Technical Section

Question 1

Which of the following statements is are correct?

(A) Increased level of volatile organic compounds in the indoor environment will result in formation of photochemical smog which causes 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 cause of chest construction and irritation of the Mucous membrane.

(D) Increased level of carbon monoxide in the indoor environment result in the formation of carboxy-hemoglobin and the long term exposure becomes a cause of cardiovascular diseases.

Ans. **B, C & D**

Question 2

The hardness of a water sample is measured directly by titration with 0.01 M solution of ethylene diamine 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 complete at the end point of the titration. The colour of the solution changes from

(A) Reddish brown to Pinkish yellow
(B) Blue to colourless
(C) Wine red to blue
(D) Blue - green to reddish brown

Ans. **C**

Sol. At the end point of titration, the color of solution changes from wine red to blue.

Hence, the correct option is (C).

Question 3

In case of bids in two-envelop system, the correct option is :

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

(B) Financial bid is opened 1^{st}

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

(D) Technical bid is opened 1^{st}

Ans. **D**

Sol. In case of bids in two envelop system technical bid is opened first.

Hence, the correct option is (D).

Question 4

In a 3-phase signal system design for a 4-leg intersection, the critical flow ratios for each phase are 0.18, 0.32, 0.22. The loss time in each of the phase is 2 sec. As per Webster's formula, the optimal cycle length (in sec, round off to the nearest integer) is _____ .

Ans. **50**

Sol. **Given :**

3-phase signal system

The critical flow ratio for phase 1^{st} $Y_1 = 0.18$

The critical flow ratio for phase 2^{nd} $Y_2 = 0.32$

The critical flow ratio for phase 3^{rd} $Y_3 = 0.22$

According to Webster method,

Optimum cycle length, $C_0 = \dfrac{1.5L+5}{1-Y}$

$\therefore \quad Y = Y_1 + Y_2 + Y_3$

$Y = 0.18 + 0.32 + 0.22 = 0.72$

$\therefore$ On putting value in above formula,

$$C_0 = \frac{1.5\times 6+5}{1-0.72} = 50 \text{ sec}$$

Question 5

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 (L_L) more than 50%

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

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

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

Ans. **A**

Sol. MH- Highly compressible silt

Ans- inorganic silt with $W_L > 50\%$

Note : When liquid limit is greater than 50% soil is called highly compressible.

Hence, the correct option is (A).

Question 6

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 soil specimen, respectively, are

(A) 1.22 and 0.15 (B) 0.15 and 1.22 (C) 0.19 and 6.60 (D) 6.60 and 0.19

Ans. **A**

Sol. **Given :**

$W_L = 60\%$

$W_P = 27\%$

$W_N = 32\%$

$I_F = 27$

$I_P = W_L - W_P = 60 - 27 = 33\%$

$$\text{Toughness index} = \frac{I_P}{I_F} = \frac{33}{27} = 1.22$$

$$\text{Liquidity index} = \frac{W_N - W_P}{I_P} = \frac{32-27}{33} = \frac{5}{33} = 0.15$$

Hence, the correct option is (A).

Question 7

The Softening point of bitumen has the same unit as that of

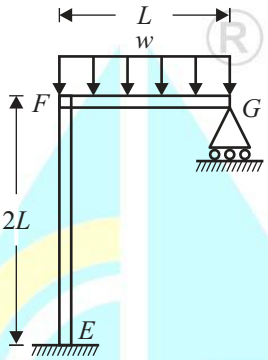
(A) Time (B) Temperature (C) Distance (D) Viscosity

Ans. **B**

Question 8

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) 0.500 *wL* (B) 0.375 *wL* (C) 0.453 *wL* (D) 0.482 *wL*



Ans. **D**

Sol. Compatibility condition, $\frac{\partial U}{\partial R}=0$

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

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

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

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

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

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

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

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

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

Hence, the correct option is (D).

Question 9

For a given transverse, latitudes and departures are calculated and it is found that sum of latitudes is equal to +2.1 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 $53^0 7'48"$ NW

(B) 3.50 m and $53^0 7'48"$ NW

(C) 0.35 m and 53.13^0 SE

(D) 3.50 and 53.13^0 SE

Ans. **B**

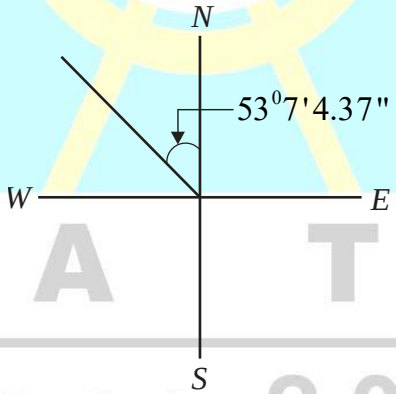
Sol. **Given :**

Sum of latitude, $\Sigma L = +2.1$ m

Sum of departure, $\Sigma D = -2.8$ m

Closing error $(e) = \sqrt{(\Sigma L)^2 + (\Sigma D)^2}$

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



Bearing, $\theta = \tan^{-1}\left(\frac{\Sigma D}{\Sigma L}\right) = \tan^{-1}\left(\frac{2.8}{2.1}\right)$

$$\theta = 53^0 7'48.37"$$

Hence, the correct option is (B).

Question 10

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 relation time (in sec), round off to two decimal places) used in the SSD calculation is_____.

Ans. **(2 - 2.04)**

Sol. **Given :**

Stopping sight distance $(SSD) = 140$ m

$V = 90$ km/hr

$g = 9.81$ m/s^2

$a = 3.5$ m/s^2

We know that, $\mu = \frac{a}{g} = \frac{3.5}{9.81}$

$$\therefore \quad SSD = Vt + \frac{V^2}{2g\mu}$$

$$140 = 25 \times t + \frac{25^2}{2 \times 9.81 \times \frac{3.5}{9.81}}$$

Reaction time, $t = 2.028$ sec

Question 11

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 150 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. **(0.093 - 0.097)**

Sol. **Given :**

For soil *M* :

Change in void ratio $\Delta e = 0.575 - 0.510$

Change in applied pressure $\Delta\sigma = 180 - 120$

For soil *N* :

$\Delta e = 0.6 - 0.55$

$\Delta\sigma = 180 - 120$

$\therefore$ Ratio of hydraulic conductivity, $\frac{K_M}{K_N} = 0.125$

$$\text{Ratio} = \frac{(C_v)_M}{(C_v)_N} = \text{find ?}$$

$$\text{Ratio} = \frac{(C_v)_M}{(C_v)_N} = \frac{\left[\frac{k[\Delta\sigma][1+e_0]}{\Delta e}\right]_M}{\left[\frac{k[\Delta\sigma][1+e_0]}{\Delta e}\right]_N} = \frac{K_M}{K_N} \times \frac{\left[\frac{1+e_0}{\Delta e}\right]_M}{\left[\frac{1+e_0}{\Delta e}\right]_N}$$

$$\text{Ratio} = 0.125 \times \frac{\left[\frac{1+0.575}{0.565}\right]}{\left[\frac{1+0.6}{0.05}\right]} = 0.095$$

$\therefore$ Ratio of coefficient of consolidation of sample *M* to *N* is 0.095.

Question 12

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

Sol. **Given :**

Grit chamber

Diameter of particle to be removed, $d = 0.25$ mm

Specific gravity, $G = 2.7$

Velocity of particles, $V_s = 2.5$ cm/s

Width of chamber, $B = 0.5$ m

Waste water of flow, $Q = 9720\ m^3/d$

Depth of flow, $Y = 0.75$ m

$$\therefore \quad \text{Plan area} = \frac{\text{Discharge } (Q)}{\text{Velocity } (V_s)}$$

$$B \times L = \frac{Q}{V_s}$$

$$0.5 \times L = \frac{9720 \times \frac{10^4}{86400}}{2.5}$$

$$L = 900 \text{ cm} = 9 \text{ m}$$

Minimum length of chamber required to remove 0.25 diameter particle is 9 m.

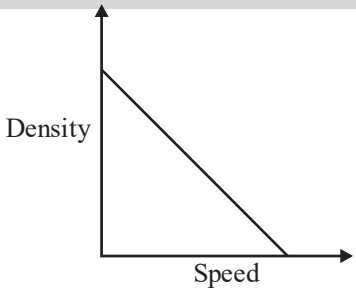
Question 13

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) V_F (B) 0 (C) $\frac{V_F}{2}$ (D) $\frac{V_F}{4}$

Ans. C

Sol. **Given :** Relation between traffic speed and density

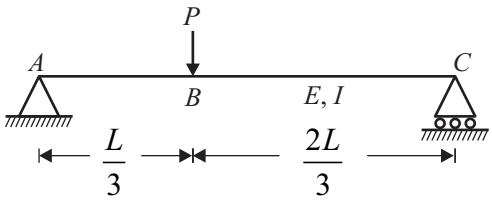


$$\therefore \quad \text{Maximum flow occur} = \frac{V_f}{2}$$

Hence, the correct option is (C).

Question 14

A prismatic steel beam is shown in the figure. The plastic moment, M_P calculated for collapse mechanism using static method and kinematic method is,



S = static, K = kinematic

(A) $M_{ps} > \frac{2PL}{9} = M_{pk}$

(B) $M_{ps} = \frac{2PL}{9} = M_{pk}$

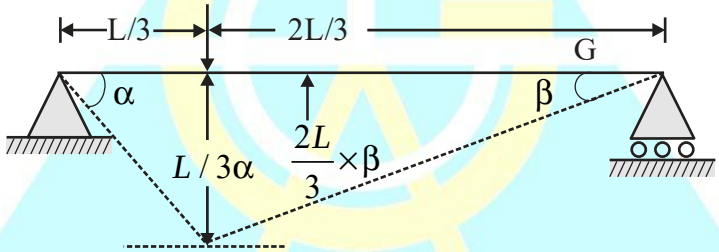
(C) $M_{ps} = \frac{2PL}{9} \neq M_{pk}$

(D) $M_{ps} < \frac{2PL}{9} = M_{pk}$

Ans. C

Sol. We know that, $\text{Angle} = \frac{\text{Arc}}{\text{Radius}}$

$\therefore$ Deflection is same at B from both A and C



Now, $\frac{L}{3}\alpha = \frac{2L}{3}\beta$ $\quad [\delta = \theta \times L]$

$\alpha = 2\beta$

$D_s = 0$

No. of plastic hinges $= D_s + 1 = 0 + 1 = 1$

$$P\left(\frac{2L}{3}\beta\right) = M_P(\alpha) + M_P(\beta)$$

$$P\left(\frac{2L}{3}\beta\right) = M_P(2\beta) + M_P(\beta)$$

$$\frac{2L}{3}\beta P = 3M_P\beta$$

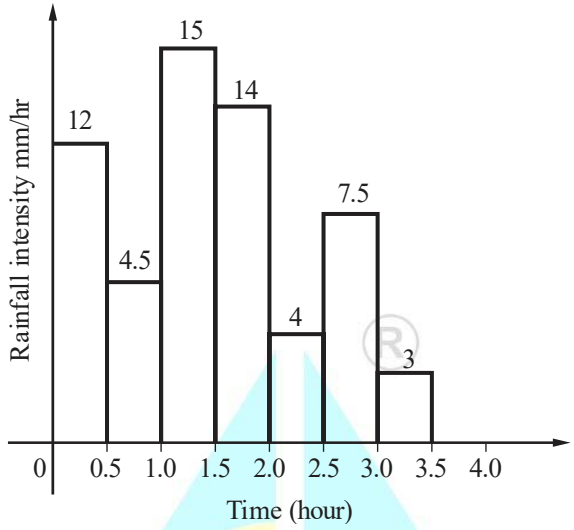
$$M_P = \frac{2L}{9}P$$

M_P Static $\leq \frac{2PL}{9} \leq M_p$ kinetic

Hence, the correct option is (C).

Question 15

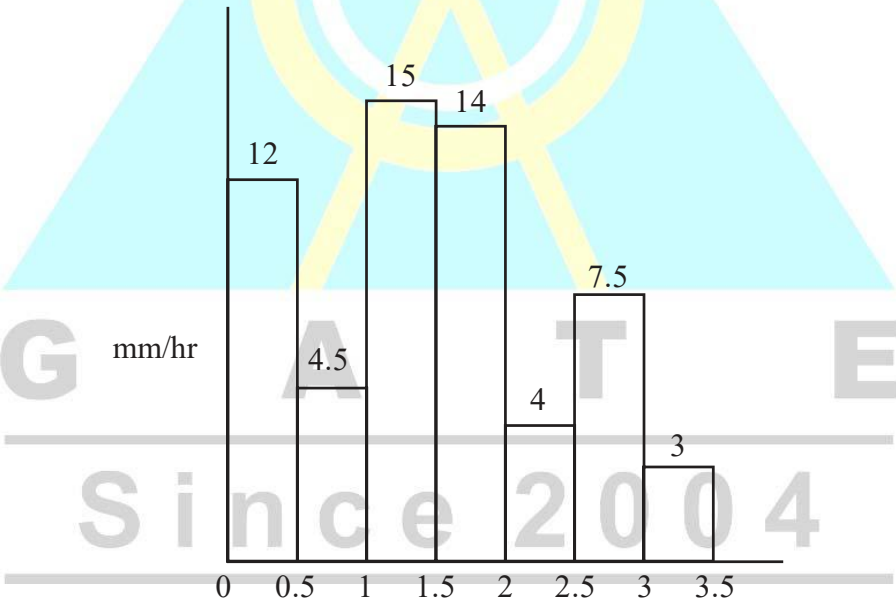
The hyetograph in the figure corresponds to a rainfall event of 3 cm.



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

Ans. **(4.18 – 4.27)**

Sol. Rainfall intensity



Rainfall $= 3\text{cm}$

Storm duration $= 3.5$ hr

Run off $= 1.6$ cm

$\phi_{index} = ???$

Rain fall $= 6 + 2.25 + 7.5 + 2 + 3.75 + 1.5 = 30$ mm $= 3$ cm

1st trial : $P = 3\,\text{cm},\ R = 1.6\ \text{cm},\ \ T_e = 3.5\ \text{hr}$

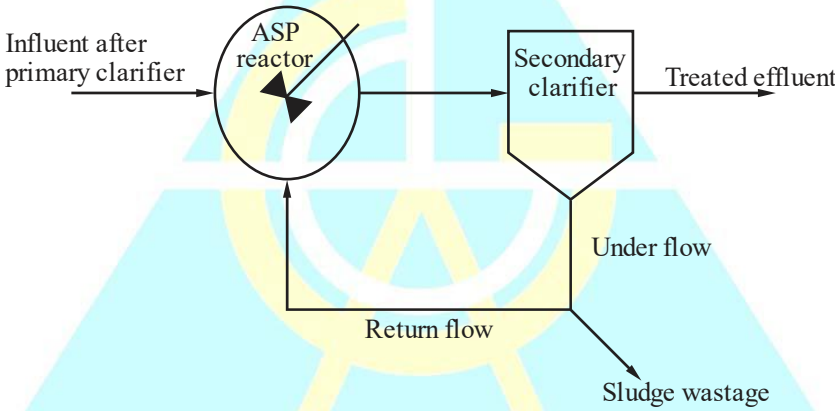
$$\phi_{index} = \frac{P-R}{T_e} = \frac{3-1.6}{3.5} = 0.4\ \text{cm/hr} = 4\ \text{mm/hr}$$

2nd trial : $P = 26.5\ \text{mm} = 2.65\ \text{cm},\ P = 1.6\ \text{cm},\ T_e = 2.5$

$$\phi_{index} = \frac{2.65-1.6}{2.5} = 0.42\ \text{cm} = 4.2\ \text{mm/hr}$$

Question 16

An activated sludge process (ASP) is designed for secondary treatment of 2500 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 under flow is maintained as 3000 mg/L and 12000 mg/L, respectively. The hydraulic retention time and mean sale 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 _____.

Ans. **37.5**

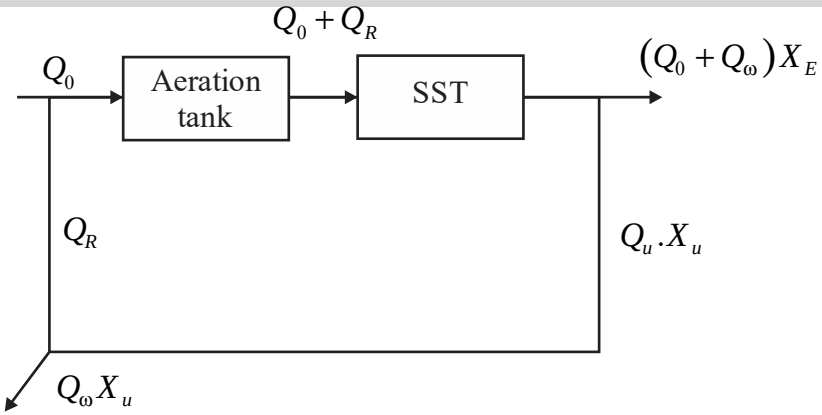
Sol. Activates sludge process, $Q_0 = 7500\ m^3/\text{day}$

Ultimate, $BOD_u = 200$ mg/L

Effluent $BOD = 20$ mg/L

Hydraulic retention time $= 0.2$ day

$\theta_c = 10$ days



$$\theta_c = \frac{V_x}{Q_w x_u + (Q_0 - Q_w)x_E}$$

$$\theta_c = \frac{V_x}{Q_w x_u}$$

$$10 = \frac{7500 \times 0.2 \times 3000}{Q_w \times 12000}$$

$$Q_w = 37.5 \text{ m}^3/\text{day}$$

Question 17

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. **(2.4 - 2.7)**

Sol. **Given :**

Weight of coarse aggregate $W_1 = 55\%$

Weight of fine aggregate $W_2 = 40\%$

Weight of filler, $W_3 = 5\%$

Bulk specific gravity of CA $G_1 = 2.55$

Bulk specific gravity of fine aggregate $G_2 = 2.65$

Bulk specific gravity of filler = 2.7

Bulk specific gravity of mix,

$$G = \frac{100}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3}} = \frac{100}{\frac{55}{2.55} + \frac{40}{2.65} + \frac{5}{2.7}}$$

$$G = \frac{100}{21.568 + 15.094 + 1.851} = \frac{100}{38.513} = 2.596$$

Question 18

The rank of 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

Ans. **B**

Sol.

$$\begin{bmatrix} 5 & 0 & 1 & 0 \\ 0 & 2 & 0 & 1 \\ -5 & 0 & -1 & 0 \\ 0 & 1 & 0 & 2 \end{bmatrix} \xrightarrow{R_1 \longleftrightarrow R_1 + R_2} \begin{bmatrix} 5 & 0 & 1 & 0 \\ 0 & 2 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 2 \end{bmatrix}$$

$$\xrightarrow{R_4 \longleftrightarrow R_4 - \frac{1}{2}R_2} \begin{bmatrix} 5 & 0 & 1 & 0 \\ 0 & 2 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{3}{2} \end{bmatrix}$$

$$R_3 \longleftrightarrow R_4 \begin{bmatrix} 5 & 0 & 1 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 0 & \frac{3}{2} \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Rank $(A) = 3$

Hence, the correct option is (B).

Question 19

The value (round off to one decimal places) of $\int_{-1}^{1} xe^{|x|}\,dx$ is

Ans. 0

Sol. $\int_{-1}^{1} xe^{-|x|}dx = \text{Odd function}$

$f(-x) = -f(x)$

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

Question 20

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

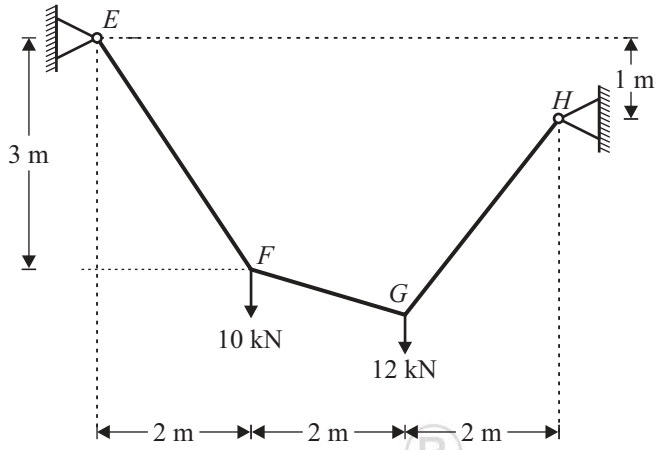
Select the correct option.

(A) (i) True and (iv) is True
(B) (iii) is False and (iv) is False
(C) (i) is False and (iii) is True
(D) (ii) is False and (iii) is False

Ans. B

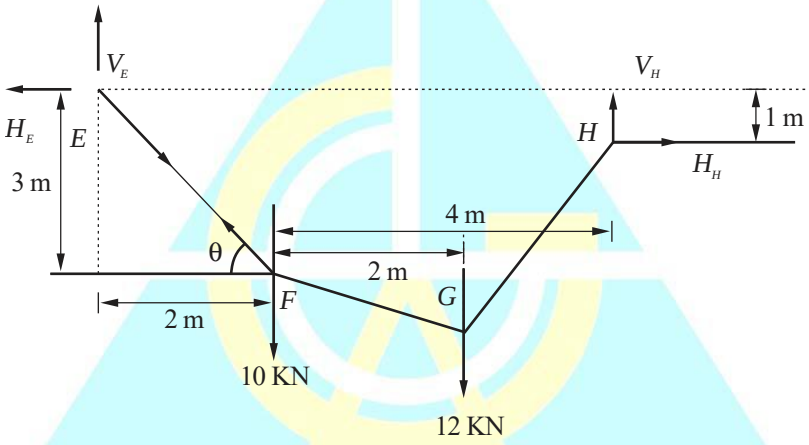
Question 21

A perfectly flexible and inextensible cable is shown in the figure (not to scale). The external load 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. **(8.23 – 8.28)**

Sol.



Left of F, $H_E \times 3 + V_E \times 2 = 0$

$$H_E = \frac{2}{3} V_E \quad \ldots(i)$$

At support, $V_E \times 6 - H_E \times 1 - 10 \times 4 - 12 \times 2 = 0$

$$6V_E - H_E = 64 \quad \ldots(ii)$$

Put value of H_E in equation (ii),

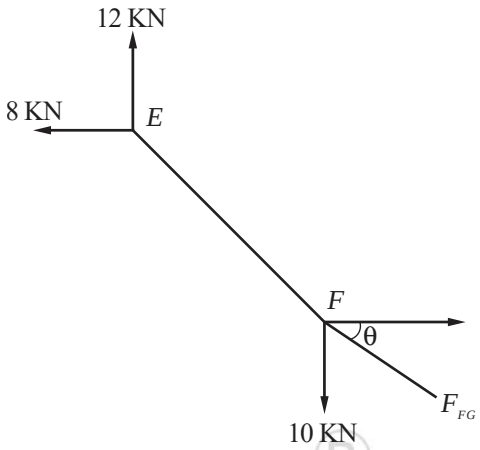
$$6V_E - \frac{2}{3} V_E = 64$$

$$V_E = \frac{3}{16} \times 64 = 12 \text{ KN}$$

$$H_E = \frac{2}{3} \times 12 = 8 \text{ KN}$$

Tension, in EF, $F_{EF} = \sqrt{V_E^2 + H_E^2}$

$$F_{EF} = \sqrt{(12)^2 + (8)^2} = 4\sqrt{13} \text{ KN}$$



$\Sigma F_H = 0$, $F_{FG}\cos\theta_1 = 8$ …(iii)

$\Sigma F_V = 0$, $F_{FG}\sin\theta_1 + 10 = 12$

$F_{FG}\sin\theta_1 = 2$ …(iv)

$(F_{FG})^2 = (8)^2 + (2)^2$

$F_{FG} = 8.2462$ KN

$F_{FG} = 8.25$ KN

Question 22

A water filtration unit is made of uniform-size 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) 0.69 cm/s (C) 6.35×10^{-3} m/s (D) 5.79×10^{-3} m/s

Ans. C

Sol. **Given :**

Diameter of sand particle, $d = 0.4$ mm

Shape factor, $\phi = 0.84$

Specific gravity, $G = 2.55$

Depth of filter bed = 0.7 m

Porosity, $n = 0.35$

Expanded, $n_e = 0.65$

Settling velocity, $V_s = 45$ cm/sec

We know that, $n' = \left(\frac{V_B}{V_S}\right)^{0.22}$

$\therefore$ $v_b = 6.35\times10^{-3}$ m/s

Backwash velocity is 6.35×10^{-3} m/s.

Hence, the correct option is (C).

Question 23

In general, the **CORRECT** sequence of surveying operations is

(A) Field observation –Reconnaissance →Data analysis → Map making

(B) Reconnaissance → Field observation → Data analysis → Map making

(C) Data analysis → Reconnaissance → Field observation → Map making

(D) Reconnaissance → Data analysis →Field observation → Map making

Ans. **B**

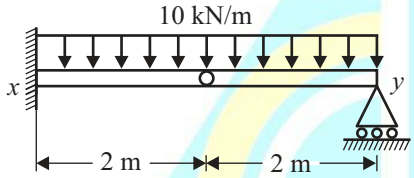
Sol. Correct sequence :

Reconnaissance → Field observation →Data analysis →Map making

Hence, the correct option is (B).

Question 24

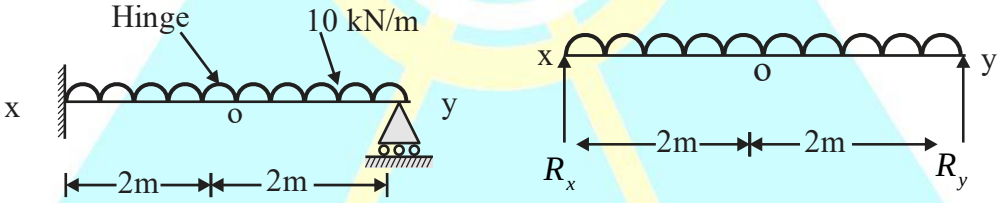
A propped cantilever beam xy with an internal hinge at the middle is carrying a uniformly distributed load of 10 kN/m. The vertical reaction as suppose x (in kN) is



(Internal hinge at middle)

Ans. **30**

Sol. Given beam,



We know, sum of moment at internal hinge is 0.

$\therefore \quad \sum M_0 = 0,$

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

$$R_y = 10 \text{ kN}$$

$\sum f_y = 0, \quad R_x + R_y = 10 \times 4$

$$R_x = 40 - 10$$

$\therefore \quad R_x = 30 \text{ kN}$

Vertical reaction at support x is 30 kN.

Question 25

Seasoning of timber for use in construction is done essentially to :

(A) Smoothen timber surfaces

(B) Increases strength and durability

(C) Remove knots from timber logs

(D) Cut timber in right season and geometry

Ans. **B**

Sol. Seasoning of timber increases strength and durability of timber which are used for different engineering purposes.

Hence, the correct option is (B).

Question 26

The most appropriate tri-axial test to assess the long term stability of an excavated clay slope is

(A) Consolidated drained test
(B) Unconfined compression test
(C) Unconsolidated undrained test
(D) Consolidated undrained test

Ans. A

Question 27

For a 2^0 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 is 1750 mm. The degree of curve is defined as the angle subtended at its center by a 30.5m are. The cant deficiency for the curve (mm round off to integer) is _____.

Ans. 57

Sol. **Given :**

Maximum sanctioned speed $V_{\max} = 100$ km/hr

Equilibrium speed $V_{eq} = 80$ km/hr

Degree of curve, $D = 2^0$

Arc length, $L = 30.5$ m

We know that angle $= \dfrac{\text{Arc}}{\text{Radious}}$

$$L = R \times D$$

$$30.5 = R \times \frac{2^0 \times \pi}{180}$$

$$R = \frac{30.5 \times 180}{2^0 \times \pi}$$

$$R = 873.76 \text{ m}$$

$$e_d = e_{theo} - e_{act} = \frac{GV_{\max}^2}{127R} - \frac{GV_{eq}^2}{127R}$$

$$e_d = \frac{1.75 \times 100^2}{127 \times 873.76} - \frac{1.75 \times 80^2}{127 \times 873.76} = 0$$

$$e_d = 0.05677 \text{ m} = 56.77 \text{ mm}$$

$\therefore$ The cant deficiency for the curve is 57 mm (round off to integer).

Question 28

If A is a square matrix then orthogonality property mandates

(A) $AA^T = A^2$ (B) $AA^T = I$ (C) $AA^T = A^{-1}$ (D) $AA^T = 0$

Ans. B

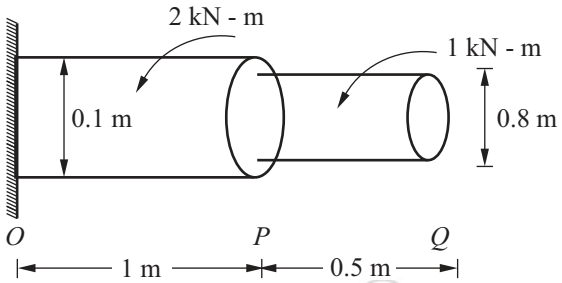
Sol. If, $AA^T = I$ or $A^{-1} = A^T$

The matrix is orthogonal.

Hence, the correct option is (B).

Question 29

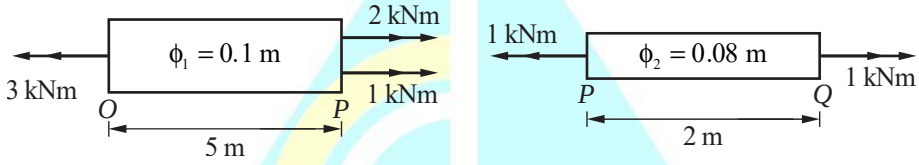
A solid circular torsional member *OPQ* is subjected to torsional moments as shown in the figure (not to scale). The yield shear strength of the constituent material is 160 MPa.



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

Ans. **(15.1 – 15.4)**

Sol.



$$(\tau_{max})_{OP} = \frac{16T_{OP}}{\pi \times \phi_1^3} = \frac{16 \times 3 \times 10^6}{\pi \times (100)^3} = 15.279 \text{ MPa}$$

$$(\tau_{max})_{PQ} = \frac{16T_{pQ}}{\pi \times \phi_2^3} = \frac{16 \times 1 \times 10^6}{\pi \times (80)^3} = 9.947 \text{ MPa}$$

$\therefore$ Absolute maximum shear stress in member $= \max\left[(\tau_{max})_{OP}, (\tau_{max})_{PQ}\right] = 15.279$ MPa

Question 30

The value of $\lim\limits_{x \to 0} \dfrac{x \ln(x)}{1 + x^2}$ is

(A) 0.5 (B) ∞ (C) 0 (D) 1

Ans. **C**

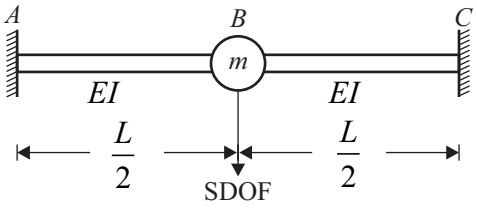
Sol. $$\lim_{x \to \infty} \left(\frac{x \ln x}{x^2 + 2}\right)\left(\frac{\infty}{\infty}\right) = \lim_{x \to \infty} \left[\frac{x\left(\frac{1}{x}\right) + \ln x}{2x}\right]\left(\frac{\infty}{\infty}\right)$$

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

Hence, the correct option is (C).

Question 31

A prismatic fixed-fixed beam, modelled with a total lumped mass of 10 kg as a single degree of freedom system as shown in the figure. If the flexural stiffness of beam is $4\pi^2$kN/m, its natural frequency of vibration (in Hz, in integer) in the flexural mode will be :



Ans. **10**

Sol. **Given :**

Total lumped mass, $m = 10$ kg

We know that, frequency $f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

Where, k = Flexural stiffness and m = Total lumped mass

$$f_n = \frac{1}{2\pi}\sqrt{\frac{4000\pi^2}{10}}$$

$$f_n = \frac{1}{2\pi} \times 20 \times \pi = 10 \text{ Hz}$$

Question 32

A rectangular open channel of 6 m width is carrying 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 given discharge will then be:

(A) 2.56 m (B) 0.82 m (C) 1.04 m (D) 3.18 m

Ans. **C**

Sol. **Given :**

Width of channel, $(B) = 6$ m

Discharge of channel, $(Q) = 20$ m^3/sec

$\therefore$ Critical depth, $Y_c = \left(\frac{q^2}{g}\right)^{\frac{1}{3}}$

$$Y_c = \left(\frac{20^2}{\frac{6^2}{9.81}}\right)^{\frac{1}{3}} = 1.04 \text{ m}$$

$\therefore$ Depth of flow at which SE will be minimum is critical depth and is value 1.04 m.

Hence, the correct option is (C).

Question 33

Strain hardening of structural steel means

(A) Strengthening steel member externally for reducing strain experienced

(B) Experiencing higher stress than yield stress with increases deformation

(C) Decreases in the stress experienced with increases strain

(D) Strain occurring before plastic flow of steel material

Ans. **D**

Question 34

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. **0.4**

Sol. **Given :** $a=0, b=0.5, n=5$

Intercept, $h=\left(\frac{b-a}{n}\right)=\frac{0.5-0}{5}=0.1$

$x_0=0,\ y_0=0$

$x_1=0.1,\ y_1=0.8$

$x_2=0.2,\ y_2=1.2$

$x_3=0.3,\ y_3=1.2$

$x_4=0.4,\ y_4=0.8$

$x_5=0.5,\ y_5=0$

Using trapezoidal formula numerical integration

$$=\frac{h}{2}[(y_0+y_5)+2(y_1+y_2+y_3+y_4)]$$

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

$$=\frac{0.1\times 8}{2}=0.4$$

Question 35

An equipment has been purchased at 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 4^{th} year using straight line method and sum of years digit method of depreciation is_____.

Ans. **20000**

Sol. **Given :**

Initial cost $(C_i)=160000$

Salvage value $(C_S)=10000$

$n=$ Life of asset 5 year

Book value after 4^{th} year by **straight line method**

$$=160000-4\left(\frac{160000-10000}{5}\right)=40000$$

Now, depreciation after m^{th} year by **sum of year digit method**

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

Depreciation after 1 year (D_1)

$$D_1 = (160000 - 10000)\frac{(5-1+1)}{\frac{5\times(5+1)}{2}} = 50000$$

Book value after 1 year $(B_1) = 160000 - 50000 = 110000$

Similarly we can calculate other depreciation and booked values

$$D_2 = (160000 - 10000)\times\frac{4}{15} = 40000$$

$$B_2 = 110000 - 40000 = 70000$$

$$D_3 = (160000 - 1000)\times\frac{3}{15} = 30000$$

$$B_3 = 70000 - 30000 = 40000$$

$$D_4 = (160000 - 10000)\times\frac{2}{15} = 20000$$

$$B_4 = 40000 - 20000 = 20000$$

$\therefore$ Difference between value of straight line method and sum of years digit method

$= 40000 - 20000 = 20000$

Question 36

A function is defined in Cartesian coordinate system as $f(x,y) = xe^y$. The value of directional derivative of the function (in integer) at point $(2,0)$ along the direction of straight line segment from point $(2,0)$ to point $(1/2,2)$ is_____.

Ans. 1

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

$\nabla\phi = \nabla f$

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

$$\nabla\phi = e^y\hat{i} + xe^y\hat{j} + 0\hat{k}$$

$$\nabla\phi_{(2,0)} = \hat{i} + 2\hat{j}$$

$$\vec{a} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} = -\frac{3}{2}\hat{i} + 2\hat{j}$$

$$\hat{n} = \frac{\vec{a}}{|\vec{a}|} = \frac{-\frac{3}{2}\hat{i} + 2\hat{j}}{\sqrt{\left(-\frac{3}{2}\right)^2 + (2)^2}}$$

$$\hat{n} = \frac{2}{5}\left(-\frac{3}{2}\hat{i} + 2\hat{j}\right) = -\frac{3\hat{i}}{5} + \frac{4}{5}\hat{j}$$

$$DD = \nabla f \cdot \hat{n} = -\frac{3}{5} + 2\times\frac{4}{5} = 1$$

Question 37

A lake has a maximum depth of 60 m. If the mean atmospheric pressure in the lake region is 91 kPa and unit weight of lake 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. **(678 – 679)**

Sol. **Given :** $P_{atm} = 91$ KPa , $h = 60$ m

Unit weight of lake water = 9790N/m^2

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

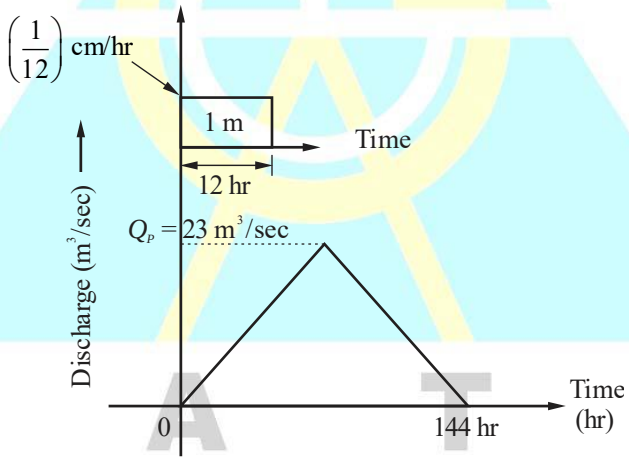
$$= \left(91 + \frac{9790\times 60}{1000}\right) \text{KPa} = 678.4 \text{ KPa}$$

Question 38

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 catchment (in km^2 , round off to the nearest integer) is_____.

Ans. **(596 – 597)**

Sol.



Let, catchment area = A km^2

We know that, Area of hydrograph = [(Area of 12 hr hyetograph) × Catchment area]

$$\frac{1}{2}\times 144\times 23\times 60\times 60 = \left(12\times\frac{1}{12}\times\frac{1}{100}\right) A\times 10^6 \text{ m}^2$$

$$A = 596.16 \text{ km}^2$$

Question 39

A horizontal angle θ is measured by four different surveyors multiple times and the values reported are given below. The most probable value of the angle θ (in degree, round off to two decimal places) is_____.

Surveyor	Angle (θ)	Number of observation
1	$36^0 30'$	4
2	$36^0 00'$	3

3	$35^0 30'$	8
4	$36^0 30'$	4

Ans. 36^0

Sol.

$$MPV = \frac{\Sigma \text{ (angle} \times \text{No. of observation)}}{\text{No. of observation}}$$

$$MPV = \frac{36^0 30' \times 4 + 36^3 \times 3 + 35^0 30 \times 8 + 36^0 30' \times 4}{19} = 36^0$$

Question 40

The smallest eigen value and corresponding eigen vector at matrix $\begin{bmatrix} 2 & -2 \\ -1 & 6 \end{bmatrix}$ is :

(A) 1.55 and $\begin{bmatrix} -2.55 \\ -0.45 \end{bmatrix}$ (B) 1.55 and $\begin{bmatrix} 2.00 \\ -0.45 \end{bmatrix}$ (C) 2.00 and $\begin{bmatrix} 1.00 \\ 1.00 \end{bmatrix}$ (D) 1.55 and $\begin{bmatrix} 2.00 \\ 0.45 \end{bmatrix}$

Ans. D

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

$\lambda^2 - tr\lambda + [A] = 0$

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

$\lambda = 1.55$

$[A]X = \lambda[X]$

$[A - \lambda I]X] = 0$

$$\begin{bmatrix} .45 & -2 \\ -1 & 4.45 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$45\,x - 2y = 0$

$45x = 2y$

$$\frac{x}{y} = \frac{2}{0.45}$$

Hence, the correct option is (C).

Question 41

The unit normal vector to the surface $x^2 + y^2 + z^2 - 48 = 0$ at the point $(4,4,4)$ is :

(A) $\frac{2}{\sqrt{2}}, \frac{2}{\sqrt{2}}, \frac{2}{\sqrt{2}}$ (B) $\frac{1}{\sqrt{5}}, \frac{1}{\sqrt{5}}, \frac{1}{\sqrt{5}}$ (C) $\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}$ (D) $\frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}}$

Ans. C

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

$$\text{Grad}\,\phi = \vec{\nabla}\phi = \hat{i}\frac{\partial \phi}{\partial x} + \hat{j}\frac{\partial \phi}{\partial y} + \hat{k}\frac{\partial \phi}{\partial z}$$

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

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

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

$$\hat{n} \simeq \left(\frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}}\right)$$

Hence, the correct option is (C).

Question 42

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

(A) $y = kx\ln(k)$ (B) $y = x\ln(kx)$ (C) $y = k\ln(kx)$ (D) $y = x\ln(x)$

Ans. **B**

Sol. **Given :**

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

We know that, $\frac{dy}{dx} + Py = 0$

$\therefore$ $P = -\frac{1}{x}$ and $Q = 1$

Integration factor (I.F.) $= e^{\int P dx} = e^{\int \frac{-1}{x} dx} = \frac{1}{x}$

$\therefore$ General solution is given by,

$$y(IF) = \int Q(IF)dx + c$$

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

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

Hence, the correct option is (B).

Question 43

A reservoir with live storage of 300 million cubic meter irrigates 40000 hectares $(1\,\text{hectare} = 10^4\ \text{m}^2)$ of a crop with 2 filling of 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. **(691 - 691.5)**

Sol. **Given :**

Live storage = 300 Mm^3

Area = 40000 hectare

2 filling $= 2 \times 300 = 600\ \text{Mm}^3$

Volume of water added $= 600\ \text{Mm}^3$

Base period (B) = 120 days

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

$$\because \quad \Delta = \frac{600\times10^6\,\text{m}^3}{40000\times10^4} = 1.5\ \text{m}$$

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

Question 44

The internal (d_i) and external (d_0) diameter of a shel by 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. **17.36**

Sol. **Given :**

Internal diameter of sampler, $D_i = 48$ mm

External diameter of sampler, $D_0 = 52$ mm

$$\therefore \text{ Area ratio, } \quad A_r = \frac{D_0^2 - D_i^2}{D_i^2}\times100$$

$$A_r = \frac{52^2 - 48^2}{48^2}\times100 = 17.36\%$$

Question 45

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) $\frac{1}{2}$ (D) $\frac{2}{3}$

Ans. **D**

Sol. We know that,

In case of laminar flow for circular pipe,

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

Energy correction factor $(\alpha) = 2$

$$\therefore \quad \left(\frac{\beta}{\alpha}\right) = \left(\frac{4}{3\times2}\right) = \left(\frac{2}{3}\right)$$

Hence, the correct option is (D).

Question 46

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

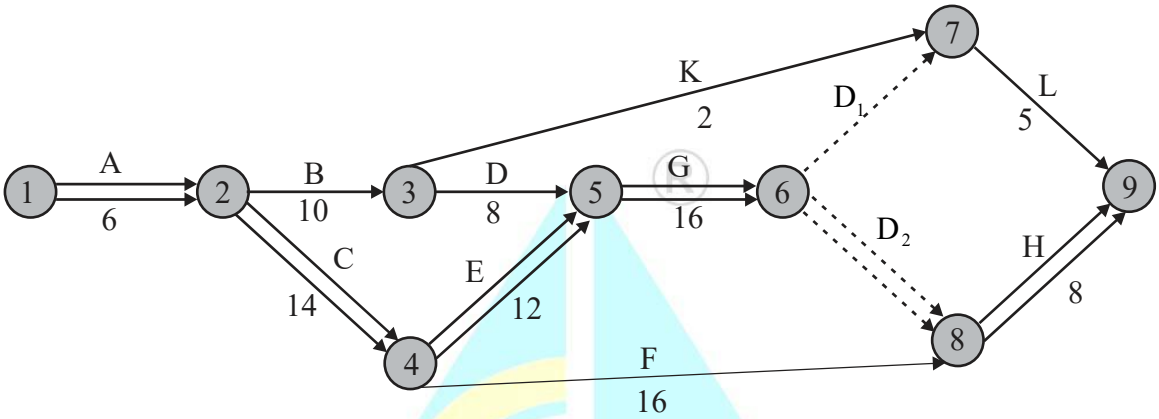
Activity	Duration (days)	Depends on
A	6	-
B	10	A
C	14	A
D	8	B
E	12	C
F	8	C
G	16	D, E

H	8	F, G
K	2	B
L	5	G, K

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

Ans. **56**

Sol. From the above given data we can draw different path of completion in following way.



Here, D_1, D_2 are dummy activities

Critical path = longest duration path

∴ **Total paths :**

(i) A – B – K - L = 23 days

(ii) A – B – D - G - D_1 - L = 45 days

(iii) A – B – D - G – D_2 - H = 48 days

(iv) A – C – E - G - D_1 - L = 53 days

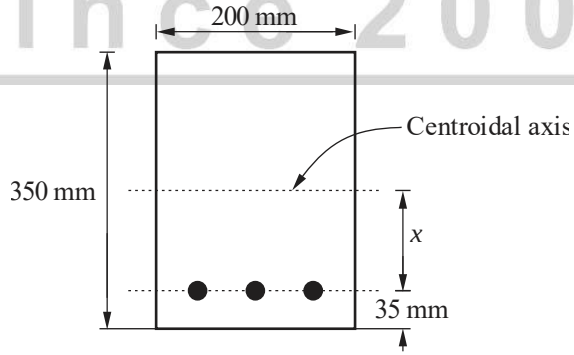
(v) A – C – E - G – D_2 - H = 56 days

(vi) A – C – E - F - H = 36 days

∴ 5^{th} path is longest path which takes 56 days to complete project hence it is critical.

Question 47

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 _____.

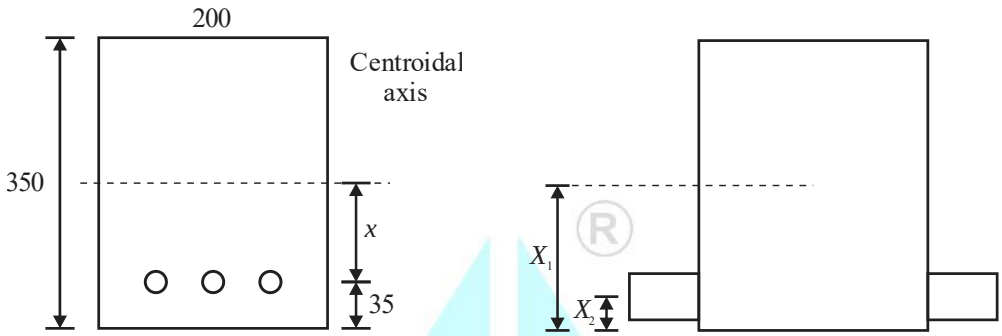
Ans. **(129.3 - 129.7)**

Sol. **Given :**

Diameter of reinforcement bar $(d) = 16$ mm

$E_c = 2\times10^{10^4}$ MPa

$E_s = 2.1\times10^5$ MPa



We know that,

Moduler ratio $m = \dfrac{E_s}{E_c} = \dfrac{2.1\times10^5}{2\times10^4} = 10.5$

$\therefore \quad mA_{st} = 10.5\times\dfrac{\pi}{4}\times16^2\times3$

$mA_{st} = 6333.45 \text{ mm}^2$

$mA_{st} - A_{st} = 5730.27 \text{ mm}^2$

Now, centroid of beam, $\bar{X} = \dfrac{A_1X_1 + A_2X_2}{A_1 + A_2}$

$$\bar{X} = \frac{\left[200\times350\times\dfrac{350}{2}\right] + [5730.27\times35]}{(200\times350) + [5730.27]}$$

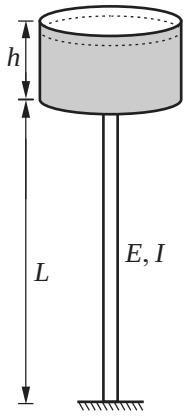
$\bar{X} = 164.41$ mm

The distance of centroidal axis from centre line of reinforcement-

$x = 164.41 - 35 = 129.41$ mm

Question 48

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^3/s



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 _____.

Ans. **(2.68 - 2.72)**

Sol. **Given :**

Diameter of solid steel column, $D = 0.075$ m

Height of column, $L = 4$ m

$\therefore$ Effective length of column, $L_e = 2L = 8$ m

By Euler's formula, $P_E = \dfrac{\pi^2 EI}{L_e^2}$

$$P_E = \frac{\pi^2 \times 200 \times 10^9 \times \frac{\pi}{64} \times 0.075^4}{8^2}$$

$$P_E = 47903.22 \text{ N}$$

$$F_{Bottom} = \rho g h \times \frac{\pi}{4} \times 1.5^2$$

$$F_{Bottom} = 1000 \times 10 \times h \times \frac{\pi}{4} \times 1.5^2$$

$$F_{Bottom} = 17671.45868h \text{ N}$$

To avoid buckling, $F_{Bottom} \le P_E$

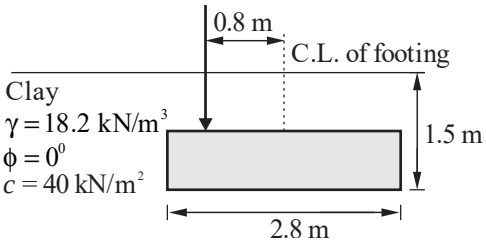
$$17621.45868h \le 47903.22$$

$$h \le 2.71 \text{ m}$$

$\therefore$ $h_{max} = 2.7$ m

Question 49

A rectangular footing of size $2.8 \text{ m} \times 3.5 \text{ m}$ 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 : $d_i = 1.1$, $d_q = 1.0$ 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 with a factor of safety of 2.5 is _____

Ans. **(440 - 441)**

Sol. Using meyerhoff formula,

$$q_u = CN_cS_cD_c + \gamma DN_qS_qD_q + 0.5\gamma BN_\gamma S_\gamma D_\gamma$$

We have, $C = 40\ \text{kN/m}^2$, $\gamma = 18.2\ \text{kN/m}^3$, $N_c = 5.14$, $S_c = 1.16$, $D_c = 1.1$,

$FOS = 2.5$, $D = 1.5\ \text{m}$, $S_q = 1$, $D_q = 1$

$$q_u = 40\times5.14\times1.16\times1.1\times1 + (18.2\times1.5)\times1\times1\times1$$

$$q_u = 262.3456 + 27.3$$

$$q_{nu} = 262.3456\ \text{kN/m}^2$$

$$q_{ns} = \frac{262.3456}{2.5} = 104.94\ \text{kN/m}^2$$

Reduced area $= (B-2e)\times L = (2.8-2\times0.8)\times3.5 = 4.2\ \text{m}^2$

$\therefore$ Net safe load $= 104.94\times4.2 = 440.75\ \text{kN}$

Question 50

A clay layer of thickness H has a preconsolidation pressure p_c and an initial void ratio e_0. The initial effective overburden stress at the mid-height of the layer is p_0. 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 $p_0 < p_c < (p_0 + \Delta p)$, then the correct expression to estimate the consolidation settlement (s_c) of the clay layer is

(A) $s_c = \frac{H}{1+e_0}\left[C_c \log\frac{p_0}{p_c} + C_c \log\frac{p_0+\Delta p}{p_c}\right]$

(B) $s_c = \frac{H}{1+e_0}\left[C_c \log\frac{p_c}{p_0} + C_c \log\frac{p_0+\Delta p}{p_c}\right]$

(C) $s_c = \frac{H}{1+e_0}\left[C_s \log\frac{p_c}{p_0} + C_c \log\frac{p_0+\Delta p}{p_c}\right]$

(D) $s_c = \frac{H}{1+e_0}\left[C_s \log\frac{p_0}{p_c} + C_c \log\frac{p_0+\Delta p}{p_c}\right]$

Ans. **C**

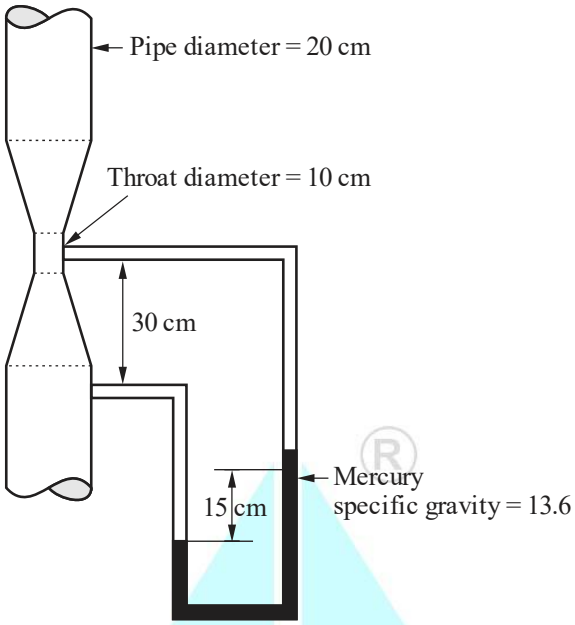
Sol. Consolidation settlement is given by,

$$S_c = \frac{H}{1+e_0}\left[c_s \log_{10}\left(\frac{P_c}{P_0}\right) + c_c \log_{10}\left(\frac{P_0+\Delta P}{P_c}\right)\right]$$

Hence, the correct option is (C).

Question 51

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 $g = 9.8\ \text{m/s}^2$. 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. **(49.10 – 49.52)**

Sol. We known that

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

$$h = X\left(\frac{\rho_m}{\rho} - 1\right)$$

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

$$Q = \frac{A_1 A_2}{A_2\sqrt{\left(\frac{A_1}{A_2}\right)^2 - 1}} \times \sqrt{2\times9.81\times1.89}$$

$$Q = \frac{\frac{\pi}{4}(0.2)^2}{\sqrt{(2)^4 - 1}} \times \sqrt{2\times9.81\times1.89} = 49.395\ l/\text{s}$$

∴ Flow rate considering no loss in venturimeter is 49.10 liter/sec.

Question 52

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

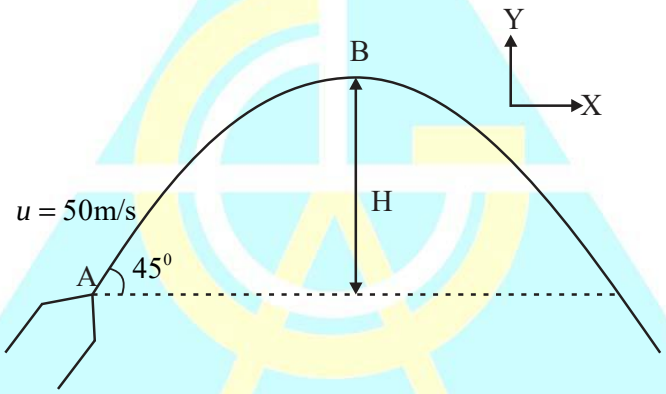
Ans. **D**

Question 53

A fire hose nozzle directs a steady stream of water of velocity 50 m/s at an angle of 45^0 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 $9.81\ \text{m/s}^2$. The maximum height (in m, round off to two decimal places) reached by the stream above the hose nozzle will then be_____.

Ans. **(63.5 – 64)**

Sol.



$g = 9.81\ \text{m/sec}^2$

At point A, $U_{AX} = u\cos 45 = 50\cos 45 = \frac{50}{\sqrt{2}}\text{m/s}$

$U_{AY} = u\sin 45 = 50\sin 45 = \frac{50}{\sqrt{2}}\text{m/s}$

At point B, $U_{BY} = 0$

Between A and B, (using equations $V_y^2 = u_y^2 + 2a_y s_y$ in y direction)

$V_y = u_{By} = 0$

$u_y = u_{Ay} = \frac{50}{\sqrt{2}}\text{m/s}$

$a_y = -g = -9.81\text{m/s}^2$

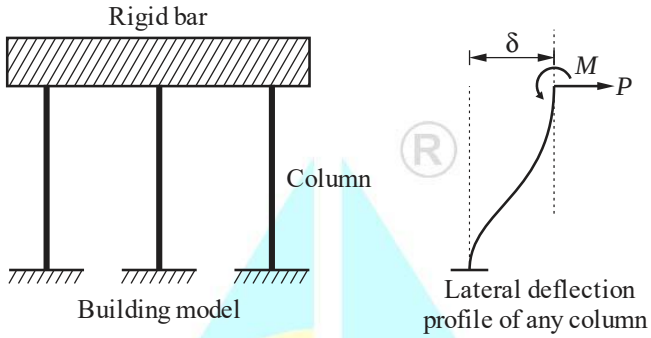
$S_y = H$

$O^2 = \left(\frac{50}{\sqrt{2}}\right)^2 + 2(-9.81)(H)$

$H = 63.71\text{m}$

Question 54

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.

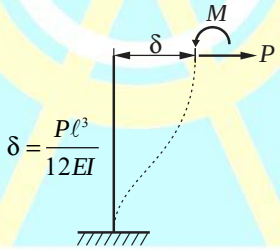


For the lateral deflection profile of the columns as shown in the figure, the natural frequency of the system for horizontal oscillation is

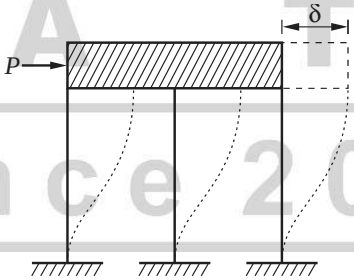
(A) $\frac{2}{L}\sqrt{\frac{EI}{m}}$ rad/s (B) $\sqrt{\frac{6EI}{mL^3}}$ rad/s (C) $6\sqrt{\frac{EI}{mL^3}}$ rad/s (D) $\frac{1}{L}\sqrt{\frac{2EI}{m}}$ rad/s

Ans. C

Sol. 1. For one column



For combined system



$$\delta = \frac{P\ell^3}{36EI} = \frac{P}{K}$$

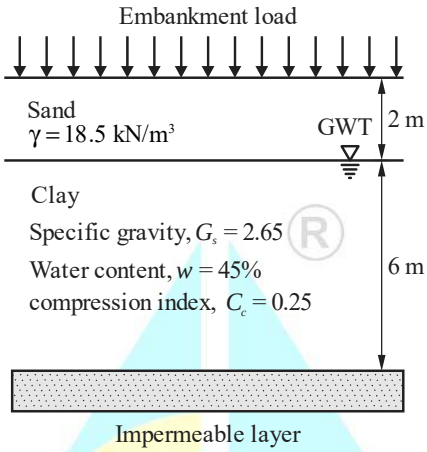
$$K = \frac{36EI}{\ell^3}$$

$$w = \sqrt{\frac{K}{m}} = 6\sqrt{\frac{EI}{m\ell^3}} \text{ rad/sec}$$

Hence, the correct option is (C).

Question 55

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 t 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 $\gamma_w = 9.81$ 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. **(0.328 – 0.334)**

Sol. **Given :**

$G = 2.65$

$w = 45\%$

$c_c = 0.25$

We know that, $e \times s = w \times G$

$$e = 0.45 \times 2.65$$

$$\therefore \quad e = 1.1925$$

$$\gamma_{sat} = \frac{\gamma_w (G+e)}{1+e}$$

$$\gamma_{sat} = \frac{2.65+1.1925}{1+1.1925} \times 9.81 = 17.193 \text{ kN/m}^3$$

Effective stress, $\bar{\sigma}_0 = 18.5 \times 2 + (17.193 - 9.81) \times 3$

$$\bar{\sigma}_0 = 59.148 \text{ kN/m}^2$$

Primary consolidation settlement,

$$\Delta H = \frac{c_c H_0 \log_{10}\left(\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}\right)}{1+e_0}$$

$$\Delta H = \frac{0.25 \times 6 \times \log_{10}\left(\frac{180}{59.148}\right)}{1+1.1925}$$

$$\Delta H = 0.331 \text{ m}$$

$\therefore$ Primary consolidation settlement of clay layer from loading is 0.331 m.

General Aptitude

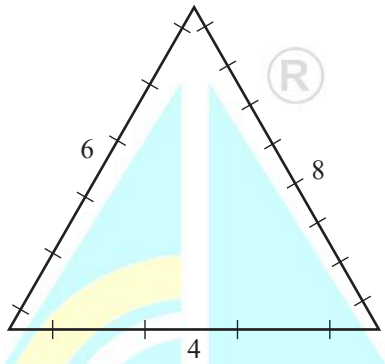
Question 1

In an equilateral triangle *PQR*, side *PQ* is divided in 4 equal parts, side *QR* is divided into 6 equal parts and *PR* is divided into 8 equal parts. The length of each sub-divided part in cm is an integer. The minimum area of triangle *PQR* possible, in cm^2, is

(A) 18 (B) $144\sqrt{3}$ (C) $48\sqrt{3}$ (D) 24

Ans. B

Sol.



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 $a = 24$

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

Hence, the correct option is (B).

Question 2

$\oplus$ and $\odot$ are 2 operators on numbers p and q such that $p \odot q = p - q$ and $p \oplus q = p \times q$ then

$$(9 \odot (6 \oplus 7)) \odot (7 \oplus (6 \odot 5)) =$$

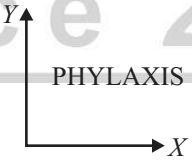
(A) 40 (B) –40 (C) –33 (D) –26

Ans. B

Sol. $[9-(6\times 7)]-[7\times 1] = -33-7 = -40$

Hence, the correct option is (B).

Question 3



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

(A) PHYLAXIS (B) ꟻHYLAXIS

(C) ꟻHYLAXIS (D) ԀHYLAXIS

Ans. C

Sol.

ꟻHYLAXIS

Hence, the correct option is (C).

Question 4

2 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) $\frac{1}{4}$ (B) $\frac{1}{12}$ (C) $\frac{1}{8}$ (D) $\frac{1}{36}$

Ans. A

Sol. $E_1 \rightarrow$ occurrence of even number on first dice

$E_2 \rightarrow$ occurrence of even number on second dice

$$P(E_1) = \frac{3}{6} = \frac{1}{2}$$

$$P(E_1) = \frac{3}{6} = \frac{1}{2}$$

$$P(E_1 \cap E_2) = P(E_1) \times P(E_2) = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$$

Hence, the correct option is (A).

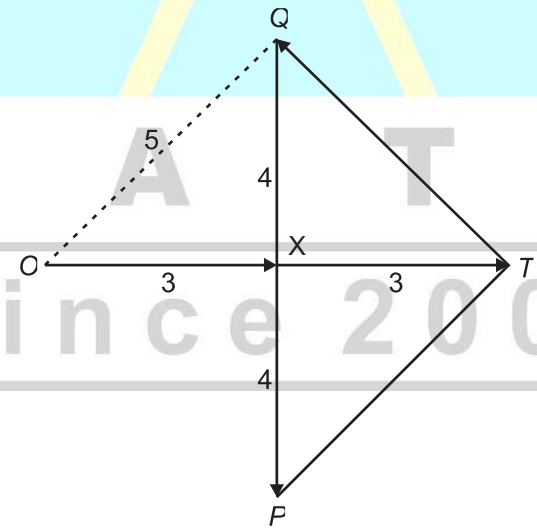
Question 5

On a planer 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 north-east direction such that you arrive at a point that is 6 units east of point O. Next, you travelled in the NW 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 same units, should be_____.

(A) 6 (B) 4 (C) 5 (D) 3

Ans. C

Sol.



The distance between point Q to point O is,

$$OQ = \sqrt{OX^2 + XQ^2}$$

$$OQ = \sqrt{3^2 + 4^2} = \sqrt{9+16}$$

$$OQ = \sqrt{25}$$

$OQ = 5$ units

Hence, the correct option is (C).

Question 6

(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) 1 and 2 (B) 1 and 4 (C) 2 and 4 (D) 3 and 4

Ans. **B**

Question 7

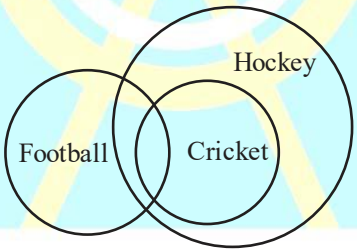
1. Some football players play cricket
2. All cricket players play hockey

Among the options given below, the statement that logically follows from the two statements 1 and 2 above, is :

(A) All football players play hockey (B) Some football players play hockey
(C) No football player plays hockey (D) All hockey players play football

Ans. **B**

Sol.



Hence, the correct option is (B).

Question 8

4 person P, Q, R, S are to be seated in row R should not be seated in 2nd position from left end of row. The number of distinct seating arrangement possible is :

(A) 6 (B) 18 (C) 24 (D) 9

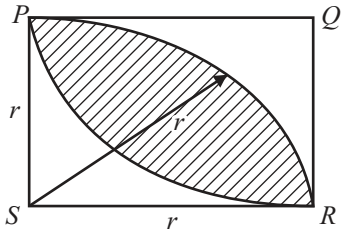
Ans. **B**

Sol. Number of arrangements $= 3 \times 3! = 18$

Hence, the correct option is (B).

Question 9

In the figure PQRS is a square. the shaded portion is formed by intersection of sectors of circle with radius equal to the side of square and center at S and Q.

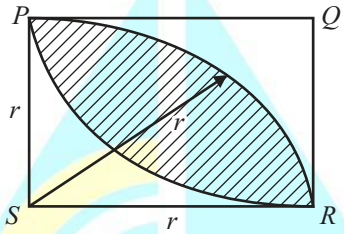


The probability that any point picked randomly within square falls in shaded area is

(A) $\frac{1}{2}$ (B) $4-\frac{\pi}{2}$ (C) $\frac{\pi}{2}-1$ (D) $\frac{\pi}{4}$

Ans. C

Sol.



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

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

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

Hence, the correct option is (C).

Question 10

The author said, "musicians rehearse before their concerts. Actors rehearse there roles before the opening of new play. On the other hand, I find it strange that many public speakers thick they can just walk on the stage and start speaking. In my opinion, it is no less important for public speakers to rehearse talks."

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

(A) The author is of the opinion that rehearsing is more important only for musicians than 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 important for musicians, actors and public speakers.

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

Ans. A