GATE – 2021

CIVIL ENGINEERING Set 2

GENERAL APTITUDE

Q. 1 – Q. 5 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: -1/3).

1. (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) (i) & (ii)

(b) (i) & (iv)

(c) (ii) & (iv)

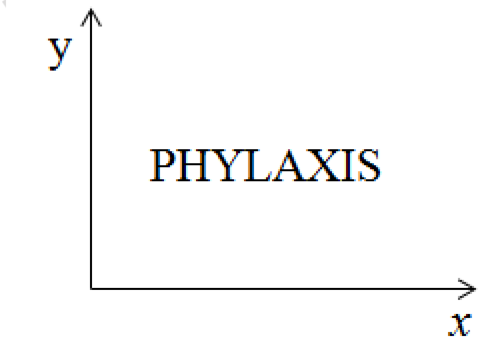
(d) (iii) & (iv)

Ans. b

Exp:

Two subjects joined with ‘and’ become plural and hence plural verb is there in first statement. In fourth sentence the subject is family which is singular and takes singular verb.

2. The mirror image of the text about the *x*-axis is



(a) 

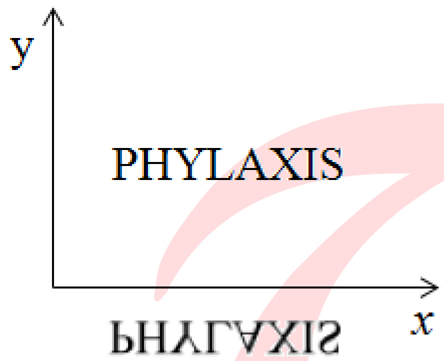
(b) 

(c) 

(d) 

Ans. b

Exp:



3. 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 is:

(a) $\frac{1}{36}$

(b) $\frac{1}{12}$

(c) $\frac{1}{8}$

(d) $\frac{1}{4}$

Ans. d

Exp:

Probability of getting even number on a dice = $\frac{3}{6} = \frac{1}{2}$

$\because$ Two dice are rolled simultaneously, Hence, required probability = $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$

4. ⊕ and ⊙ are two operators on numbers p and q such that

p ⊙ q = p – q, and p ⊕ q = p × q

then, (9 ⊙ (6 ⊕ 7)) ⊙ ((7 ⊕ (6 ⊙ 5)) =

(a) 40

(b) –26

(c) –33

(d) –40

Ans. d

Exp:

[9 – (6 × 7)] – [7 × 1] = –33 – 7 = –40

5. Four persons P, Q, R and S are to be seated in a cow. 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) 6

(b) 9

(c) 18

(d) 24

Ans. c

Exp:

Number of arrangements = 3 × 3! = 18

Q. 6 – Q. 10 Multiple Choice Question (MCQ), carry two mark each (for each wrong answer: -2/3).

6. 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 18 units North of point P. The distance of point Q to point O, in the same units, should be ________.

(a) 3

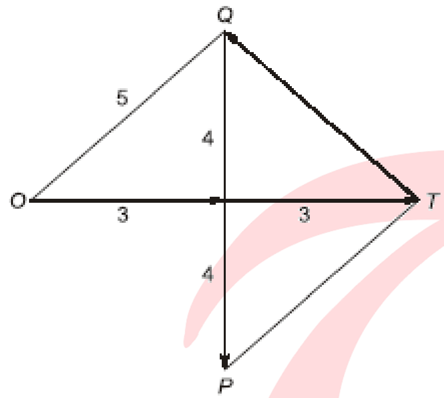
(b) 4

(c) 5

(d) 6

Ans. c

Exp:



OQ = $\sqrt{3^2 + 4^2} = 5\,\text{units}$

7. The author said, "Musicians rehearse before their concerts, "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 spears to rehearse their talks."

Based on the above passage, which one of the following is TRUE?

(a) The author is of the opinion that rehearsing is important for musicians, actors and public speakers.

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

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

(d) The author is of the opinion that rehearsal is more important for actors than musicians.

Ans. a

Exp:

The last sentence of the passage decides the answer with the key words "No Less Important".

8. 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 & 2 above, is:

(a) No football player plays hockey.

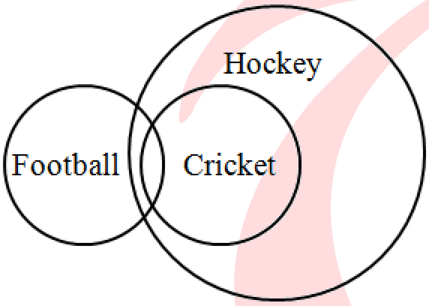
(b) Some football players play hockey.

(c) All football players play hockey.

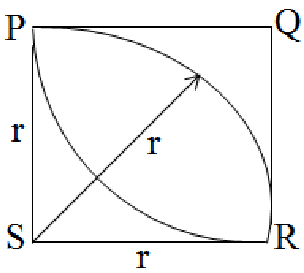
(d) All hockey players play football.

Ans. b

Exp:



9. In the figure shown below, 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) $4-\frac{\pi}{2}$

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

(c) $\frac{\pi}{2}-1$

(d) $\frac{\pi}{4}$

Ans. c

Exp:

Probability = $\frac{fA}{TA}$

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

$$\frac{fA}{TA} = \frac{\left(\frac{\pi r^2}{4} - \frac{r^2}{2}\right) \times 2}{r^2} = \left(\frac{\pi}{2} - 1\right)$$

10. 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^2, is

(a) 18

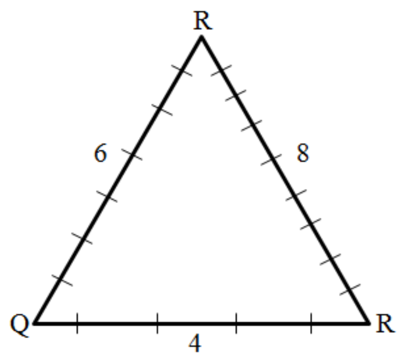
(b) 24

(c) 48 $\sqrt{3}$

(d) 144 $\sqrt{3}$

Ans. d

Exp:



For $\left(\frac{a}{4}, \frac{a}{6}, \frac{a}{8}\right)$ to be integer, a must be LCM of 4, 6 and 8. So a = 24

Area = $\frac{\sqrt{3}}{4}a^2 = \frac{\sqrt{3}}{4} \times 24^2 = 144\sqrt{3}$

CIVIL ENGINERING (TECHNICAL)

Q. 1 – Q. 16 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: –1/3).

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

(a) 0

(b) 1.0

(c) 0.5

(d) ∞

Ans. a

Exp:

$$\lim_{x\to\infty} \frac{x\ln(x)}{1+x^2} \qquad \left(\frac{\infty}{\infty}\text{ form}\right)$$

$$= \lim_{x\to\infty}\left(\frac{x\left(\frac{1}{x}\right)+\ln x}{2x}\right) \qquad \left(\frac{\infty}{\infty}\text{ form}\right)$$

$$= \lim_{x\to\infty}\left(\frac{0+\frac{1}{x}}{2}\right) = \lim_{x\to\infty}\left(\frac{1}{2x}\right) = \frac{1}{2\times\infty} = 0$$

2. 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) 1

(b) 2

(c) 3

(d) 4

Ans. c

Exp:

$$\begin{bmatrix} 5 & 0 & 1 & 0 \\ 0 & 2 & 0 & 1 \\ -5 & 0 & -1 & 0 \\ 0 & 1 & 0 & 2 \end{bmatrix} \xrightarrow{R_3 \longleftrightarrow R_1 + R_3} \begin{bmatrix} 5 & 0 & 1 & 0 \\ 0 & 2 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 2 \end{bmatrix}$$

Number of non zero rows = 3. Hence, rank of matrix = 3.

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

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

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

(c) $\frac{2}{\sqrt{2}}, \frac{2}{\sqrt{2}}, \frac{2}{\sqrt{2}}$

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

Ans. b

Exp:

$$\phi = x^2 + y^2 + z^2 - 48, \ P(4,4,4)$$

grad ϕ = $\vec{\nabla}\phi = \hat{i}\frac{\partial \phi}{\partial x} + \hat{j}\frac{\partial \phi}{\partial y} + \hat{k}\frac{\partial \phi}{\partial z}$

= $(2x)\hat{i} + (2y)\hat{j} + (2z)\hat{k}$

$$\vec{n} = (\text{grad}\,\phi)_P = 8\hat{i} + 8\hat{j} + 8\hat{k}$$

$$\hat{n} = \frac{\vec{n}}{|\vec{n}|} = \frac{8\hat{i} + 8\hat{j} + 8\hat{k}}{\sqrt{64+64+64}} = \frac{\hat{i} + \hat{j} + \hat{k}}{\sqrt{3}}$$

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

(a) $AA^T = I$

(b) $AA^T = 0$

(c) $AA^T = A^{-1}$

(d) $AA^T = A^2$

Ans. a

Exp:

If, $AA^T = I$ or $A^{-1} = A^T$

The matrix is orthogonal.

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

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

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

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

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

Ans. c

Exp:

6. Strain hardening of structural steel means

(a) experiencing higher stress than yield stress with increased deformation

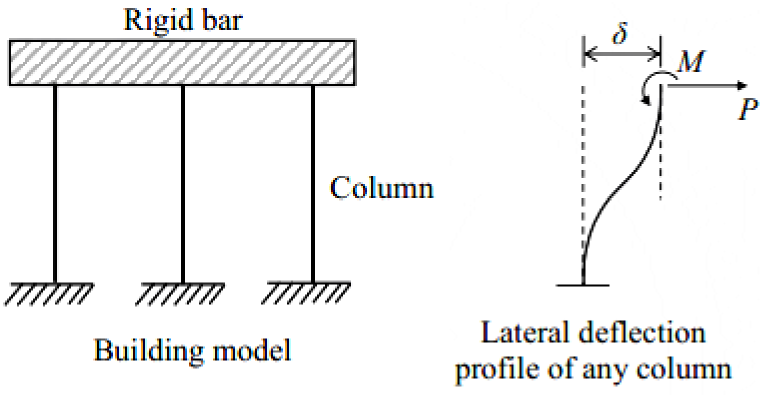
(b) strengthening steel member externally for reducing strain experienced

(c) strain occurring before plastic flow of steel material

(d) decrease in the stress experienced with increasing strain

Ans. a

7. 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 force (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.



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

(a) $6\sqrt{\dfrac{EI}{mL^3}}$ rad/s

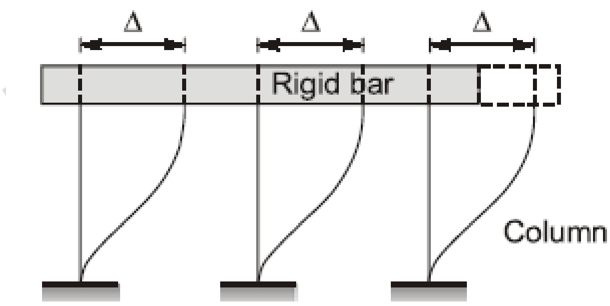
(b) $\dfrac{1}{L}\sqrt{\dfrac{2EI}{m}}$ rad/s

(c) $2\sqrt{\dfrac{6EI}{mL^3}}$ rad/s

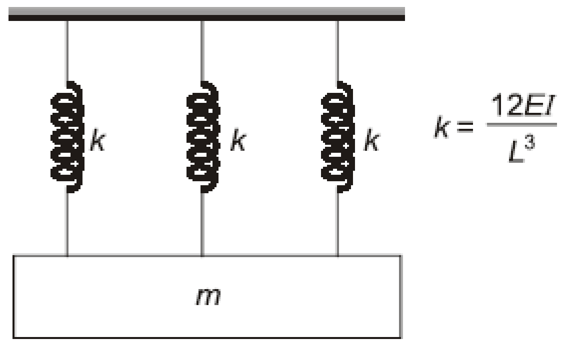
(d) $\dfrac{2}{L}\sqrt{\dfrac{EI}{m}}$ rad/s

Ans. a

Exp:



As the deflection will be same in all the 3 columns, so it represents a parallel connection.



$k_{eq} = 3k = \frac{36EI}{L^3}$

Natural frequency (ω) = $\sqrt{\frac{k}{m}} = \sqrt{\frac{36EI}{mL^3}} = 6\sqrt{\frac{EI}{mL^3}}$ rad/s

8. Seasoning of timber for use in construction is done essentially to

(a) increase strength and durability

(b) smoothen timber surfaces

(c) remove knots from timber logs

(d) cut timber in right season and geometry

Ans. a

Exp:

9. In case of bids in Two-Envelop System, the correct option is

(a) Technical bid is opened first

(b) Financial bid is opened first

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

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

Ans. a

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

(a) consolidated drained test

(b) unconsolidated undrained test

(c) consolidated undrained test

(d) unconfined compression test

Ans. a

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

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

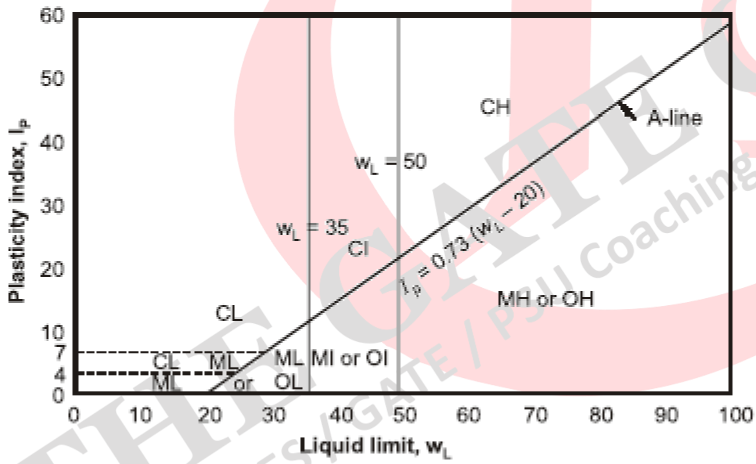
(b) Inorganic silts of low plasticity with liquid limit less than 50%

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

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

Ans. a

Exp:



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

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

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

(c) 1

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

Ans. b

Exp:

For laminar flow through pipe,

$$\frac{Momentum\,correction\ factor}{Kinetic\,energy\,correction\ factor} = \frac{4/3}{2} = \frac{2}{3}$$

13. 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) 0

(b) $\frac{v_f}{4}$

(c) $\frac{v_f}{2}$

(d) v_f

Ans. c

Exp:

Speed at maximum flow = $\frac{v_f}{2}$

14. 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) Both [a] and [r] are true but [r] is not the correct reason for [a]

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

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

Ans. d

Exp:

15. 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) Blue-green to reddish brown

(b) Blue to colourless

(c) Reddish brown to pinkish yellow

(d) wine red to blue

Ans. d

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

(a) distance

(b) temperature

(c) time

(d) viscosity

Ans. b

Q. 17 Multiple Select Question (MSQ), carry ONE mark (no negative marks).

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

(a) 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.

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

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

Ans. a, b, c

Q.18 – Q.25 Numerical Answer Type (NAT), carry ONE mark each (no negative marks)

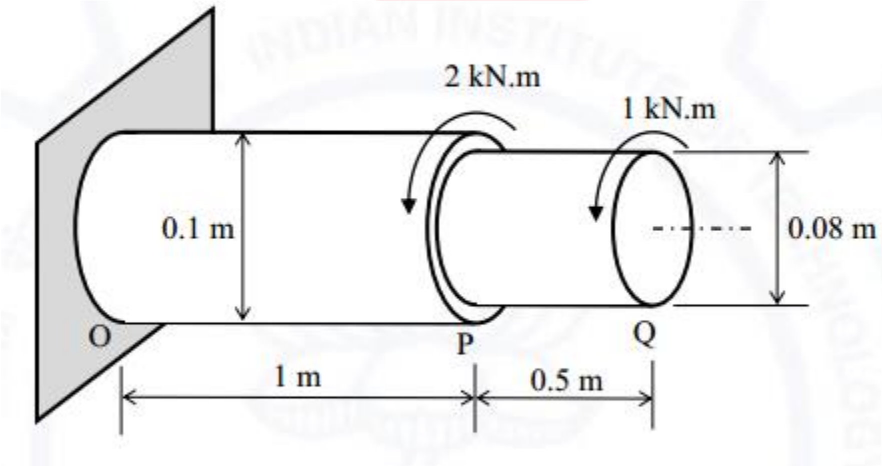
18. The value (round off to one decimal place) of $\int_{-1}^{1} xe^{|x|}dx$ is ________.

Ans. 0.0 – 0.0

Exp:

Odd function.

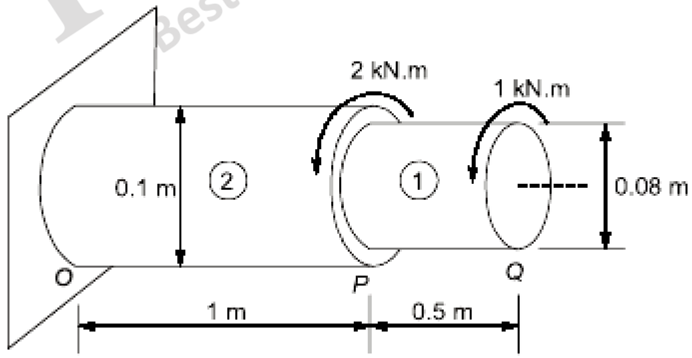
19. A solid circular torsional member OPQ is subjected to torsional moment as shown in the figure (not to scale). The yield shear strength of the constituent material is 160 MPa.



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

Ans. 14.0 – 16.0

Exp:



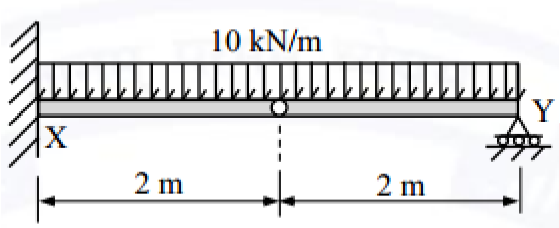
$$\tau_{\max OP} = \frac{16T_{OP}}{\pi d_{OP}^3} = \frac{16\times 3\times 10^3}{\pi \times 100^3} = 15.27\ \text{N/mm}^2$$

$$\tau_{\max PQ} = \frac{16T_{PQ}}{\pi d_{PQ}^3} = \frac{16\times1\times10^6}{\pi\times80^3} = 9.94\ \text{N/mm}^2$$

τ_{max} = 9.94 N/mm^2

Absolute max shear stress = 15.27 ≃ 15.3 N/mm^2

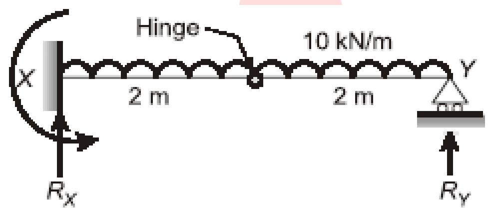
20. A propped cantilever beam XY, with an internal hinge at the middle, is carrying a uniformly distributed load of 10 kN/m, as shown in the figure.



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

Ans. 30

Exp:



BM = 0 at hinge

$R_Y \times 2 - 10 \times 2 \times 1 = 0$

R_Y = 10 kN

$R_X + R_Y = 10 \times 4$

R_X = 30 kN

21. 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 ________.

Ans. 17.25 – 17.45

Exp:

Outside diameter = 52 mm

Inside diameter = 48 mm

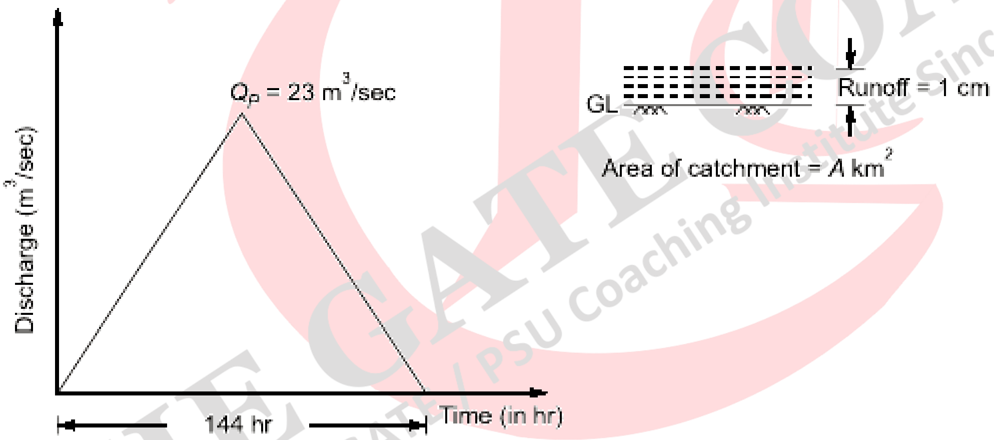
$$A_r = \frac{\frac{\pi}{2}(D_2)^2 - \frac{\pi}{4}(D_1)^2 \times 100}{\frac{\pi}{4}(D_1)^2}$$

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

22. 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 ________.

Ans. 595 – 598

Exp:



Area of hydrograph = Total direct runoff volume

$\Rightarrow \quad \frac{1}{2} \times 23\,m^3/sec \times 144 \times 3600\,sec$ = Area of catchment × Runoff depth

$\Rightarrow \quad \frac{1}{2} \times 23 \times 144 \times 3600\,m^3 = A \times \frac{1}{100}\,m$

∴ Area of catchment = 596.16 × 10^6 m^2 = 596.16 km^2

23. 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 ________.

Ans. 677.50 – 679.50

Exp:

Absolute pressure at maximum depth of the lake = $P_{atm} + \rho gh$

$$= 91 + \frac{9790(60)}{1000} = 678.41\,\text{kPa}$$

24. 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 2s. As per Webster's formula, the optimal cycle length (in s, round off to the nearest integer) is ________.

Ans. 48 – 52

Exp:

L = 2 × 3 = 6 sec

n = 3

y = (0.18 + 0.32 + 0.22)

$$C_o = \left(\frac{1.5L+5}{1-y}\right) = \left(\frac{1.5\times6+5}{1-(0.18+0.32+0.22)}\right) = 50\,\text{sec}$$

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

Surveyor	Angle θ	Number of 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 ________.

Ans. 36 – 36

Exp:

$$\text{MPV} = \frac{(36^o30'4)+(36^o\times3)+(35^o30'\times8)+(36^o30'\times4)}{4+3+8+4} = 36^o$$

Q.26. – Q.35 Multiple Choice Question (MCQ), carry TWO mark each (for each wrong answer: –2/3).

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

(a) $y = x \ln(kx)$

(b) $y = k \ln(kx)$

(c) $y = x \ln(x)$

(d) $y = x\, k \ln(k)$

Ans. a

Exp:

$$\frac{dy}{dx} - \frac{y}{x} = 1$$

$$\frac{dy}{dx} + Py = Q$$

$$P = -\frac{1}{x}, Q = 1$$

$$IF = e^{\int P dx} = e^{\int \frac{-1}{x} dx} = \frac{1}{x}$$

y(IF) = ∫Q(IF)dx + c

$$y\left(\frac{1}{x}\right) = \int 1.\frac{1}{x} dx + \ln x$$

$y = x\ln(xk)$

27. The smallest eigenvalue and the corresponding eigenvector of the matrix

$\begin{bmatrix} 2 & -2 \\ -1 & 6 \end{bmatrix}$, respectively, are

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

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

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

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

Ans. a

Exp:

$$A = \begin{bmatrix} 2 & -2 \\ -1 & 6 \end{bmatrix} \qquad \Rightarrow \qquad |A - \lambda I| = 0$$

$\Rightarrow \qquad \lambda = (4 + \sqrt{6})$ and $(4 - \sqrt{6})$

Taking $\lambda = (4 - \sqrt{6}) = 1.55$

$AX = \lambda X$

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

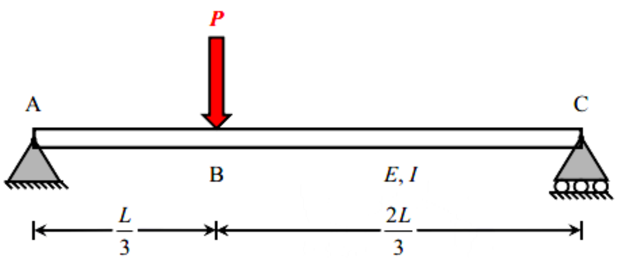
$$\begin{bmatrix} 2-\left(4-\sqrt{6}\right) & -2 \\ -1 & 6-\left(4-\sqrt{6}\right) \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$x_1 = \left(\frac{2}{-2+\sqrt{6}}\right) x_2$$

Let, $x_2 = K$ then $x_1 = \left(\frac{2}{-2+\sqrt{6}}\right) K$

$$\Rightarrow \qquad \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} \frac{2}{-2+\sqrt{6}} K \\ K \end{bmatrix} = \begin{bmatrix} \frac{2}{-2+\sqrt{6}} \end{bmatrix} = \begin{bmatrix} 2.00 \\ 0.45 \end{bmatrix}$$

28. A prismatic steel beam is shown in the figure.



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

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

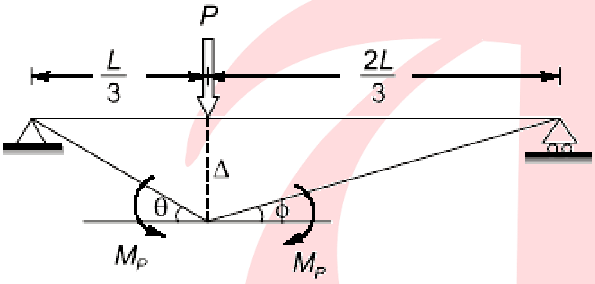
(b) $M_{p,static} = \frac{2PL}{9} \neq M_{p,\ kinematic}$

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

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

Ans. c

Exp:



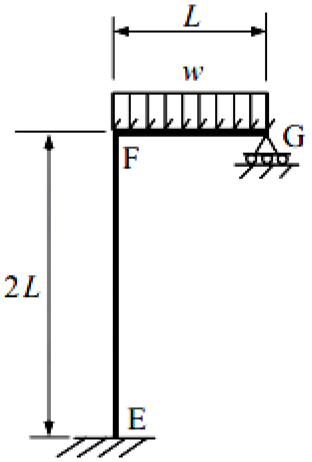
At collapse, $M_p\theta + M_P\phi = P\Delta$

$$\Rightarrow \qquad 3M_P\frac{\Delta}{l} + \frac{3M_P\Delta}{2l} = P\Delta$$

$$M_P = \frac{2Pl}{9}$$

Also, $M_{P',\ static} = M_{p',\ kinematic}$

29. 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

Ans.c

Exp:

The above problem can be solved by using two methods listed below:

1st method:

$$\frac{wL^4}{8EI}+\frac{wL^2(2L)}{2EI}\times L=\frac{RL^3}{3EI}+\frac{RL\times 2L\times L}{EI}$$

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

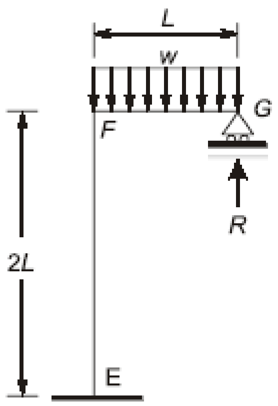
$$\frac{9wL^4}{8EI}=\frac{7RL^3}{3EI}$$

$$R=\frac{27wL}{56}=0.482\,wL$$

2nd method:

Compatibility condition,

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



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

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

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

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

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

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

$$\Rightarrow \quad 2RL^3 + \frac{RL^3}{3} = \frac{wL^4}{8} + wL^4 = \frac{9}{8}wL^4$$

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

$$\Rightarrow \quad R = \frac{27}{56}wL = 0.482\,wL$$

30. A clay layer of thickness H has a preconsolidation 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) $s_c = \frac{H}{1+e_o}\left[C_c \log\frac{p_c}{p_o} + C_s \log\frac{p_o+\Delta p}{p_c}\right]$

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

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

Ans. b

31. 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) 0.82 m

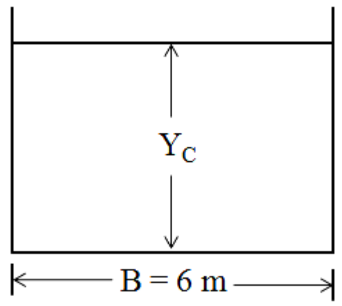
(b) 1.04 m

(c) 2.56 m

(d) 3.18 m

Ans. b

Exp:



Minimum specific energy will correspond to a critical flow condition.

The critical depth (Y_C) = $\left[\frac{q^2}{g}\right]^{1/3}$

$$Y_C = \left[\frac{(20/6)^2}{9.81}\right]^{1/3} = 1.042\,\text{m}$$

32. 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) (i) is True and (iv) is False

(c) (ii) is False and (iii) is False

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

Ans. d

33. 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) 5.79×10^{-3} m/s

(b) 6.35×10^{-3} m/s

(c) 0.69cm/s

(d) 0.75 cm/s

Ans. b

Exp:

n' = Porosity of expanded bed

$$n' = \left(\frac{V_B}{V_s}\right)^{0.22}$$

$$0.65 = \left(\frac{V_B}{4.5\,\text{cm/s}}\right)^{0.22}$$

$V_B = 6.35 \times 10^{-3}$ m/s

34. 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) 3.50 m and 53°7'48'' NW

(b) 2.45 m and 53°7'48'' NW

(c) 0.35 m and 53.13° SE

(d) 3.50 m and 53.13° SE

Ans. a

Exp:

e_L = +2.1 m

e_D = –2.8 m

$$e = \sqrt{e_L^2 + e_D^2} = \sqrt{(2.1)^2 + (2.8)^2} = 3.5\,\text{m}$$

Bearing of closing error = $\tan^{-1}\left(\frac{e_D}{e_L}\right) = \tan^{-1}\left(\frac{-2.8}{2.1}\right) = -53.13^o = 53^o 7' 48''\,\text{NW}$

35. 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

(a) 0.15 and 1.22

(b) 0.19 and 6.60

(c) 1.22 and 0.15

(d) 6.60 and 0.19

Ans. c

Exp:

Flow index = 27

Plasticity index, $I_P = W_L - W_P = 33$

Toughness index, $I_T = \frac{I_p}{I_f} = \frac{33}{27} = 1.22$

Liquidity index, $I_L = \frac{W_n - W_P}{W_L - W_P} = 0.151$

Q.36 – Q.55 Numerical Answer Type (NAT), carry TWO mark each (no negative marks).

Q.36 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 ________.

Ans. 1 – 1

Exp:

$f(x, y) = xe^y$

P(2, 0) and Q$\left(\frac{1}{2}, 2\right)$

grad f = $\hat{i}\,(e_y) + \hat{j}\,(xe^y) + \hat{k}\,(0)$

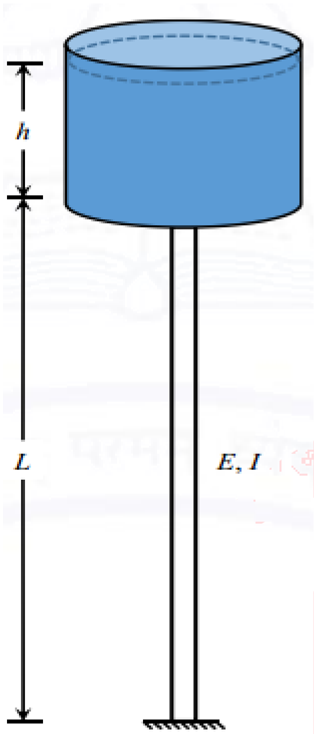
$\Rightarrow$ $(\text{grad } f)_P = \hat{i} + 2\hat{j}$

$$\overrightarrow{PQ} = \left(\frac{1}{2} - 2\right)\hat{i} + (2-0)\hat{j} = -\frac{3}{2}\hat{i} + 2\hat{j}$$

Required directional derivative = $(\text{grad } f)_P\, \widehat{PQ}$

$$= \left(\hat{i} + 2\hat{j}\right) \times \frac{\left(-\frac{3}{2}\hat{i} + 2\hat{j}\right)}{\sqrt{\frac{9}{4} + 4}} = \frac{\frac{-3}{2} + 4}{\sqrt{\frac{25}{4}}} = 1$$

37. 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 sel-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 ________.

Ans. 2.5 – 2.9

Exp:

Given :

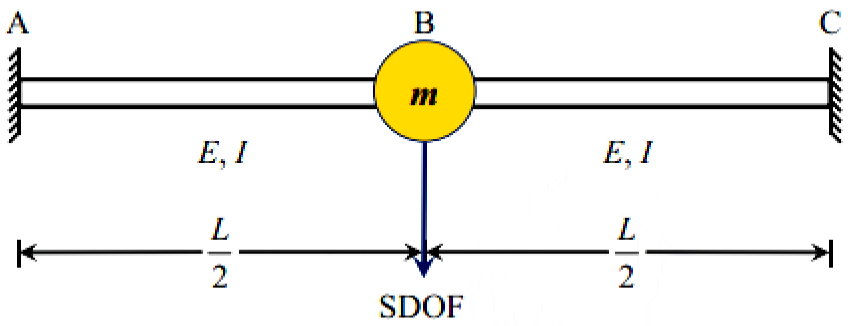
L = 4 m, ρ = 1000 kg/m^3, g = 10 m/s^2 , E = 200 GPa, D_i = 1.5 m, d = 75 mm

$$\frac{\pi^2 EI}{L_e^2} = \frac{\pi}{4} D_i^2 \times h \times \rho g$$

$$\frac{\pi^2 E \times \frac{\pi}{64} d^4}{(L)^2} = \frac{\pi}{4} D_i^2 \times h \times \rho g$$

$$h = \frac{4\pi^2 E d^4}{64 L^2 \times D_i^2 \times \rho g} = \frac{4\pi^2 \times 200 \times 10^9 \times (0.075)^4}{64 \times 4^2 \times 1.5^2 \times 10^4} \approx 10.7\,\text{m}$$

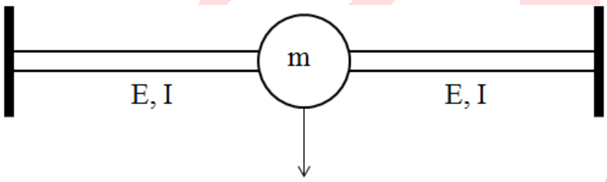
38. A prismatic fixed-fixed beam, modelled with a total lumped-mass of 10 kg as a single degree of freedom (SDOF) system is shown in the figure.



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 ________.

Ans. 10 – 10

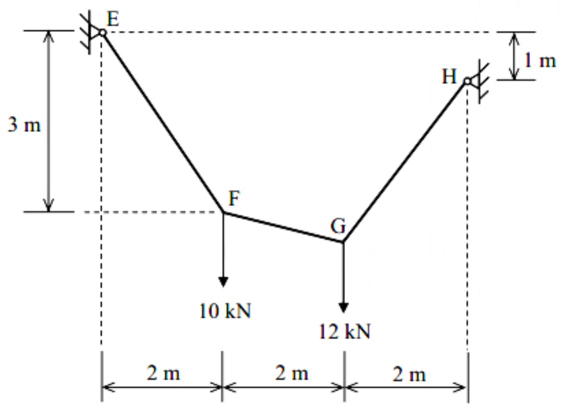
Exp:



Cyclic frequency (f) = $\dfrac{\omega}{2\pi} = \dfrac{1}{2\pi}\sqrt{\dfrac{k}{m}}$

$$f = \frac{1}{2\pi}\sqrt{\frac{\left(4\pi^2 \times 1000\right) N/m}{10\,kg}} = 10 \text{ Hz}$$

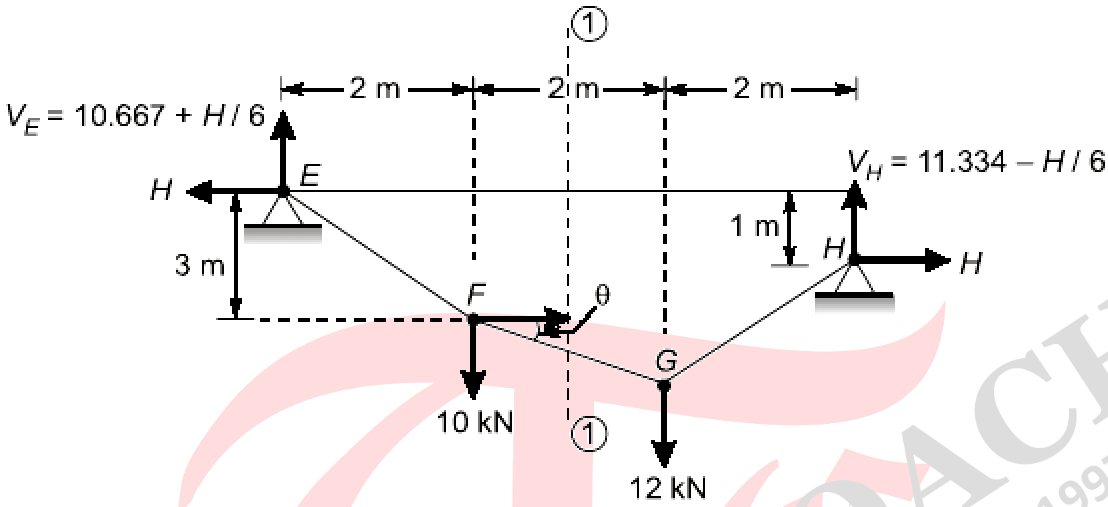
39. A perfectly flexible and inextensible cable is shown in the figure (not to scale). The external loads at F and G are acting vertically.



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

Ans. 8.10 – 8.40

Exp:



$\sum M_F \circlearrowright = 0$

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

$$\Rightarrow \quad (10.667 \times 2) + \frac{H}{3} - 3H = 0$$

H = 8.00 kN

$V_E = 10.667 + \frac{8}{6} = 12.00$ kN

$V_H = 11.334 - \frac{8}{6} = 10.00$ kN

Consider LHS of section (1) – (1)

$T\cos\theta = 8.0$

$T\sin\theta = 12.00 - 10 = 2.0$

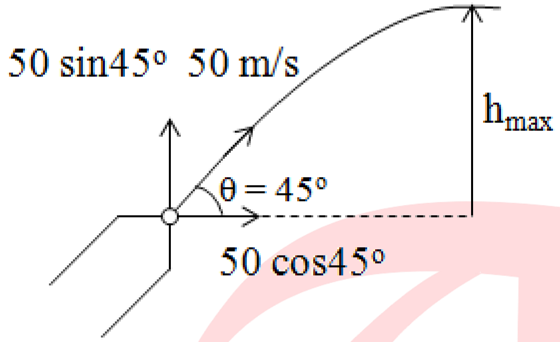
$\therefore \quad T^2\cos^2\theta + T^2\sin^2\theta = (8)^2 + (2)^2$

T = 8.246 kN

40. 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 ________.

Ans. 63.50 – 63.90

Exp:



As we know that

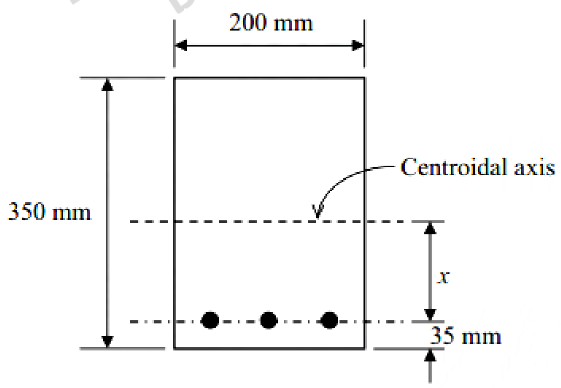
$V^2 - u^2 = 2aS$

In vertical direction (↑)

$0^2 - (50\sin45^o)^2 = 2(-9.81)h_{max}$

$$h_{max} = \frac{(50\sin 45^o)^2}{2(9.81)} = 63.71\text{m}$$

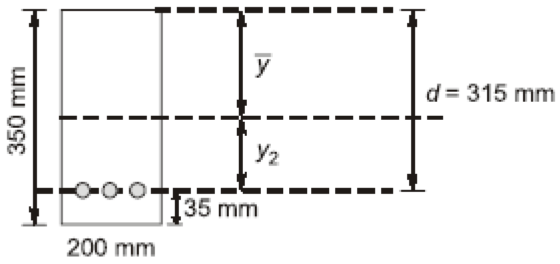
41. A rectangular cross-section of a reinforced concrete beam is shown in the figure. The diameter of each reinforcing bar is 16 mm. The value of modulus of elasticity of concrete and steel are 2.0 × 10^4 MPa and 2.1 × 10^5 MPa, respectively.



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

Ans. 129.0 – 130. 0

Exp:



$$m = \frac{E_s}{E_c} = \frac{2.1\times10^5}{2\times10^4} = 10.5$$

$$A_{st} = 3\times\frac{\pi}{4}(16)^2 = 603.20\,\text{mm}^2$$

$$\bar{y} = \frac{\left(B\times D\times\frac{D}{2} + (m-1)\times A_{st}\times d\right)}{B\times D + (m-1)\times A_{st}}$$

$$= \frac{\left(200\times\frac{350^2}{2} + (10.5-1)\times603.2\times315\right)}{200\times350 + (10.5-1)\times603.2} = 185.59\text{ mm}$$

Distance of N-A from reinforcement

$y_2 = d - \bar{y} = 315 - 185.59 = 129.4$ mm

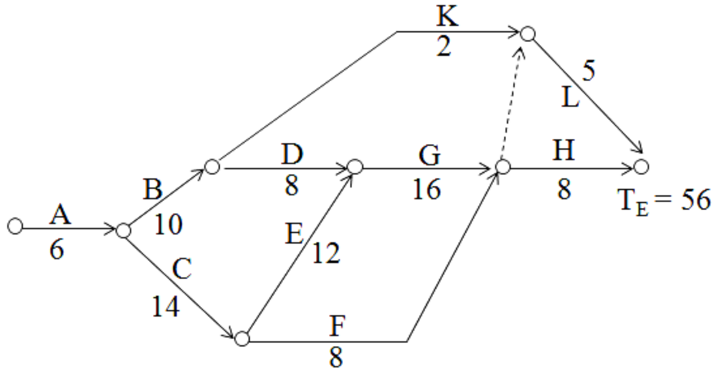
42. The activity details for a small project are given in the Table.

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 ________.

Ans. 56 – 56

Exp:



Project duration = 56 days

43. An equipment has been purchased at an initial cost of Rs. 160,000 and has an estimated salvage value of Rs. 10,000. The equipment has an estimated life of 5years. The difference between the book values (in Rs. in integer) obtained at the end of 4^{th} year using straight line method and sum of years digit method of depreciation is ________.

Ans. 20,000 – 20,000

Exp:

C_i = 160,000, C_s = 10,000, n = 5 years

$$D_m = \frac{C_i - C_s}{n} = \frac{160,000 - 10,000}{5} = 30,000/-$$

Book value of the end of 4 years

$B_4 = C_i - 4\,D_m$

= 160,000 – 4 × 30,000 = 40000

According to sum of years digit method

$$D_m = (C_i - C_s)\left[\frac{(n-m+1)}{\frac{n(n+1)}{2}}\right]$$

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

$$\therefore \qquad D_1 = (C_i - C_s)\frac{(5-1+1)}{15} = 50,000$$

∴ $B_1 = 160,000 - 50,000 = 110,000$

$D_1 = 150,000 \times \frac{(5-2+1)}{15} = 40,000$

∴ $B_2 = 110,000 - 40,000 = 70,000$

$D_3 = 150,000 \times \frac{(5-3+1)}{15} = 30,000$

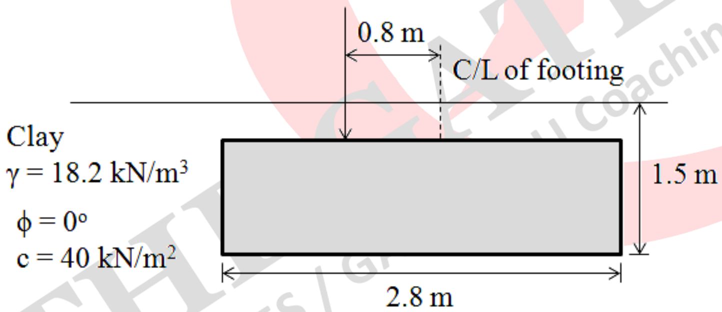
$B_3 = 70,000 - 30,000 = 40,000$

$D_4 = 150,000 \times \frac{(5-4+1)}{15} = 20,000$

∴ $B_4 = 40,000 - 20,000 = 20,000$

Difference = 20,000/-

44. 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 ________.

Ans. 439.00 to 442.00

Exp:

Given data: 2.8 × 3.56, e = 0.8, $D_f = 1.5$ m

$N_c = 5.14$	$N_q = 1,$	$N_r = 0$
$S_c = 1.16,$	$S_q = 1,$	$S_r = 1.0$
$d_c = 1.1,$	$d_q = 1,$	$d_r = 1.0$
$i_c = 1,$	$i_q = 1,$	$i_r = 1.0$

$\gamma = 18.2$, $c = 40$ kN/m^2

$B' = B - 2e_x = 2.8 - 2(0.8) = 1.2$ m

Ultimate bearing capacity,

$q_u = CN_cS_cd_ci_c + \gamma D_fN_qS_qd_qi_q + 0.5B'\gamma N_rS_rd_r$

$q_u = 40 \times 5.14 \times 1.16 \times 1.1 + 18.2 \times 1.5 \times 1 + 0$

$q_{nu} = q_u - \gamma D_f = 262.346$ kN/m^2

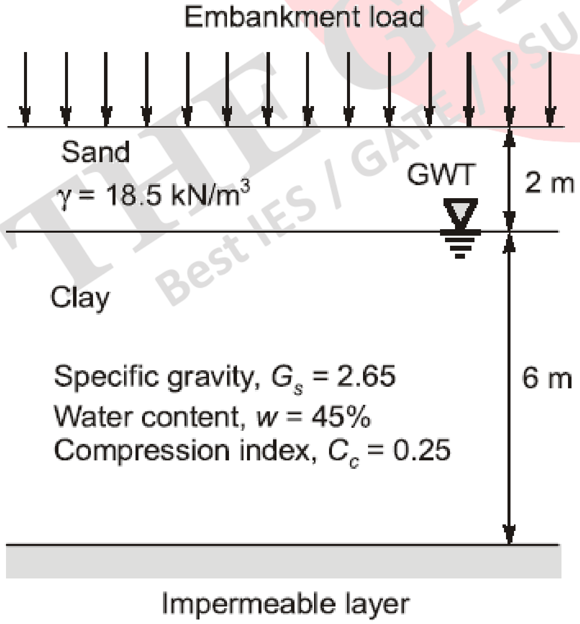
$q_{nu} = \dfrac{q_{nu}}{F} = 104.938$ kN/m^2

Net safe load $= q_{ns} \times A = \dfrac{q_{nu}}{F} \times (B' \times L)$

$= 104.938 \times 1.2 \times 3.5$ kN $= 440.739$ kN

Load applied on the footing = 440.740 kN

45. 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 effectiveness 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, $\gamma_w = 9.81$ 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 ________.

Ans. 0.32 – 0.34

Exp:

Primary consolidation settlement,

$$\Delta H = \frac{C_c H}{1+e_o}\log_{10}\left(\frac{\bar{\sigma}_o + \Delta\bar{\sigma}}{\bar{\sigma}_o}\right)$$

$\bar{\sigma}_o + \Delta\bar{\sigma}$ = Effective stress at the center of clay layer after embankment loading = 180 kN/m^2

$\bar{\sigma}_o$ = Effective stress at the centre of clay layer before embankment loading.

γ_{sub} of clay layer = $\frac{G-1}{1+e}\gamma_w = \frac{(2.65-1)}{1+\frac{wG}{1}}\times 9.81 = \frac{1.65\times 9.81}{1+0.45\times 2.65} = 7.383\,\text{kN/m}^3$

$\bar{\sigma}_o$ = (18.5 × 2) + (7.383) × 3 = 59.149 kN/m^2

$e_o = \frac{wG}{1}$ = 0.45 2a2f 2.65 = 1.1925

$$\Rightarrow \qquad \Delta H = \frac{0.25\times 6}{1+1.1925}\log_{10}\left(\frac{180}{59.149}\right) = 0.33\,\text{m}$$

46. 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 two decimal places) obtained is ________.

Ans. 0.38 – 0.42

Exp:

$y = 10x - 20x^2$

a = 0, b = 0.5, n = 5

So, $\quad h = \frac{b-a}{n} = 0.1$

And

x	0	0.1	0.2	0.3	0.4	0.5
y	0	0.8	1.2	1.2	0.8	0
	y_o	y_1	y_2	y_3	y_4	y_5

$$I = \int_0^{0.5} f(x)\,dx = \frac{h}{2}\left[y_o + y_5 + 2\left(y_1 + y_2 + y_3 + y_4\right)\right]$$

$$= \frac{0.1}{2}\left[0+0+2\left(0.8+1.2+1.2+0.8\right)\right] = 0.40$$

47. 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 ________.

Ans. 0.090 – 0.100

Exp:

$$m_v = \frac{a_v}{1+e_o} = \frac{\Delta e}{(1+e_o)\times(\Delta\bar{\sigma})}$$ ($\Delta\bar{\sigma}$ is smae for both M and N)

$$m_{v1} = \frac{0.575-0.510}{(1+0.575)\times\Delta\bar{\sigma}}$$

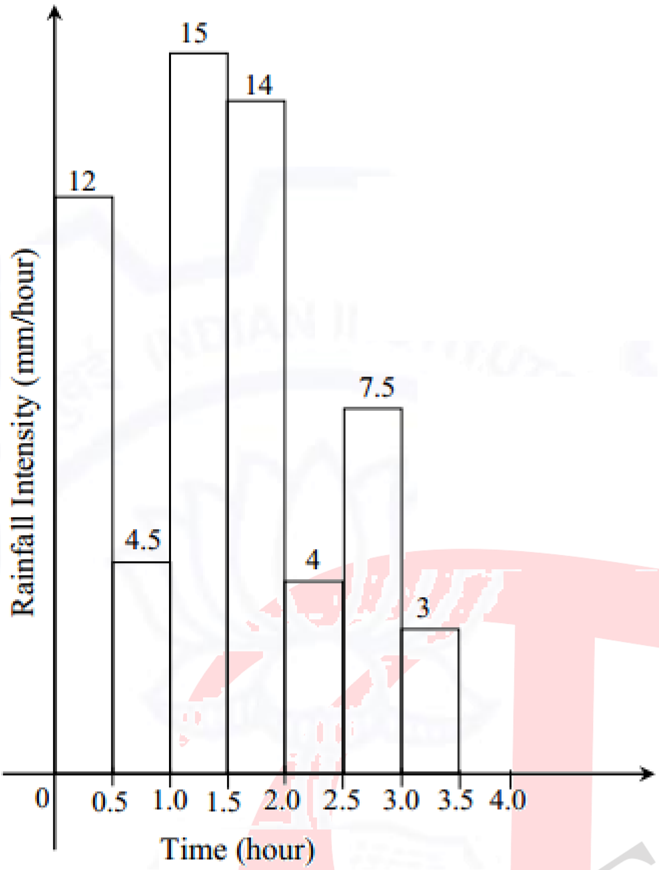
$$m_{v2} = \frac{0.600-0.550}{(1+0.600)\times\Delta\bar{\sigma}}$$

$$\frac{C_{V1}}{C_{V2}} = \frac{\dfrac{k_1}{m_{v1}\gamma_w}}{\dfrac{k_2}{m_{v2}\gamma_w}} = \frac{k_1}{k_2}\times\frac{m_{v2}}{m_{v1}}$$

$$= 0.125\left(\frac{1.575}{1.6}\right)\times\left(\frac{0.60-0.55}{0.575-0.510}\right)$$

$= 0.0947 \simeq 0.095$

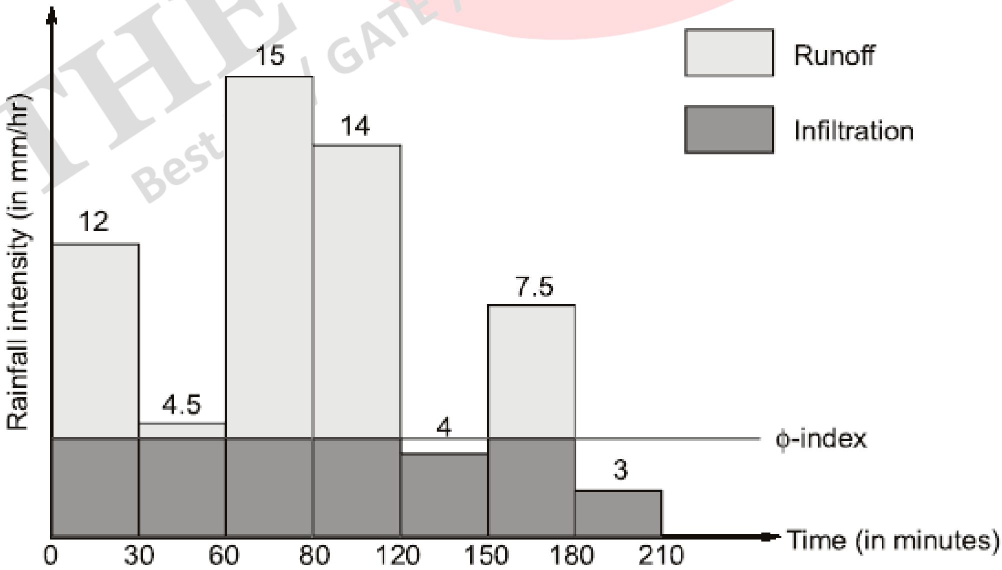
48. The hyetograph in the figure corresponds to a rainfall event of 3 cm.



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 ________.

Ans. 4.2 – 4.2

Exp:



Total rainfall = 3 cm

Total runoff = 1.6 cm

∴ Total infiltration = 3 – 1.6 = 1.4 cm

$$W-index = \frac{Total\ infiltration}{Total\ duration\ of\ storm} = \frac{1.4}{(210/60)}\ \text{cm/hr}$$

= 4 mm/hr

As ϕ-index > W-index

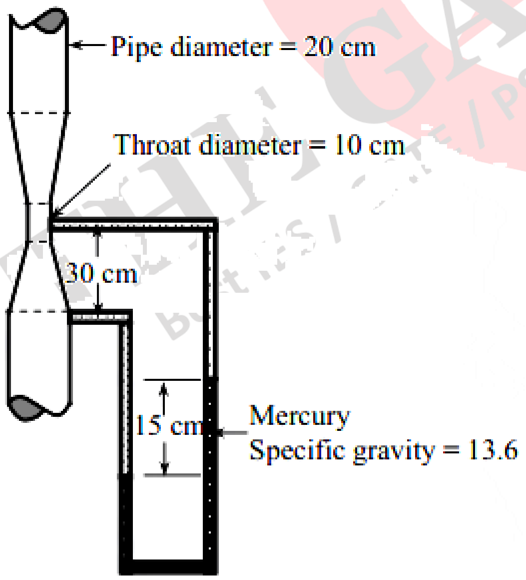
Hence, storm of intensities 4 mm/hr and 3 mm/hr will not produce rainfall exam.

$$\phi-index = \frac{Total\ infiltration\ in\ which\ rainfall\ excess\ occur}{Time\ period\ in\ which\ rainfall\ excess\ occur}$$

$$= \frac{Total\ infiltration - infiltration\ in\ which\ no\ rainfall\ excess\ occur}{T_{excess}}$$

$$\frac{14\,mm - \left(4\times\frac{30}{60}+3\times\frac{30}{60}\right)}{\left(\frac{150}{60}\right)\text{hr}} = 4.2\ \text{mm/hr}$$

49. 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 ________.

Ans. 49.0 – 50.0

Exp:

Discharge (Q) = $C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh}$ [∵ $C_d = 1$]

$$h = X\left(\frac{\rho_m}{\rho} - 1\right) = 0.15\left(\frac{13.6\times10^3}{10^3} - 1\right) = 1.89 \text{ m}$$

$$Q = \frac{A_1 A_2}{A_2\sqrt{\left(\frac{A_1}{A_2}\right)^2 - 1}} \times \sqrt{2\times9.8\times1.89}$$

$$= \frac{\frac{\pi}{4}(0.2)^2}{\sqrt{(2)^4 - 1}} \times \sqrt{2\times9.8\times1.89} = 49.395\, l/s \simeq 49.40\, l/s$$

50. A reservoir with a live storage of 300 million cubic metre irrigates 40,000 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 ________.

Ans. 689 to 693

Exp:

Live storage = 300 Mm^3

Area = 40,000 hectare

Since 2 filling so volume of water needed = 600 Mm^3

B = 120 days

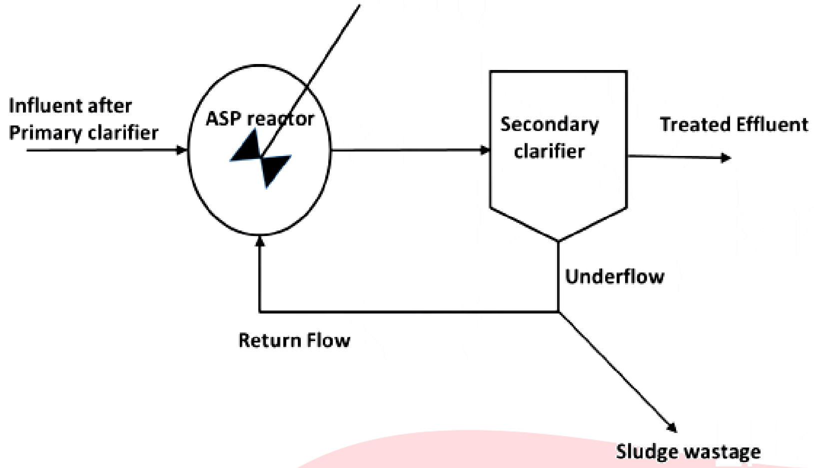
Duty = $\frac{8.64\,B}{\Delta}$

$$\Delta = \frac{600\times10^6}{40,000\times10^4} = 1.5\,\text{m}$$

Duty = $\frac{8.64\times120}{1.5} = 691.2$ ha/cumec

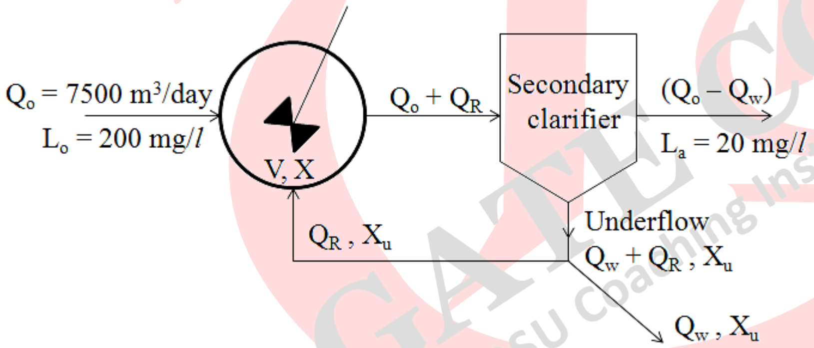
51. An activated sludge process (ASP) is designed for secondary treatment of 7500 m^3/day of municipal wastewater. After primary clarifier, the ultimate BOD of the influent, which enters into ASP reactor is 200 mg/L. treated effluent after secondary clarifier is required to have an ultimate BOD of 20 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.



Ans. 37.0 – 38.0

Exp:



Given, X = 3000 mg/l, X_u = 12,000 mg/l

Since, HRT = $\frac{V}{Q_o}$

⇒ Volume of reactor,

V = Q_o × HRT = 7500 × 0.2 m^3 = 1500 m^3

Sludge age, $\theta_C = \frac{VX}{(Q_o - Q_w)X_e + Q_w X_u}$ $(X_e \approx 0)$

$$10 = \frac{1500 \times 3000}{Q_w \times 12000}$$

Q_w = 37.5 m^3/day

52. 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 is ________.

Ans. 9 – 9

Exp:

Minimum length of chamber

$L_{min} = V_{flow} \times t_d$

$V_{flow} = 0.30$ m/s

$$t_d = \frac{H}{V_{settling}} = \frac{0.75}{2.5 \times 10^{-2}} = 30 \sec$$

$\Rightarrow \quad L_{min} = 0.3$ m/s $\times$ 30 s = 9 m

53. 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 ________.

Ans. 2.58 – 2.61

Exp:

$$G_m = \frac{55 + 40 + 5}{\frac{55}{2.55} + \frac{40}{2.65} + \frac{5}{2.70}} = 2.596$$

54. 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/s^2 and 3.5 m/s^2, respectively. The perception/reaction time (in s, round off to two decimal places) used in the SSD calculation is ________.

Ans. 1.90 – 2.10

Exp:

SSD = 140 m

V = 90 kmph

a = 3.5 m/s^2

$$SSD = Vt_R + \frac{V^2}{2gf}$$

a = gf

$$140 = \left(\frac{5}{18}\times 90\times t_R\right) + \frac{\left(\frac{5}{18}\times 90\right)^2}{2\times 3.5}$$

t_R = 2.028 seconds = 2.01 seconds

55. For a 2^o 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 ________.

Ans. 55 – 59

Exp:

Length of curve = Radius × Degree of curve

$$\frac{30.5\times 180}{2^o\times \pi} = R$$

R = 873.76 m

$C_d = C_{th} - C_{act}$

$$C_{act} = \frac{GV^2}{127R} = \frac{1750\times 100^2}{127\times 873.76} = 157.70\,\text{mm}$$

$$C_{ev} = \frac{GV^2}{127R} = \frac{1750\times 80^2}{127\times 873.76} = 100.930\,\text{mm}$$

$C_{def} = C_{act} - C_{th}$ = 157.70 – 100.930 = 56.77 mm ≃ 57 mm