5 to 6 Months	Abids (CE, ME, CS) Kukatpally (EC, EE)
		1st & 17th June 2021		

ESE + GATE + PSUs – 2022 (REGULAR BATCHES)

Regular	Daily 6 to 8 Hours	**2nd & 17th April 2021**	9 to 10 Months	Kukatpally (EC, EE) Abids (CE, ME)
		1st & 17th May 2021		
		1st & 17th June 2021		

ESE + GATE + PSUs – 2022 (SPARK BATCHES)

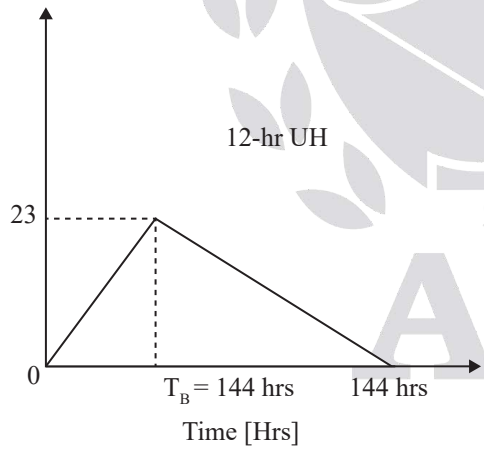
Spark	Daily 6 to 8 Hours	**17th May 2021**	9 to 10 Months	Kukatpally (EC, EE) Abids (CE, ME)
		1st & 17th June 2021		



12. A 12-hour unit hydrograph (of 1 cm excess rainfall) of a catchment is of a triangular shape with a base width of 144 hour and a peak discharge of 23 m^3/s. The area of the catchment (in km^2, round off to the nearest integer) is _____

12. Ans: 596

Sol:



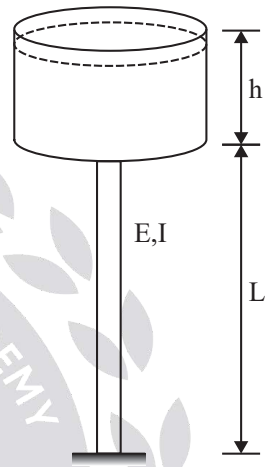
Area of UH = C.A × 0.01

$\frac{1}{2} \times 144 \times 3600 \times 23 = C.A \times 0.01$

$C.A = 596.16 \times 10^6\ m^2$

$C.A = 596\ km^2$

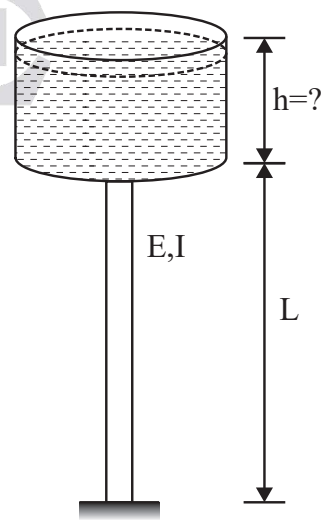
13. An elevated cylindrical water storage tank is shown in the figure. The tank has inner diameter of 1.5 m. It is supported on a solid steel circular column of diameter 75 mm and total height (L) of 4 m. Take, water density = 1000 kg/m^3 and acceleration due to gravity = 10 m/s^2



If elastic modulus (E) of steel is 200 GPa, ignoring self-weight of the tank, for the supporting steel column to remain unbuckled, the maximum depth (h) of the water permissible (in m, round off to one decimal place) is _____

13. Ans: 2.7

Sol:



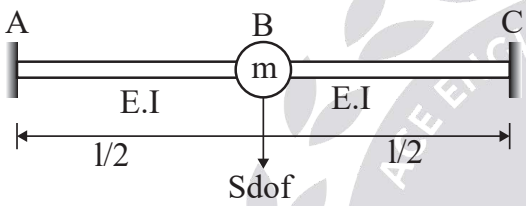
$P_{cr} = \frac{\pi^2 EI}{\ell_e^2}$ = Buckling load = weight of water

$\frac{\pi^2 EI}{(2\ell)^2} = (\rho g h) \times \frac{\pi}{4} d_i^2 = \rho g \times$ volume of tank

$$\frac{\pi^2 \times 200 \times 10^9 \times \pi (75 \times 10^{-3})^4}{(2 \times 4)^2 64} = 1000 \times 10 \times h \times \frac{\pi}{4} \times 1.5^2$$

h = 2.7 m

14. A prismatic fixed-fixed beam, modelled with a total lumped-mass of 10 kg as a single degree of freedom (SDOF) system is shown in the figure.



If the flexural stiffness of the beam is $4\pi^2$ kN/m, its natural frequency of vibration (in Hz, in integer) in the flexural mode will be _____

14. Ans: 10

Sol: Given Data:

m = 10 kg

$K = 4\pi^2 \times 10^3$

$\Rightarrow$ Natural frequency $f_n = \frac{1}{2\pi} \cdot \sqrt{\frac{k}{m}}$

$$= \frac{1}{2\pi} \cdot \sqrt{\frac{4\pi^2 \times 10^3}{10}}$$

$$= \frac{2\pi \times 10}{2\pi} = 10$$

15. The rank of the matrix $\begin{bmatrix} 5 & 0 & -5 & 0 \\ 0 & 2 & 0 & 1 \\ -5 & 0 & 5 & 0 \\ 0 & 1 & 0 & 2 \end{bmatrix}$ is

(a) 2 (b) 3

(c) 4 (d) 1

15. Ans: (b)

Sol: $R_2 (-) R_4, R_3 \rightarrow R_3 + R_1$

$$\begin{bmatrix} 5 & 0 & -5 & 0 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 0 \\ 0 & 2 & 0 & 1 \end{bmatrix}$$

$R_4 \rightarrow R_4 - 2R_1$

$$\begin{bmatrix} 5 & 0 & -5 & 0 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -3 \end{bmatrix}$$

$R_3 (-) R_4$

$$\begin{bmatrix} 5 & 0 & -5 & 0 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & -3 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Rank = 3

16. A horizontal angle θ is measured by four different surveyors multiple times and the values reported are given below.

Surveyor	Angle θ	Number o Observations
1	36°30′	4
2	36°00′	3
3	35°30′	8
4	36°30′	4

The most probable value of the angle θ (in degree, round off to two decimal places) is _____

16. Ans: 36

Sol: Treating number of observations as weight

Most probable value

$$= \frac{4 \times 36^\circ 30' + 3 \times 36^\circ + 8 \times 35^\circ 30' + 4 \times 36^\circ 30'}{4 + 3 + 8 + 4}$$

$= 36^\circ$

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17. Seasoning of timber for use in construction is done essentially to
(a) increase strength and durability
(b) cut timber in right season and geometry
(c) smoothen timber surfaces
(d) remove knots from timber logs

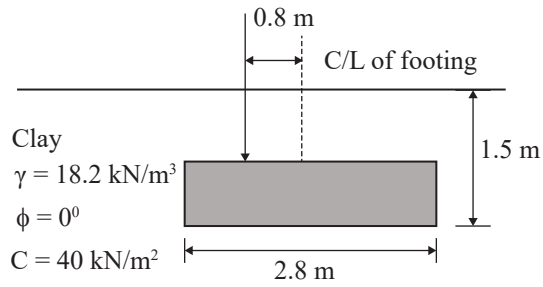
17. Ans: (a)

Sol: Option 1 Increase strength and durability
The process of drying of timber is known as seasoning
Natural tree has more the 50% weight of water of its dry weight
If we directly use this timber the because of irregular drying internal stresses will develop between fibres of timber and it will develop lots of defects (warps, shakes etc)

Seasoning

1. Reduces the shrinkage and warping in timber section
2. Increases the strength, durability and workability
3. Reduces the tendency to spilt and decay
4. Make it suitable for preservation and painting.
5. Reduce its weight

18. A rectangular footing of size 2.8 m × 3.5 m is embedded in a clay layer and a vertical load is placed with an eccentricity of 0.8 m as shown in the figure (not to scale). Take Bearing capacity factors: $N_c = 5.14$. $N_q = 1.0$, and $N_\gamma = 0.0$; Shape factors: $s_c = 1.16$, $s_q = 1.0$ and $s_\gamma = 1.0$; Depth factors: $d_c = 1.1$, $d_q = 1.0$ and $d_\gamma = 1.0$; and Inclination factors: $i_c = 1.0$ and $i_q = 1.0$ and $i_\gamma = 1.0$.



Using Meyerhoff's method, the load (in kN, round off to two decimal places) that can be applied on the footing with a factor of safety of 2.5 is

_____

18. Ans: 440.74

Sol: The footing has one way eccentricity
$\therefore e_x = 0.8$ m, $e_y = 0$
Modified or useful width, $B' = B - 2e_x$
$= 2.8 - (2 \times 0.8) = 1.2$ m

$L' = L - 2e_y = 3.5$ m
Meyerhoff's equation to find ultimate bearing capacity, q_u

$$\therefore q_u = CN_c.S_c.d_c.i_c + \gamma D_f N_q.S_q.d_q.i_q + 0.5\gamma B'N_\gamma S_\gamma.d_\gamma.i_\gamma$$

$$\therefore q_u = 40 \times 5.14 \times 1.16 \times 1.1 \times 1 + 18.2 \times 1.5 \times 1 \times 1 \times 1 \times 1 + 0 \quad (\because N_\gamma = 0)$$

$q_u = 289.6456$ kN/m²
Net ultimate bearing capacity,
$q_{nu} = q_u - \gamma D_f$
$= 289.6456 - 18.2 \times 1.5 = 262.3456$ kN/m

Net safe bearing capacity of soil,

$$q_{ns} = \frac{q_{nu}}{F} = \frac{262.3456}{2.5}$$
$$= 104.938$$

Net load that can be applied, $Q_n = q_{ns} \times B' \times L'$
$= 104.938 \times 1.2 \times 3.5$
$= 440.741$ kN
Say 440.74 kN

19. The hardness of a water sample is measured directly by titration with 0.01 M solution of ethylenediamine tetraacetic acid (EDTA) using eriochrome black T (EBT) as an indicator. The EBT reacts and forms complexes with divalent metallic cations present in the water. During titration, the EDTA replaces the EBT in the complex. When the replacement of EBT is complete at the end point of the titration, the colour of the solution changes from
(a) wine red to blue
(b) reddish brown to pinkish yellow
(c) blue to colourless
(d) blue-green to reddish brown

19. Ans: (a)

Sol: Hardness end point of titration →wine red to blue

20. An equipment has been purchased at an initial cost of ₹160000 and has an estimated salvage value of ₹10000. The equipment has an estimated life of 5 years. The difference between the book values (in ₹, in integer) obtained at the end of 4th year using straight line method and sum of years digit method of depreciation is _____

20. Ans: 20,000

Sol: Initial cost (P) = 1,60,000
Salvage value (SV) = 10,000
Useful life (n) = 5 years
Straight Line Method:

$$\text{Annual depreciation (D)} = \frac{P - SV}{n} = \frac{1,60,000 - 10,000}{5} = 30000$$

$$\text{Book value after 4 years } (BV_4) = P - 4D = 1,60,000 - 4(30,000) = 40,000$$

SOY Method (Sum of years Digit)

$$SOY = \frac{n(n+1)}{2} = \frac{5 \times 6}{2} = 15$$

$$d_m = \frac{n - (m-1)}{SOY}$$

$$D_m = (P - SV) \times d_m$$

$$BV_m = BV_{m-1} - D_m$$

$$d_1 = \frac{5-(1-1)}{15} = \frac{5}{15}\ ;\ D_1 = (1,60,000 - 10000) \times \frac{5}{15} = 50000$$

$$d_2 = \frac{4}{15}\ ;\ D_2 = 40,000$$

$$d_3 = \frac{3}{15}\ ;\ D_3 = 30,000$$

$$d_4 = \frac{2}{15};\ D_4 = 20,000$$

$$d_5 = \frac{2}{15}\ ;\ D_5 = 10,000$$

$BV_o = 1,60,000$
$BV_1 = 1,60,000 - 50,000 = 1,10,000$
$BV_2 = 1,10,000 - 40,000 = 70,000$
$BV_3 = 70,000 - 30,000 = 40,000$
$BV_4 = 40,000 - 20,000 = 20,000$
$BV_5 = 20,000 - 10,000 = 10,000$
Difference of Book value obtained in two methods = 40,000 – 20,000 = 20,000

21. A function is defined in Cartesian coordinate system as $f(x, y) = xe^y$. The value of the directional derivative of the function (in integer) at the point (2, 0) along the direction of the straight line segment from point (2. 0) to point $\left(\frac{1}{2}, 2\right)$ is _____

21. Ans: (a)

Sol: $\nabla f = \left(\frac{i\partial}{\partial x} + \frac{j\partial}{\partial y}\right) xe^y = e^y i + xe^y j$

$\nabla f|_{(2,0)} = i + 2j$

Vector along the direction of the straight line segment from (2,0) to $\left(\frac{1}{2}, 2\right)$ is given by $\bar{a} = \left(\frac{1}{2} - 2\right)i + (2-0)j$

$\bar{a} = \frac{-3}{2}i + 2j$

Unit vector along $\bar{a}$ is $\frac{\frac{-3}{2}i + 2j}{\sqrt{\frac{9}{4} + 4}}$

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Batch Type	Timings	Batch Date	Duration	Venue
Morning, Evening Batches	**6am to 8am & 6pm to 8:30pm**	20th March 2021	8 to 10 Months	Abids, Dilsukhnagar, Kukatpally.

GATE + PSUs – 2022 & ESE + GATE + PSUs – 2022 — @ DELHI

Regular Batches	Daily 5 to 6 Hours	5th March 2021	6 to 7 Months	ACE campus Saket
		7th April 2021		
		15th May 2021		
		5th June 2021		

GATE + PSUs – 2022 & ESE + GATE + PSUs – 2022 — @ PUNE

Regular / Weekend Batches	Daily 5 to 6 Hours	20th March 2021	6 to 7 Months	Pune Classroom

GATE + PSUs – 2022 & 2023 — @ VIZAG

Weekend Batch	Saturday **2 pm to 8 pm** Sunday **9am to 6pm**	3rd April 2021	6 to 7 Months	Vizag Classroom

GATE + PSUs – 2022 & 2023 — @ VIJAYAWADA

Weekend Batch	Saturday **2 pm to 8 pm** Sunday **9am to 6pm**	3rd April 2021	6 to 7 Months	Vijayawada Classroom

GATE + PSUs – 2022 — @ TIRUPATI

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The value of the directional derivative is

$$\nabla f.\frac{\bar{a}}{|\bar{a}|} = \frac{(i+2j).\left(-\frac{3}{2}i+2j\right)}{\frac{5}{2}}$$

$$= \frac{-\frac{3}{2}+4}{5/2} = \frac{5/2}{5/2} = 1$$

22. A water filtration unit is made of uniform-size sand particles of 0.4 mm diameter with a shape factor of 0.84 and specific gravity of 2.55. The depth of the filter bed is 0.70 m and the porosity is 0.35. The filter bed is to be expanded to a porosity of 0.65 by hydraulic backwash. If the terminal settling velocity of sand particles during backwash is 4.5 cm/s, the required backwash velocity is

(a) 0.75 cm/s (b) 6.35×10^{-3} m/s

(c) 5.79×10^{-3} m/s (d) 0.69 cm/s

22. Ans: (b)

Sol: d = 0.4 mm z = 0.7 m

Q = 0.84 n = 0.35

S = 2.55 $n_e = 0.65$

$v_s = 4.5$ cm/sec

ROB $v_b = ?$

$v_b = v_s\,[n_e]^{4.5} = 4.5\times10^{-2}\times[0.65]^{4.5}$

$= 0.00647$ m/sec

$= 6.47\times10^{-3}$ m/sec

23. The ratio of the momentum correction factor to the energy correction factor for a laminar flow in a pipe is

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

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

23. Ans: (c)

Sol: For Laminar flow,

Kinetic Energy correction factor, $(\alpha) = 2$

Momentum correction factor, $(\beta) = \frac{4}{3}$

$\therefore \frac{\beta}{\alpha} = \frac{4/3}{2} = \frac{2}{3}$

24. Relationship between traffic speed and density is described using a negatively sloped straight line. If v_f is the free-flow speed then the speed at which the maximum flow occurs is

(a) $\frac{v_f}{4}$ (b) 0 (c) $\frac{v_f}{2}$ (d) v_f

24. Ans: (c)

Sol: Given Speed density relation is linear maximum flow occurs at $\frac{v_f}{2}$ as per Greenshield's model.

25. As per the Unified Soil Classification System (USCS), the type of soil represented by 'MH' is

(a) Inorganic silts of high plasticity with liquid limit more than 50%

(b) Inorganic clays of high plasticity with liquid limit less than 50%

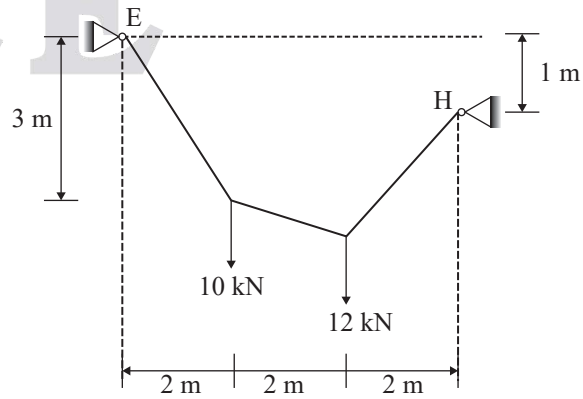
(c) Inorganic clays of low plasticity with liquid limit more than 50%

(d) Inorganic silts of low plasticity with liquid limit less than 50%

25. Ans: (a)

Sol: MH: Inorganic silt of high plasticity with $w_L > 50\%$

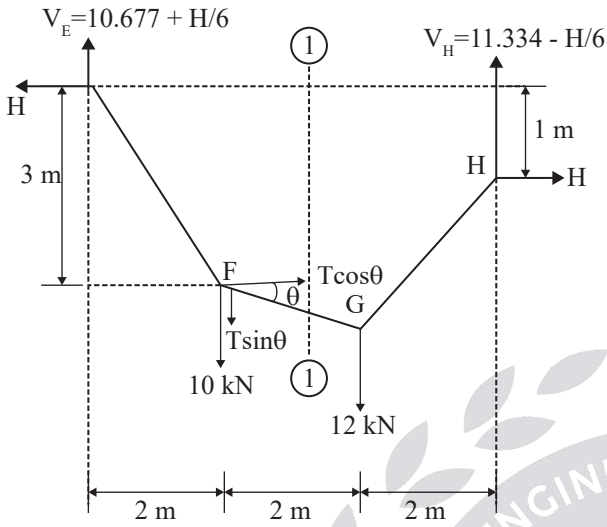
26. A perfectly flexible and inextensible cable is shown in the figure (not to scale). The external loads at F and G are acting vertically.



The magnitude of tension in the cable segment FG (in kN, round off to two decimal places) is ———

26. Ans:8.246

Sol:



$\Sigma M_F = 0$ ↳–ve ↲+ve [Left part]

$$\left(10.667 + \frac{H}{6}\right)2 - H \times 3 = 0$$

$H = 8$ kN

$V_E = 10.667 + \frac{8}{6}$

$V_E = 12$ kN

$V_H = 10$ kN

Consider left hand side of section (1) – (1)

$\Sigma H = 0$

$T \cos\theta = H$

$T \cos\theta = 8$

$T \sin\theta = 2$

$\therefore T^2\cos^2\theta + T^2\sin^2\alpha = 8^2 + 2^2$

$T = 8.246$ kN

Tension in segment GF is 8.246 kN

27. The unit normal vector to the surface $X^2 + Y^2 + Z^2 - 48 = 0$ at the point (4, 4, 4) is

(a) $\frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}}$ (b) $\frac{2}{\sqrt{2}}, \frac{2}{\sqrt{2}}, \frac{2}{\sqrt{2}}$

(c) $\frac{1}{\sqrt{5}}, \frac{1}{\sqrt{5}}, \frac{1}{\sqrt{5}}$ (d) $\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}$

27. Ans: (a)

Sol: The unit normal vector to the sphere $X^2 + Y^2 + Z^2 = r^2$ at a point (x_1, y_1, z_1) is given by

$$= \frac{x_1 i + y_1 j + z_1 k}{\sqrt{48}}$$

$$= \frac{4i + 4j + 4k}{\sqrt{48}} = \frac{i + j + k}{\sqrt{3}}$$

28. In case of bids in Two-Envelop system, the correct option is

(a) Technical bid is opened first

(b) Either of the two (Technical and Financial) bids can be opened first

(c) Financial bid is opened first

(d) Both (Technical and Financial) bids are opened simultaneously

28. Ans: (a)

Sol: Option 1 technical bid is opened first

Opening of Tender

First technical bid is opened and after ensuring that all the technical aspects of a contractor are in order than only financial bid is opened

1. Envelope 1 (Technical bid)
1. Cover letter
2. Registration Details
3. Pre-qualification documents
4. Earnest money deposit
5. Assumptions & Deviations in making of tender
6. Drawings
2. Envelope 2 (Financial Bid)
1. Forms of tender

29. An activated sludge process (ASP) is designed for secondary treatment of 7500 m^3/day of municipal wastewater. After primary clarifier, the ultimate BOD of the influent, which enters into ASP reactor is 200 mg/L. Treated effluent after secondary clarifier is required to have an ultimate BOD of

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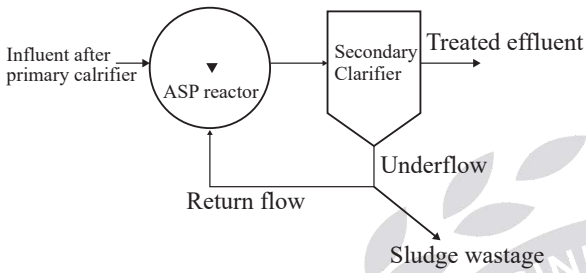
20 mg/L. Mix liquor volatile suspended solids (MLVSS) concentration in the reactor and the underflow is maintained as 3000 mg/L and 12000 mg/L, respectively. The hydraulic retention time and mean cell residence time are 0.2 day and 10 days, respectively. A representative flow diagram of the ASP is shown below.



The underflow volume (in m^3/day, round off to one decimal place) of sludge wastage is _____

29. Ans: 37.5

Sol: $Q = 7500\ m^3/day$

$y_i = 200\ mg/l$ $\quad y_e = 20\ mg/l$ $\quad X = 3000\ mg/l$

HDT = 0.2 day

$X_U = 12000\ mg/li$

MCRT $\theta_c = 10$ days $\quad Q_w = ?$

$\because X_e$ is not given

$$\theta_c = \frac{VX}{Q_w X_U + (Q - Q_w)X_e}$$

$$\theta_c = \frac{VX}{Q_w X_U} \qquad X_e = 0$$

$$10 = \frac{(7500 \times 0.2) \times 3000}{Q_w \times 12000} \qquad V = Q \times DT$$

$$= 7500 \times 0.2$$

$$= 1500\ m^3$$

$$\Rightarrow Q_w = \frac{7500 \times 0.2 \times 3000}{10 \times 12000} = 37.5\ m^3/day$$

30. Read the statements given below.

(i) Value of the wind profile exponent for the "very unstable' atmosphere is smaller than the wind profile exponent for the 'neutral' atmosphere.

(ii) Downwind concentration of air pollutants due to an elevated point source will be inversely proportional to the wind speed.

(iii) Value of the wind profile exponent for the 'neutral' atmosphere is smaller than the wind profile exponent for the 'very unstable' atmosphere.

(iv) Downwind concentration of air pollutants due to an elevated point source will be directly proportional to the wind speed.

Select the correct option.

(a) (i) is False and (iii) is True

(b) (ii) is False and (iii) is False

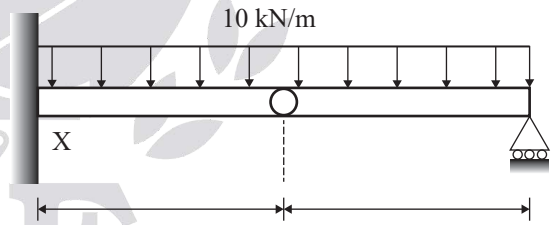
(c) (i) is True and (iv) is True

(d) (iii) is False and (iv) is False

30. Ans: (d)

Sol: Concentration $\alpha \frac{1}{\text{wind speed}}$

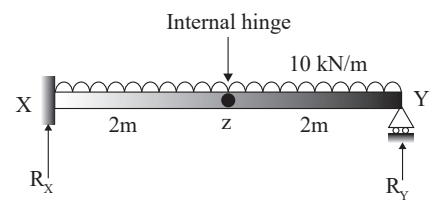
31. A propped cantilever beam XY, with an internal hinge at the middle, is carrying a uniformly distributed load of 10 kN/m, as shown in the figure.



The vertical reaction at support X (in kN, in integer) is _____

31. Ans: 30

Sol:



$\Sigma V = 0$

$R_x + R_y = 10 \times 4$

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Bending moment at the internal hinge is zero

$BM_z = 0$ ↳–ve +↲ve [Right side]

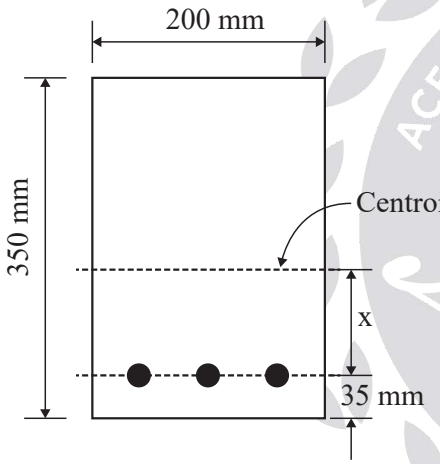
$-R_y \times 2 + 10 \times 2 \times \frac{2}{2} = 0$

$R_y = 10$ kN (↑)

$R_x = 40 - 10$

$R_x = 30$ kN (↑)

32. A rectangular cross-section of a reinforced concrete beam is shown in the figure. The diameter of each reinforcing bar is 16 mm. The values of modulus of elasticity of concrete and steel are 2.0×10^4 MPa and 2.1×10^5 MPa, respectively.

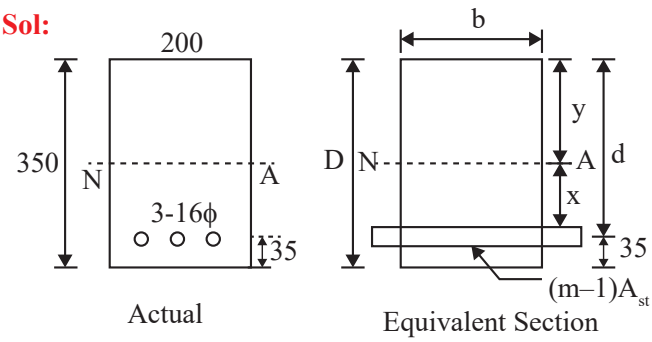


The distance of the centroidal axis from the centerline of the reinforcement (x) for the uncracked section (in mm, round off to one decimal place) is

_____

32. 129.4

Sol:



$M = \frac{E_s}{E_c} = 10.5$

Centroid of an equivalent section

$\bar{y} = \frac{A_1y_1 + A_2y_2}{A_1 + A_2}$

$$= \frac{200 \times 350 \times \frac{350}{2} + (10.5-1) \times 3 \times \frac{\pi}{4} \times 16^2 \times 315}{200 \times 350 + (10.5-1) \times 3 \times \frac{\pi}{4} \times 16^2}$$

= 185.6 mm

X = d – y = 315 – 185.6 = 129.4 mm

33. If k is a constant, the general solution of $\frac{dy}{dx} - \frac{y}{x} = 1$ will be in the form of

(a) y = xk ln (k) (b) y = x ln (x)

(c) y = x ln (kx) (d) y = k ln (kx)

33. Ans: (c)

Sol: The given D.E is in the form of $\frac{dy}{dx} + py = Q$

Integrating factor = $e^{\int pdx} = e^{-\int \frac{1}{x}dx}$

$= e^{-\log x} = \frac{1}{x}$

Solution to the D.E is given by $y.\frac{1}{x} = \int \frac{1}{x}dx + e$

$y.\frac{1}{x} = \log x + \log k \Rightarrow y = x \log kx$

34. The stopping sight distance (SSD) for a level highway is 140 m for the design speed of 90 km/h. The acceleration due to gravity and deceleration rate are 9.81 m/s² and 3.5 m/s², respectively. The perception / reaction time (in s, round off to two decimal places) used in the SSD calculation is

_____

34. Ans: 2.03

Sol: Given: SSD = 140 m

Level highway

V = 90 kmph = 25 m/s

g = 9.81 m/s²

a = 3.5 m/s² = f.g

t = ?

$$SSD = vt + \frac{v^2}{2gf}$$

$$140 = vt + \frac{v^2}{2g\left(\frac{a}{g}\right)}$$

$$140 = 25 \times t + \frac{25^2}{(2 \times 3.5)}$$

$$140 = 25 \times t + 89.29$$

$$t = 2.028 \simeq 2.03 \text{ sec}$$

35. A reservoir with a live storage of 300 million cubic metre irrigates 40000 hectares (1 hectare = 10^4 m^2) of a crop with two fillings of the reservoir. If the base period of the crop is 120 days, the duty for this crop (in hectares per cumec, round off to integer) will then be _____

35. Ans: 691

Sol: With two fillings of reservoir

Volume, $V = 2 \times 300 = 600$ million m^3

$= 6 \times 10^8$ m^3

Area irrigated A = 40,000 ha

$$\Delta = 8.64 \frac{B}{D}$$

$$\frac{V}{A} = 8.64 \frac{B}{D}$$

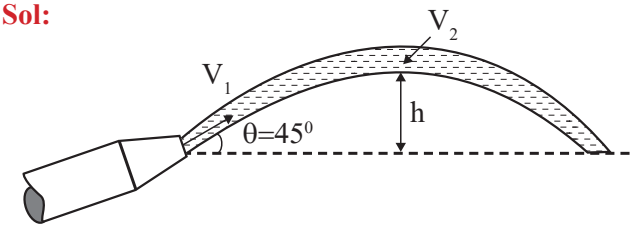
$$\frac{6 \times 10^8}{4 \times 10^8} = \frac{8.64 \times 120}{D}$$

$\Rightarrow D = 691.2$ ha/cumec $= 691$ ha/cumec

36. A fire hose nozzle directs a steady stream of water of velocity 50 m/s at an angle of 45° above the horizontal. The stream rises initially but then eventually falls to the ground. Assume water as incompressible and inviscid. Consider the density of air and the air friction as negligible, and assume the acceleration due to gravity as 9.81 m/s^2 . The maximum height (in m, round off to two decimal places) reached by the stream above the hose nozzle will then be _____

36. Ans: 63.71

Sol:



The water jet performs projectile motion in which horizontal component of velocity remains constant. At point (2) only horizontal component is present which is given by

$V_2 = V_1 \cos\theta = 50 \cos(45) = 35.36$ m/s²

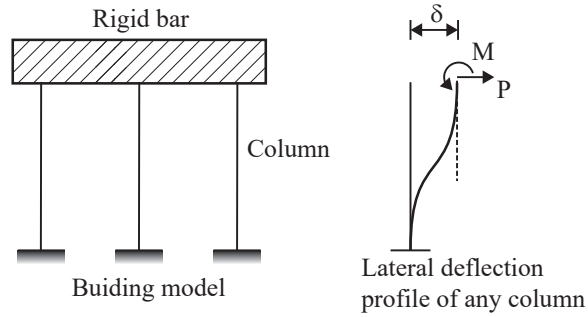
Applying Bernoulli's equation between (1) & (2)

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + h_f$$

$$\frac{V_1^2}{2g} = \frac{V_2^2}{2g} + h$$

$$h = \frac{V_1^2 - V_2^2}{2g} = \frac{50^2 - 35.36^2}{2 \times 9.81} = 63.71 \text{ m}$$

37. A single story building model is shown in the figure. The rigid bar of mass 'm' is supported by three massless elastic columns whose ends are fixed against rotation. For each of the columns, the applied lateral forces (P) and corresponding moment (M) are also shown in the figure. The lateral deflection (δ) of the bar is given by $\delta = \frac{PL^3}{12EI}$, where L is the effective length of the column, E is the Young's modulus of elasticity and I is the area moment of inertia of the column cross-section with respect to its neutral axis.



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For the lateral deflection profile of the columns as shown in the figure, the natural frequency of the system for horizontal oscillation is

(a) $6\sqrt{\frac{EI}{mL^3}}$ rad/s (b) $\frac{2}{L}\sqrt{\frac{EI}{m}}$ rad/s

(c) $\frac{1}{L}\sqrt{\frac{2EI}{m}}$ rad/s (d) $2\sqrt{\frac{6EI}{mL^3}}$ rad/s

37. Ans: (a)

Sol:

1. $\delta = \frac{PL^3}{12EI}$

$\therefore$ Stiffness of bar, $K = \frac{P}{\delta} = \frac{12EI}{L^3}$

2. Equivalent stiffness k_e,
The bars are in parallel arrangement

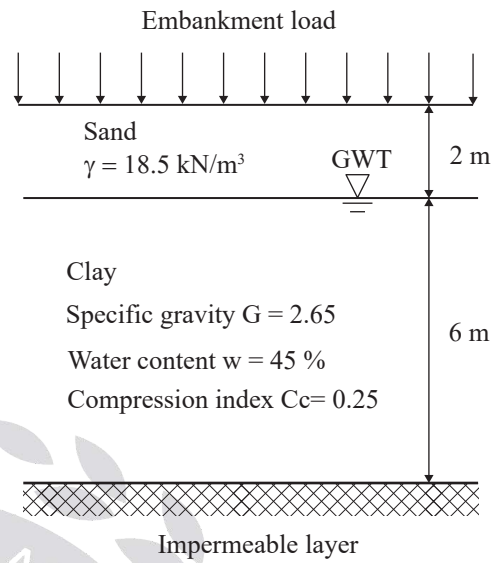
$\therefore k_e = k + k + k = \frac{36EI}{L^3}$

3. Natural Frequency ω_n,

$\omega_n = \sqrt{\frac{k_e}{m}}$ rad/sec

$= \sqrt{\frac{36EI}{mL^3}} = 6\sqrt{\frac{EI}{mL^3}}$ rad/sec

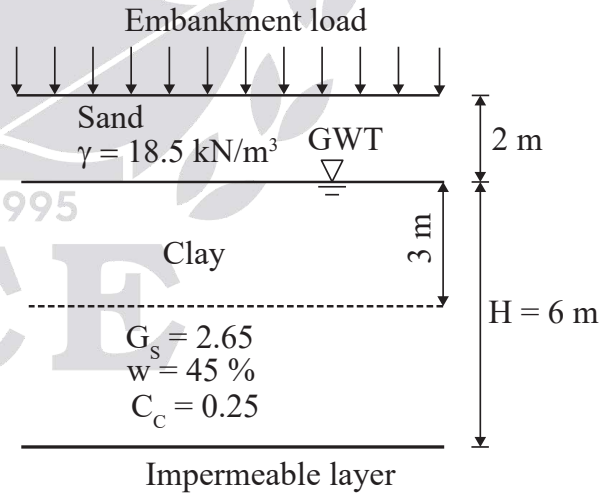
38. The soil profile at a road construction site is as shown in figure (not to scale). A large embankment is to be constructed at the site. The ground water table (GWT) is located at the surface of the clay layer, and the capillary rise in the sandy soil is negligible. The effective stress at the middle of the clay layer after the application of the embankment loading is 180 kN/m^2. Take unit weight of water, γ_w = 9.81 kN/m^3



The primary consolidation settlement (in m, round off to two decimal places) of the clay layer resulting from this loading will be _____

38. Ans: 0.33

Sol:



$\therefore$ For clay layer $e_o S_r = wG_s$

$e_o \times 1 = 0.45 \times 2.65$

$e_o = 1.1925$

$\gamma_{sat} = \left(\frac{G_s + e}{1 + e}\right)\gamma_w = \left(\frac{2.65 + 1.1925}{1 + 1.1925}\right) \times 9.81$

$= 17.193$ kN/m^3

At centre of clay layer:

Initial overburden pressure

$\sigma_o^1 = \gamma_{sand} \times 2 + \gamma_{clay}^1 \times 3$

$\sigma_o^1 = 18.5 \times 2 + (17.193 - 9.81) \times 3 = 59.148\ kN/m^2$

After application of embankment loads,

$\sigma_f^1 = 180\ kN/m^2$

$$S_f = \frac{C_c}{1+e_o} \times H \times \log_{10}\left(\frac{\sigma_f^1}{\sigma_o^1}\right) = \frac{0.25}{1+1.1925} \times 6 \times \log_{10}\left(\frac{180}{59.148}\right)$$

$\therefore S_f = 0.3307$ m

Say 0.33 m

39. Determine the correctness or otherwise of the following Assertion [a] and the Reason [r].

Assertion [a]: One of the best ways to reduce the amount of solid wastes is to reduce the consumption of raw materials.

Reason [r]: Solid wastes are seldom generated when raw materials are converted to goods for consumption.

(a) Both [a] and [r] are true and [r] is the correct reason for [a]

(b) [a] is true but [r] is false

(c) Both [a] and [r] are true [r] is not the correct reason for [a]

(d) Both [a] and [r] are false

39. Ans: (c)

Sol: Solid waste generated by the use of raw material, processing and finished goods.

40. The internal (d_i) and external (d_o) diameters of a Shelby sampler are 48 mm and 52 mm, respectively. The area ratio (A_r) of the sampler (in % round off to two decimal places) is _____

40. Ans: 17.36

Sol: $d_i = 48$ mm

$d_o = 52$ mm

$$A_r = \frac{d_o^2 - d_i^2}{d_i^2} \times 100 = \frac{52^2 - 48^2}{48^2} \times 100 = 17.36\%$$

41. If A is a square matrix then orthogonality property mandates

(a) $AA^T = A^{-1}$ (b) $AA^T = A^2$

(c) $AA^T = 0$ (d) $AA^T = I$

41. Ans: (d)

Sol: Condition for Orthogonal matrix is $AA^T = A^TA = I$ (or) $A^T = A^{-1}$

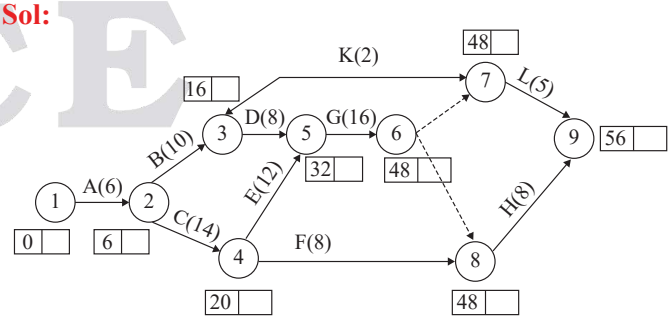
42. The activity details for a small project are given in the Table.

Activity	Duration (days)	Depends on
A	6	-
B	10	A
C	14	A
D	8	B
E	12	C
F	8	C
G	16	D,E
H	8	F, G
K	2	B
L	5	G, K

The total time (in days, in integer) for project completion is _____

42. 56

Sol:



The total time required to complete the project = 56 days

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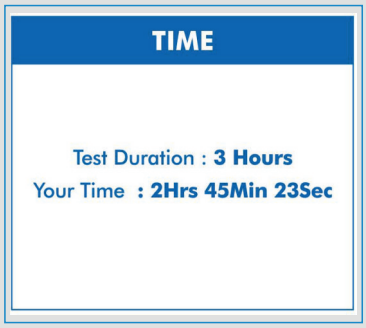

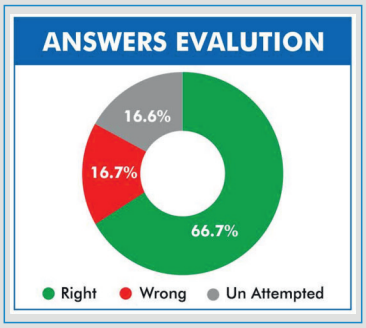

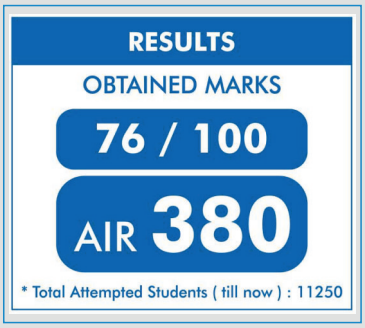

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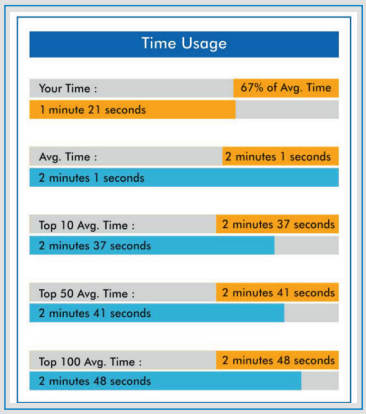

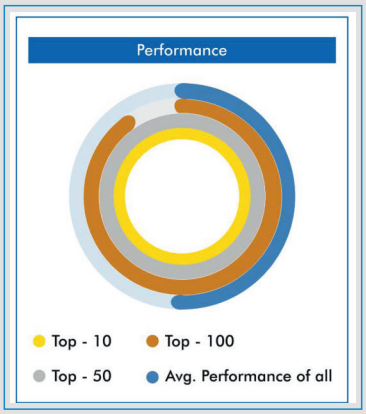

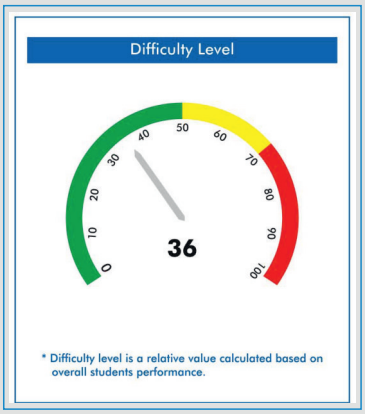

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43. Numerically integrate, $f(x) = 10x - 20x^2$ from lower limit a = 0 to upper limit b = 0.5. Use Trapezoidal rule with five equal subdivisions. The value (in units, round off to decimal places) obtained is _____.

43. Ans: 0.4

Sol: $f(x) = 10x - 20x^2 = y$

Step size $= \frac{b-a}{n} = \frac{0.5}{5} = 0.1$

x	0	0.1	0.2	0.3	0.4	0.5
y	0	0.8	1.2	1.2	0.8	0

Required answer $= \frac{h}{2}[(y_o + y_5) + 2(y_1 + y_2 + y_3 + y_4)]$

$= \frac{0.1}{2}[0 + 2(0.8 + 1.2 + 1.2 + 0.8)]$

$= 0.4$

44. The value (round off to one decimal place) of $\int_{-1}^{1} xe^{|x|}dx$ is_____.

44. Ans: 0

Sol: $xe^{|x|}$ is an odd function $\Rightarrow f(-x) = -f(x)$

$\Rightarrow \int_{-1}^{1} xe^{|x|}dx = 0$

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

(a) Volatile organic compounds act as one of the precursors to the formation of photochemical smog in the presence of sunlight.

(b) Increased levels of volatile organic compounds in the indoor environment will result in the formation of photochemical smog which is a cause of cardiovascular diseases.

(c) Long term exposure to the increased level of photochemical smog becomes a cause of chest constriction and irritation of the mucous membrane.

(d) Increased levels of carbon monoxide in the indoor environment result in the formation of carboxyhemoglobin and the long term exposure becomes a cause of cardiovascular diseases.

45. Ans: (a, c and d)

Sol: Indoor environment photochemical smog does not form.

46. The softening point of bitumen has the same unit as that of

(a) temperature (b) time

(c) viscosity (d) distance

46. Ans: (a)

Sol: Softening point is the temperature at which bitumen becomes soft and starts flowing.

47. A clay layer of thickness H has a pre-consolidation pressure p_c and an initial void ratio e_o. The initial effective overburden stress at the mid-height of the layer is P_o. At the same location, the increment in effective stress due to applied external load is Δp. The compression and swelling indices of the clay are C_c and C_s, respectively. If $P_o < P_c < (P_o + \Delta p)$, then the correct expression to estimate the consolidation settlement (S_c) of the clay layer is

(a) $S_c = \frac{H}{1+e_o}\left[C_s \log\frac{p_o}{p_c} + C_c \log\frac{p_o+\Delta p}{p_c}\right]$

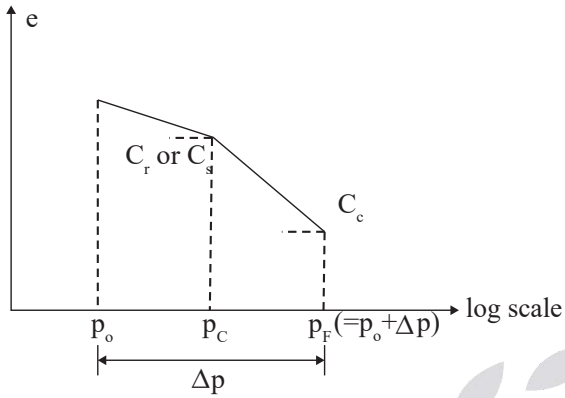
(b) $S_c = \frac{H}{1+e_o}\left[C_o \log\frac{p_c}{p_o} + C_s \log\frac{p_o+\Delta p}{p_c}\right]$

(c) $S_c = \frac{H}{1+e_o}\left[C_c \log\frac{p_o}{p_c} + C_s \log\frac{p_o+\Delta p}{p_c}\right]$

(d) $S_c = \frac{H}{1+e_o}\left[C_s \log\frac{p_c}{p_o} + C_c \log\frac{p_o+\Delta p}{p_c}\right]$

47. Ans: (d)

Sol:

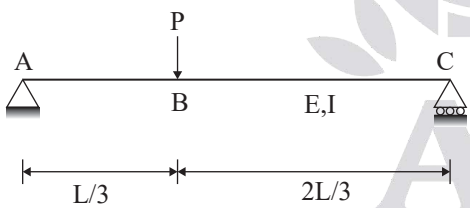


As the soil is initially in over consolidate state ($p_o < p_c$), due to the external applied load (Δp), the soil initially undergoes re-compression upto p_c and then changes to virgin compression from p_c to p_f.

The re-compression index (C_r) is also called Swelling index, (C_S).

$$S_c = \frac{H_o}{1+e_o}\left[C_s \log \frac{p_c}{p_o} + C_c \log\left(\frac{p_o+\Delta p}{p_c}\right)\right]$$

48. A prismatic steel beam is shown in the figure



The plastic moment, M_p calculated for the collapse mechanism using static method and kinematic method is

(a) $M_{p,static} > \frac{2PL}{9} = M_{p,kinematic}$

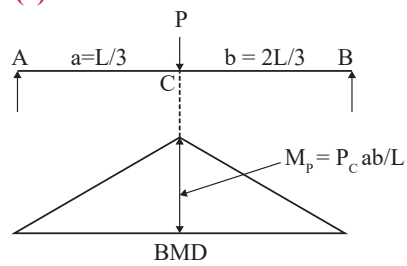
(b) $M_{p,static} < \frac{2PL}{9} = M_{p,kinematic}$

(c) $M_{p,static} = \frac{2PL}{9} = M_{p,kinematic}$

(d) $M_{p,static} = \frac{2PL}{9} \neq M_{p,kinematic}$

48. Ans: (c)

Sol:



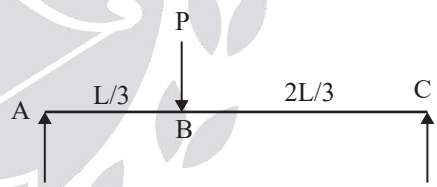
Static Method:

The maximum bending moment of $\frac{Pab}{L}$ evidently occurs under the load, when the load is increased to the collapse load w_c, the maximum bending moment will be equal to $\frac{P_c ab}{L}$. This should evidently be equal to the plastic moment of resistance M_P.

$$\therefore \frac{P_c ab}{L} = M_P$$

$$M_P = P_c \times \frac{L}{3} \times \frac{2L}{3} \times \frac{1}{L}$$

$$M_P = \frac{2P_c L^2}{9L} = \frac{2P_c L}{9}$$

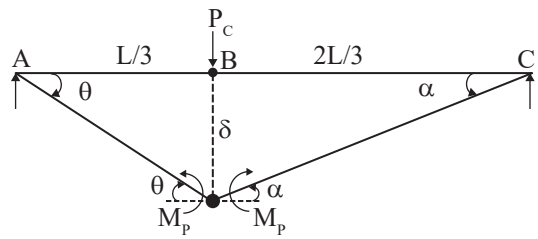


Kinematic Method:

Static indeterminacy (D_s) = 0

Number of possible plastic hinges (N) = 1 [at B]

No. of plastic hinges required to form a mechanism (n) = $D_s + 1 = 1$



$$\delta = \delta$$

$$\frac{L}{3}\theta = \frac{2L}{3}\alpha$$

$$\alpha = \frac{\theta}{2}$$

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External work done $(W_e) = P_c \times \delta$

$= P_c \times \frac{L}{3}\theta$

Internal work done $(W_i) = M_p\theta + M_p\,\alpha$

$= M_P\theta + M_P\left(\frac{\theta}{2}\right)$

$= 1.5\, M_p\theta$

$W_e = W_i$

$P_c \times \frac{L}{3}\theta = 1.5M_P\theta$

$M_P = \frac{P_cL}{4.5} = \frac{2P_cL}{9}$

$M_{p,static} = \frac{2P_cL}{9} = M_{P,kinematic}$

49. Strain hardening of structural steel means
(a) decrease in the stress experienced with increasing strain
(b) experiencing higher stress than yield stress with increased deformation
(c) strengthening steel member externally for reducing strain experienced
(d) strain occurring before plastic flow of steel material

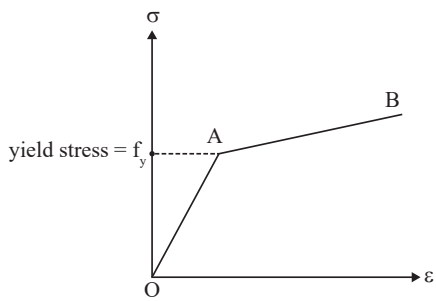
49. Ans: (b)

Sol: Strain hardening is experiencing higher stress than yield stress with increased deformation

In the figure AB = Strain hardening zone

OA = Linear elastic zone

Stress corresponding to point 'A' is yield stress.



50. The void ratio of a clay soil sample M decreased from 0.575 to 0.510 when the applied pressure is increased from 120 kPa to 180 kPa. For the same increment in pressure, the void ratio of another clay soil sample N decreases from 0.600 to 0.550. If the ratio of hydraulic conductivity of sample M to sample N is 0.125, then the ratio of coefficient of consolidation of sample M to sample N (round off to three decimal places) is _____

50. Ans: 0.095

Sol: Sample M

$e_o = 0.575$

$e_f = 0.510$

$\Delta\sigma' = 180 - 120 = 60$ kPa

$m_{v_1} = \frac{\Delta e}{1 + e_o} \times \frac{1}{\Delta\sigma'}$

$= \frac{0.575 - 0.51}{1 + 0.575} \times \frac{1}{60}$

$\therefore m_{v_1} = 6.878 \times 10^{-4}\ m^2/kN$

Sample N

$e_o = 0.560$

$e_f = 0.55$

$\Delta\sigma' = 60$ kPa

$m_{v_2} = \frac{\Delta e}{1 + e_o} \times \frac{1}{\Delta\sigma'}$

$= \frac{0.6 - 0.55}{1 + 0.60} \times \frac{1}{60}$

$\therefore m_{v_2} = 5.208 \times 10^{-4}\ m^2/kN$

Given: $\frac{K_1}{K_2} = 0.125$ $\therefore C_v = \frac{K}{m_v\gamma_w}$

$\frac{C_{v_1}}{C_{v_2}} = \frac{K_1}{K_2} \times \frac{m_{v_2}}{m_{v_1}}$

$= 0.125 \times \frac{5.20 \times 10^{-4}}{6.878 \times 10^{-4}}$

$\therefore \frac{C_{v_1}}{C_{v_2}} = 0.0946 \simeq 0.095$

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Total Selections in Top 10 **58**

EE : 9	EC : 9	ME:7	CE : 7	CS : 7	IN : 6	PI : 9	XE : 4

51. The value of $\lim_{x\to\infty}\frac{x\ln(x)}{1+x^2}$ is

(a) ∞ (b) 0.5

(c) 0 (d) 1.0

51. Ans: (c)

Sol:

$\lim_{x\to\infty}\frac{x\ln(x)}{1+x^2}=\frac{\infty}{\infty}$ →Indeterminate form

Using L'Hospital rule, we get

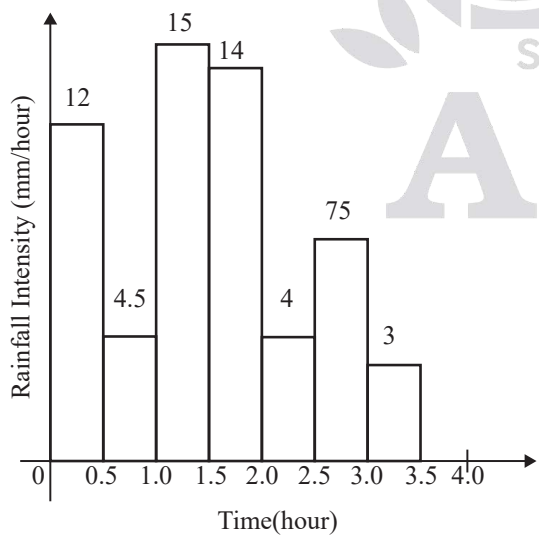
$\lim_{x\to\infty}\frac{x.\frac{1}{x}+\ln(x)}{2x}=\lim_{x\to\infty}\frac{1+\ln x}{2x}=\frac{\infty}{\infty}$

Apply L'Hospital rule again, we get

$\lim_{x\to\infty}\frac{1/x}{2}=0$

$\therefore \lim_{x\to\infty}\frac{x\ln(x)}{1+x^2}=0$

52. The hyetograph in the figure corresponds to a rainfall event of 3 cm.



If the rainfall event has produced a direct runoff of 1.6 cm, the ϕ-index of the event (in mm/hour, round off to one decimal place) would be _____

52. Ans: 4.2

Sol: Given Data: P = 3 cm, t = 3.5 hours

R = 1.6 cm = 16 mm

t(Hrs)	0-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5
i, mm/hr	12	4.5	15	14	4	7.5	3
P,mm	6	2.25	7.5	7	2	3.75	1.5

To Find ϕ-Index:

Trial 1: Assume t_e = 3.5 hrs

P_e = 6 + 2.25 + 7.5 + 7 + 2+3.75+1.5 = 30 mm

ϕ_1-Index = $\frac{P_e-R}{t_e}=\frac{30-16}{3.5}$ = 4 mm/hr

Eliminate intensities 4 mm/hr & 3 mm/hr which doesn't produces runoff

Trial-2: Assume t_e = 2.5 hrs

P_e = 30 – [2+1.5] = 26.5 mm

ϕ_2-Index= $\frac{P_e-R}{t_e}=\frac{26.5-16}{2.5}$ =4.2 mm/hr

53. In general, the CORRECT sequence of surveying operations is

(a) Reconnaissance → Field observations → Data analysis → Map making

(b) Reconnaissance → Data analysis → Field observations → Map making

(c) Data analysis → Reconnaissance → Field observations → Map making

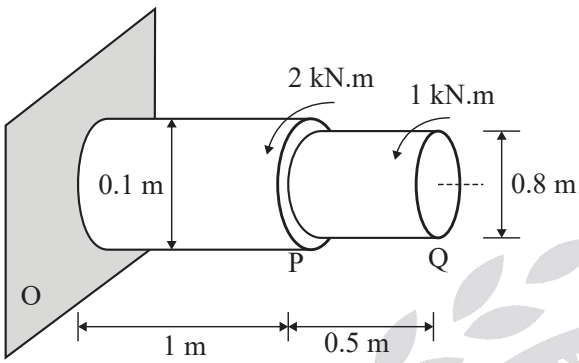
(d) Field observations → Reconnaissance → Data analysis → Map making

53. Ans: (a)

Sol: Reconnaissance → Site visit

Field observation → Preliminary/Detailed Survey

54. A solid circular torsional member OPQ is subjected to torsional moments as shown in the figure (not to scale). The yield shear strength of the constituent material is 160 MPa.



The absolute maximum shear stress in the member (in MPa, round off to one decimal place) is _____

54. Ans:15.3

Sol: FBD of PQ:

$T = 1$ kN-m

$$\tau_{max} = \frac{16T}{\pi d^3} = \frac{16(1\times10^6)}{\pi(80)^3}$$

$\tau_{max} = 9.9$ MPa $\rightarrow$ (1) (< 160/2 = 80 MPa)

FBD of OP:

$T = 2 + 1 = 3$ kN-m

$$\tau_{max} = \frac{16T}{\pi d^3} = \frac{16(3\times10^6)}{\pi(100^3)}$$

$\tau_{max} = 15.27$ MPa $\rightarrow$ (2) (< 160/2 = 80 MPa)

$\therefore$ Absolute max shear stress = 15.27 MPa

$\simeq$ 15.3 MPa

55. A grit chamber of rectangular cross-section is to be designed to remove particles with diameter of 0.25 mm and specific gravity of 2.70. The terminal settling velocity of the particles is estimated as 2.5 cm/s. The chamber is having a width of 0.50 m and has to carry a peak wastewater flow of 9720 m^3/d giving the depth of flow as 0.75 m. If a flow-through velocity of 0.3 m/'s has to be maintained using a proportional weir at the outlet end of the chamber, the minimum length of the chamber (in m, in integer) to remove 0.25 mm particles completely_____

55. Ans: 9

Sol: $d = 0.25$ mm $S = 2.7$ $V_s = 2.5$ cm/sec

$B = 0.5$ m $Q = 9720\ m^3$/day

$H = 0.75$ m $v_H = 0.3$ m/sec $L = ?$

100% removal

For 100% removal

$$\frac{H}{v_s} \le \frac{L}{v_H} \Rightarrow \frac{H}{v_s} = \frac{L}{v_H}$$

$$\frac{0.75}{2.5\times10^{-2}} = \frac{L}{0.3}$$

$\Rightarrow L = 9$ m

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