Section-I: General Ability

1. "His face ___________ with joy when the solution of the puzzle was __________ to him."
The words that best fill the blanks in the above sentence are
(A) Shone, shown (B) shone, shone (C) shown, shone (D) shown, shown

Key: (A)

2. "Although it does contain some pioneering ideas, one would hardly characterize the work as _______."
The words that best fill the blanks in the above sentence is
(A) innovative (B) simple (C) dull (D) boring

Key: (B)

3. $\underbrace{a+a+a+.....+a}_{\text{n times}}=a^2b$ and $\underbrace{b+b+b+.....+b}_{\text{m times}}=ab^2$, where a,b,n and m are natural numbers.
What is the value of
$\left(\underbrace{m+m+m+.....+m}_{\text{n times}}\right)\left(\underbrace{n+n+n+.....+n}_{\text{m times}}\right)$?
(A) $2a^2b^2$ (B) a^4b^4 (C) $ab(a+b)$ (D) a^2+b^2

Key: (B)

Exp: Given

$$\underbrace{a+a+.....+a}_{n-\text{times}}=a^2b$$

$$\Rightarrow na=a^2b$$
$$\Rightarrow n=ab----(1)$$

$$\text{given } \underbrace{b+b+...+b}_{m-\text{times}}=ab^2$$

$$\Rightarrow mb=ab^2$$
$$\Rightarrow m=ab-----(2)$$

$$\therefore \left(\underbrace{m+m+...+m}_{n-\text{times}}\right)\left(\underbrace{n+n+...+n}_{m-\text{times}}\right)=mn\times mn$$

$$=(mn)^2$$
$$=\left(a^2b^2\right)^2\left(\because \text{from}(1)\&(2)\right)$$
$$=a^4b^4$$

4. A three-member committee to be formed from a group of 9 people. How many such distinct committees can be formed?

(A) 27 (B) 72 (C) 81 (D) 84

Key: (D)

Exp: $9C_3 = \frac{9!}{3!(9-3)!} = \frac{9\times8\times7}{6} = 84$

5. For a non-negative integers, a, b, c, what would be the value of a + b + c if

log a + log b + log c=0?

(A) 3 (B) 1 (C) 0 (D) -1

Key: (A)

Exp: $\log a + \log b + \log c = 0$

$\Rightarrow \log abc = 0$

$\Rightarrow abc = 1$

$\Rightarrow a = b = c = 1$

$a + b + c = 3$

6. A faulty wall clock is known to gain 15minutes every 24 hours. It is synchronized to the correct time at 9AM on 11th July. What will be the correct time to the nearest minute when the clock shows 2PM on 15th July of the same year?

(A) 12:45PM (B) 12:58PM (C) 1:00PM (D) 2:00PM

Key: (B)

Exp: Clock is gaining 15 min. in every 24 hours

$\Rightarrow$ Gaining per hour $= \frac{15}{24}$ minutes

No. of hours from 11th July 9am to 15th July 2pm =101

Total time gain $= 101 \times \frac{15}{24} \simeq 63$ min.

$\therefore$ correct time $=$ 2pm $-$ 63 min $\simeq$ 12.58 pm

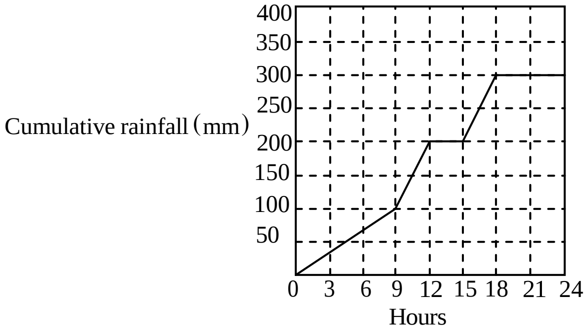
7. The annual average rainfall in a tropical city is 1000mm. On a particular rainy day (24-hour period), the cumulative rainfall experienced by the city is shown in the graph. Over the 24-hour period, 50% of the rainfall falling on a rooftop, which had an obstruction free area of $50m^2$, was harvested into a tank. What is the total volume of water collected in the tank in liters?

(A) 25,000

(B) 18,750

(C) 7,500

(D) 3,125



Key: **(C)**

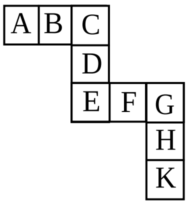
Exp: Cumulative rain fall = 300mm = 0.3m

$50\%\text{ of rain fall} = \frac{0.3}{2} = 0.15\text{m}$

Total volume of water collected in tank $= 50 \times 0.15$

$= 7.5\text{m}^3 = 7500\text{ litre}$

8. Each of the letters in the figure below represents a unique integer from 1 to 9. The letters are positioned in the figure such that each of (A+B+C), (C+D+E), (E+F+G) and (G+H+K) is equal to 13. Which integer does E represent?



(A) 1 (B) 4 (C) 6 (D) 7

Key: **(B)**

Exp: According to the question

$A+B+C = C+D+E = E+F+G = G+H+K = 13$

$\text{Adding all} \Rightarrow A+B+2C+D+2E+F+2G+H+K = 52 ....(1)$

&

$A+B+C+D+E+F+G+H+K = 45 ....(2)$

$(\because \text{sum of no's from 1 to 9})$

$(1)-(2) \Rightarrow C+E+G = 7 ....(3)$

$\text{and also } C+D+E = 13 ....(4)$

$(4)-(3) \Rightarrow D-G = 6$

$$\begin{array}{r} C+D+E=13 \\ -\quad E+F+G=13 \\ \hline (C-F)+(D-G)=0 \end{array}$$

$\Rightarrow (D-G) = (F-C)$

$\Rightarrow (F-C) = 6 \quad (\because D-G=6)$

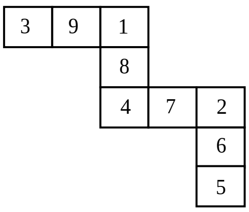
Possible differences for getting '6' are $9-3=6$

$7-1=6$

$8-2=6$

But suitable differences for (D-G) &(F-C) are 8-2 &7-1

$\therefore$ structure of numbers satisfying given conditions is



$\Rightarrow E = 4$

9. In manufacturing industries, loss is usually taken to be proportional to the square of the deviation from a target. If the loss is Rs. 4900 for a deviation of 7 Units, what would be the loss in Rupees for a deviation of 4 units from the target?

(A) 400 (B) 1200 (C) 1600 (D) 2800

Key: **(C)**

Exp: Given Loss $\alpha\left(\text{Deviation}\right)^2$

$\Rightarrow \boxed{\text{Loss} = K\left(\text{Deviation}\right)^2}$ where K is a proportionality constant

Given loss = 4900, Deviation = 7

$$\Rightarrow 4900 = K(7)^2$$
$$\Rightarrow K = 100$$

For a deviation of 4 units, Loss $= 100(4)^2$
$$= 1600$$

10. Given that $\dfrac{\log P}{y-z} = \dfrac{\log Q}{z-x} = \dfrac{\log R}{x-y} = 10$ for $x \neq y \neq z$, what is the value of the product PQR?

(A) 0 (B) 1 (C) xyz (D) 10^{xyz}

Key: **(B)**

Exp: $\log P = 10(y-z)$

$\log Q = 10(z-x)$

$\log R = 10(x-y)$

$\Rightarrow \log P + \log Q + \log R = 10(y-z+z-x+x-y)$

$$\Rightarrow \log PQR = 0$$
$$\Rightarrow PQR = 1$$

Section-II: Civil Engineering

1. The clay mineral, whose structural units are held together by potassium bond is

(A) Halloysite (B) Illite (C) Kaolinite (D) Smectite

Key: (B)

2. As per IS 10500:2012, for drinking water in the absence of alternate source of water, the permissible limits for chloride and sulphate, in mg/L, respectively are

(A) 250 and 200 (B) 1000 and 400 (C) 200 and 250 (D) 500 and 1000

Key: (B)

Exp: Acceptable limits for Drinking water, as per IS 10500:2012

Chlorides - 250 mg/l

Sulphates – 200 mg/l

But in the absence of alternate source of water, the permissible limits are extended -

Chlorides - 1000 mg/l

Sulphates – 400 mg/l

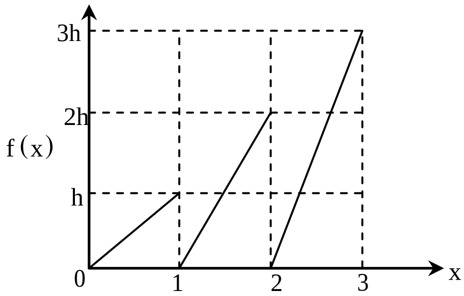
3. Dupuit's assumptions are valid for

(A) artesian aquifer (B) confined aquifer

(C) leaky aquifer (D) unconfined aquifer

Key: (D)

4. The graph of a function f(x) is shown in the figure.



For f(x) to be a valid probability density function, the value of h is

(A) 1/3 (B) 2/3 (C) 1 (D) 3

Key: (A)

Exp: Since f(x) is a valid probability density function

$$\Rightarrow \int_0^1 f(x)dx + \int_1^2 f(x)\,dx + \int_2^3 f(x)dx = 1$$

$$\Rightarrow \int_0^1 hxdx + \int_1^2 2h(x-1)dx - \int_2^3 3h(x-2)dx = 1$$

$$\Rightarrow h\frac{x^2}{2}\Big|_0^1 + 2h\left(\frac{x^2}{2} - x\right)\Big|_1^2 + 3h\left(\frac{x^2}{2} - 2x\right)\Big|_2^3 = 1 \Rightarrow 3h = 1 \Rightarrow h = \frac{1}{3}$$

5. The quadratic equation $2x^2-3x+3=0$ is to be solved numerically starting with an initial guess as $x_0=2$. The new estimate of x after the first iteration using Newton-Raphson method is _______

Key: **(1)**

Exp: $f(x) = 2x^2 - 3x + 3$

$\Rightarrow f^1(x) = 4x - 3$

Given $x = 2$

New estimate of 'x' after 1^{st} iteration,

$$x_1 = x_0 - \frac{f(x_0)}{f^1(x_0)}$$

$$= 2 - \frac{f(2)}{f^1(2)} = 2 - \frac{5}{5} = 1$$

6. A probability distribution with right skew is shown in the figure.

The correct statement for the probability distribution is
(A) Mean is equal to mode
(B) Mean is greater than median but less than mode
(C) Mean is greater than median and mode
(D) Mode is greater than median

Key: **(C)**

Exp: For right skew

Mode < media < mean

&

For left skew

Mean < Median < Mode

7. The solution of the equation $x\frac{dy}{dx} + y = 0$ passing through the point (1,1) is

(A) x (B) x^2 (C) x^{-1} (D) x^{-2}

Key: **(C)**

Exp: $\frac{xdy}{dx} + y = 0$

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

Integrating

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

$$\Rightarrow \log_e y = -\log_e x + \log_e c$$

$$= \log_e (c/x)$$

$$\Rightarrow y = \frac{c}{x}$$

$$(1,1) \Rightarrow c = 1$$

$$\therefore y = \frac{1}{x} = x^{-1}$$

8. As per IS 456:2000, the minimum percentage of tension reinforcement (up to two decimal places) required in reinforced concrete beams of rectangular cross section (considering effective depth in the calculation of area) using Fe500 grade steel is ___________

Key: (0.17)

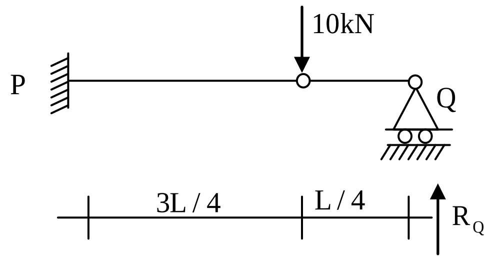
Exp: Min. percentage of tension reinforcement

$$\frac{A_s}{bd} = \frac{0.85}{f_y}$$

$$\frac{A_s}{bd} = \frac{0.85}{f_y}$$

$$= \frac{0.85}{500} \times 100 = 0.17\%$$

9. A vertical load of 10kN acts on a hinge located at a distance of L/4 from the roller support Q of a beam of length L (see figure).



The vertical reaction at support Q is

(A) 0.0kN (B) 2.5kN (C) 7.5kN (D) 10.0kN

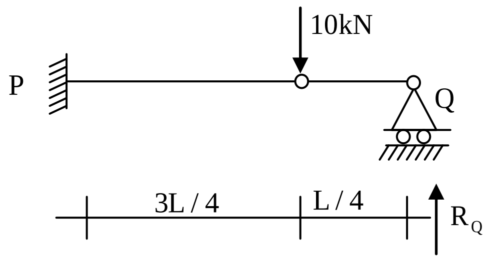
Key: (A)

Exp: Let R_Q be the support reaction at Q.

For equilibrium, $\Sigma M_c = 0$

$$R_Q \times \frac{1}{4} = 0$$

$$\Rightarrow R_Q = 0$$



10. Probability (up to one decimal place) of consecutively picking 3 red balls without replacement from a box containing 5 red balls and 1 white ball is _______

Key: (0.5)

Exp: 5 Red

1 white

$$\text{Required probability} = \frac{5}{6}\times\frac{4}{5}\times\frac{3}{4}$$
$$= \frac{1}{2} = 0.5$$

11. The intensity of irrigation for the Kharif season is 50% for an irrigation project with culturable command area of 50,000 hectares. The duty for the Kharif season is 1000 hectare/cumec. Assuming transmission loss of 10%, the required discharge (in cumec, up to two decimal places) at the head of the canal is __________.

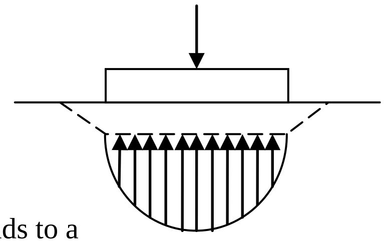
Key: (27.78 cumecs)

Exp: $\text{Area} = 50,000 \text{ hectares}$

$\text{Duty} = 1000 \text{ hectare/cumec.}$

$$\text{Discharge}(Q) = \frac{\text{Area}}{\text{Duty}} = \frac{50\% \text{ of } 50000}{90\% \text{ of } 1000} = \frac{25000}{900} = 27.78 \text{ cumecs.}$$

12. The contact pressure and settlement distribution for a footing are shown in the figure.



The figure corresponds to a

(A) rigid footing on granular soil
(B) flexible footing on granular soil
(C) flexible footing on saturated clay
(D) rigid footing on cohesive soil

Key: (A)

13. A fillet weld is simultaneously subjected to factored normal and shear stresses of 120MPa and 50MPa, respectively. As per IS 800:2007, the equivalent stress (in MPa, up to two decimal places) is _________

Key: (147.99)

Exp: Equivalent shear stress as per IS:800-2007 is given by

$$f_e = \sqrt{f_a^2 + 3q^2}$$

Here, $f_a = 120\text{MPa}$ & $q = 50\text{MPa}$

$$\therefore f_e = \sqrt{(120)^2 + 3(50)^2} = 147.99\text{MPa}$$

14. As per IRC : 37-2012, in order to control subgrade rutting in flexible pavements, the parameter to be considered is

(A) horizontal tensile strain at the bottom of bituminous layer
(B) vertical compressive strain on top of subgrade
(C) vertical compressive stress on top of granular layer
(D) vertical deflection at the surface of the pavement

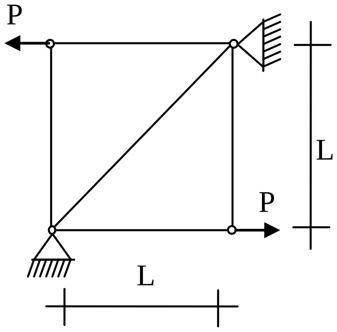
Key: (B)

15. The setting time of cement is determined using

(A) Le chatelier apparatus
(B) Briquette testing apparatus
(C) Vicat apparatus
(D) Casagrande's apparatus

Key: (C)

16. All the members of the planar truss (see figure), have the same properties in terms of area of cross section (A) and modulus of elasticity (E).

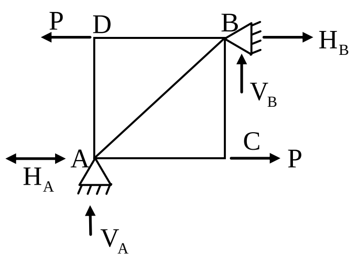


For the loads shown on the truss, the statement that correctly represents the nature of forces in the members of the truss is:

(A) There are 3 members in tension, and 2 members in compression
(B) There are 2 members in tension, 2 members in compression, and 1 zero-force member
(C) There are 2 members in tension, 1 member in compression, and 2 zero-force members
(D) There are 2 members in tension, and 3 zero-force members

Key: (D)

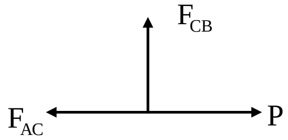
Exp:



$H_A + H_B = 0$
$H_A = H_B = P$

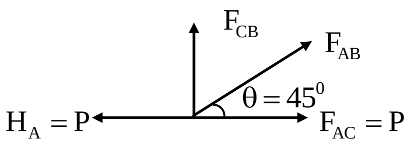
$\Sigma M_A = 0$
$V_B \times L + P \times L - H_B \times L = 0$
$V_B \times L = H_B \times L - P \times L$
$V_B = H_B - P = P - P = 0$
$V_A = 0.$

Joint C



$F_{AC} = P(\text{Tension})$
$F_{CB} = 0$

Joint A



$P = P + F_{AB} . \cos 45$

$F_{AB} = 0$

$F_{AD} + F_{AB} \sin 45 = 0$

$F_{AD} = 0$

Zero force members = AD, AB, BC

17. A reinforced concrete slab with effective depth of 80mm is simply supported at two opposite ends on 230mm thick masonry walls. The centre to centre distance between the walls is 3.3m. As per IS 456:2000. The effective span of the slab (in m, up to two decimal places) is _____

Key: **(3.15)**

Exp: Effective span: taken as lesser of two

(a) clear span + effective depth=(3.3-0.23) +0.08=3.15

(b) C/C distance between the walls=3.3m

$\therefore$ effective span =3.15m

18. The initial concavity in the load penetration curve of a CBR test is NOT due to

(A) uneven top surface (B) high impact at start of loading

(C) inclined penetration plunger (D) soft top layer of soaked soil

Key: **(B)**

Exp: Load penetration curve of CBR test is concave due to

i. Top layer of soaked soil is too soft (or) slushy after soaking in water
ii. The top surface of the specimen is not even
iii. The penetration plunger of the loading machine is not vertical resulting in the bottom surface of plunger not being horizontal and not fully in contact with top surface of the specimen.

19. Peak Hour factor (PHF) is used to represent the proportion of peak sub-hourly traffic flow within the peak hour. If 15-minute sub-hours are considered, the theoretically possible range of PHF will be

(A) 0 to 1.0 (B) 0.25 to 0.75 (C) 0.25 to 1.0 (D) 0.5 to 1.0

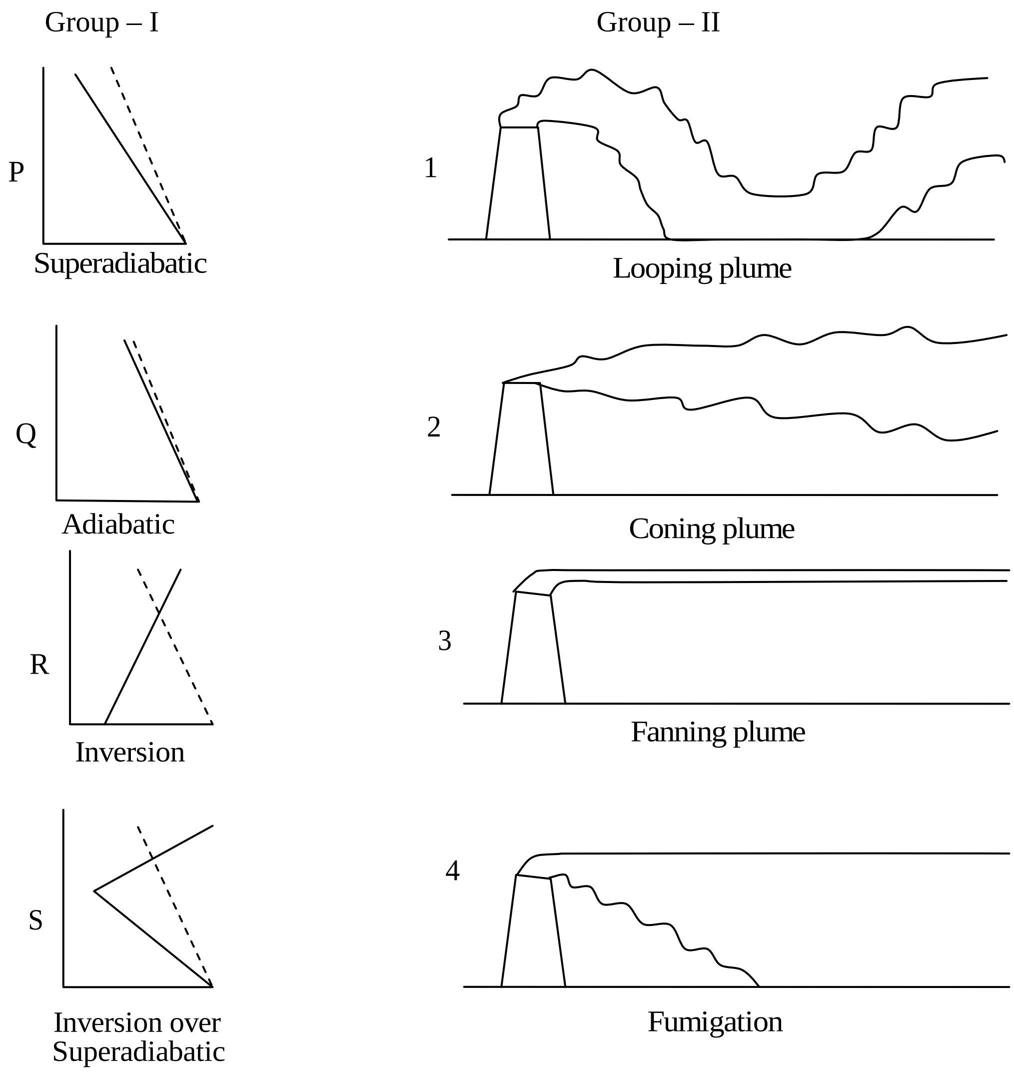
Key: **(C)**

Exp: Peak hour factor (PHF) is the hourly volume during maximum volume hour of day divided by the peak 15-minute flow rate within a peak hour.

The possible values of PHF can range b/w 0.25 and 1.00

20. In the figures, Group I represents the atmospheric temperature profiles (P,Q,R and S) and Group II represents dispersion of pollutants from a smoke stack (1,2,3 and 4). In the figures of

Group I, the dashed line represents the dry adiabatic lapse rate, whereas the horizontal axis represents temperature and the vertical axis represents the altitude.



The correct match is

(A) P-1, Q-2, R-3, S-4
(B) P-1, Q-2, R-4, S-3
(C) P-1, Q-4, R-3, S-2
(D) P-3, Q-1, R-2, S-4

Key: (A)

21. A flownet below a dam consists of 24 equipotential drops and 7 flow channels. The difference between the upstream and downstream water levels is 6m. The length of the flow line adjacent to the toe of the dam at exit is 1m. The specific gravity and void ratio of the soil below the dam are 2.70 and 0.70, respectively. The factor of safety against piping is

(A) 1.67 (B) 2.5 (C) 3.4 (D) 4

Key: (D)

Exp: $(FOS)_{piping} = \frac{i_{cr}}{i_{ex}}$

$$i_{cr} = \frac{G-1}{1+e} = \frac{2.70-1}{1+0.7} = \frac{1.7}{1.7} = 1$$

$$\Delta H = \frac{H}{N_d} = \frac{6}{24}$$

$$i_{exit} = \frac{\Delta H}{\Delta L} = \frac{6/24}{1} = \frac{1}{4}$$

$$(FOS)_{piping} = \frac{1}{1/4} = 4$$

22. A structural member subjected to compression, has both translation and rotation restrained at one end, while only translation is restrained at the other end. As per IS 456:2000, the effective length factor recommended for design is

(A) 0.50 (B) 0.65 (C) 0.70 (D) 0.80

Key: (D)

23. For a given discharge in an open channel, there are two depths which have the same specific energy. These two depths are known as

(A) alternate depths (B) critical depths (C) normal depths (D) sequent depths

Key: (A)

24. A culvert is designed for a flood frequency of 100 years and a useful life of 20 years. The risk involved in the design of the culvert (in percentage, up to two decimal places) is ________

Key: (18.2)

Exp: $\text{Risk} = 1 - q^n$

$$= 1 - \left(1 - \frac{1}{T}\right)^n$$

$$= 1 - \left(1 - \frac{1}{100}\right)^{20}$$

$$= 0.182$$

$$= 18.2\%$$

25. Which one of the following statements is NOT correct?

(A) When the water content of soil lies between its liquid limit and plastic limit, the soil is said to be in plastic state.

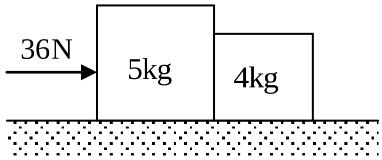
(B) Boussinesq's theory is used for the analysis of stratified soil.

(C) The inclination of stable slope in cohesive soil can be greater than its angle of internal friction.

(D) For saturated dense fine sand, after applying overburden correction, if the standard penetration Test value exceeds 15, dilatancy correction is to be applied.

Key: (B)

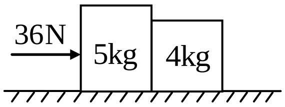
26. Two rigid bodies of mass 5 kg and 4 kg are at rest on a frictionless surface until acted upon by a force of 36N as shown in the figure. The contact force generated between the two bodies is



(A) 4.0N (B) 7.2N (C) 9.0N (D) 16.0N

Key: (D)

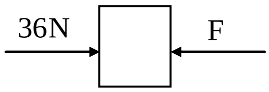
Exp:



$36N = 9 \times a \Rightarrow a = \frac{36}{9} = 4m/s^2$

$\text{Force on } 1^{st} \text{ blcok} = F = ma = 5 \times 4 = 20N$

FBD



$36 - F = 20$

$F = 36 - 20 = 16N$

27. A coal containing 2% sulphur is burned completely to ash in a brick kiln at a rate of 30 kg/min. The sulphur content in the ash was found to be 6% of the initial amount of sulphur present in the coal fed to the brick kiln. The molecular weights of S, H and O are 32, 1 and 16g/mole, respectively, The annual rate of sulphur dioxide (SO_2) emission from the kiln (in tonnes/year. up to two decimal places) is ________

Key: (592.87)

Exp: $\text{Total amount of coal} = 30 \times 24 \times 60 \times 365 = 15768000 \text{ kg in a year}$

$\text{Sulphur} = 2\% \text{ of coal} = \frac{2}{100} \times 15768000 = 315360\text{kg}$

$\text{sulphur content} = 6\% \text{ of } 315360 = 18921.6 \text{ kg in ash}$

$\text{remaining sulphur} = 0.94 \times 315360 = 296438.4\text{kg}$

$s + o_2 \rightarrow so_2$

$32\text{gm} \rightarrow 64 \text{ gm}$

$294638.4 \rightarrow ?$

$= \frac{64}{32} \times 296438.4$

$= 592876.8\text{kg}$

$= 592.87 \text{ tonnes}$

28. The compression curve (void ratio, e vs. Effective stress, σ'_v) for a certain clayey soil is a straight line in a semi-logarithmic plot and it passes through the points (e=1.2; σ'_v=50 kPa)

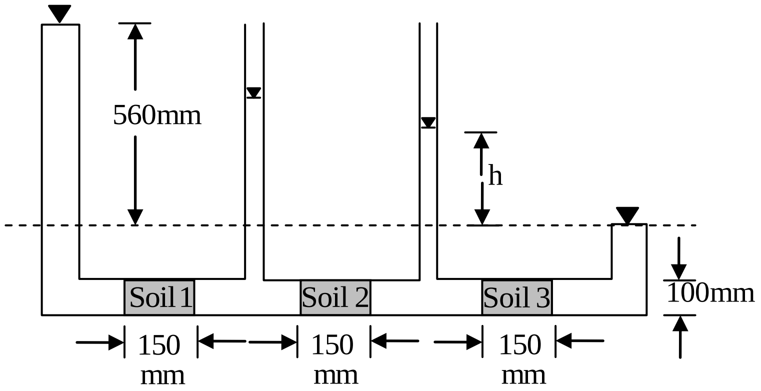
and (e=0.6; σ'_v=800 kPa). The compression index (up to two decimal places) of the soil is______

Key: (0.498)

Exp: Compression index $(C_c) = \dfrac{\Delta e}{\log\left(\dfrac{\bar{\sigma}_2}{\sigma_1}\right)}$

$$= \frac{1.2 - 0.6}{\log\left(\frac{800}{50}\right)} = \frac{0.6}{\log 16} = 0.498$$

29. Three soil specimens (Soil 1, Soil 2 and Soil 3), each 150mm long and 100mm diameter, are placed in series in a constant head flow set up as shown in the figure. Suitable screens are provided at the boundaries of the specimens to keep them intact. The values of coefficient of permeability of Soil 1, Soil 2 and Soil 3 are 0.01, 0.003 and 0.03 cm/s, respectively.



The value of h in the set up is

(A) 0mm (B) 40mm (C) 255mm (D) 560mm

Key (B)

Exp: Soils are placed in series

$$K_{eq} = \frac{H_1 + H_2 + H_3}{\frac{H_1}{K_1} + \frac{H_2}{K_2} + \frac{H_3}{K_3}} = \frac{150 + 150 + 150}{\frac{150}{0.1} + \frac{150}{0.03} + \frac{150}{0.3}} \text{mm/sec.}$$

$$= \frac{450}{150\left(\frac{1}{0.1} + \frac{1}{0.03} + \frac{1}{0.3}\right)} = 0.0643 \text{ mm/sec}$$

$$K_{eq}\, iA = K_3.i_3.A$$

$$K_{eq}\frac{h}{L} = K_3\frac{h_3}{L_3}$$

$$0.0643 \text{ mm/sec} \times \frac{560\text{mm}}{450\text{mm}} = 0.3\text{mm/sec} \times \frac{h_3}{150}\text{mm}$$

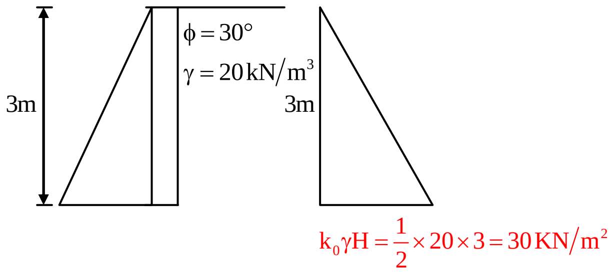
$$h_3 = \frac{0.0643 \times 560 \times 150}{450 \times 0.3} = 40.008\,\text{mm}$$

30. A 3 m high vertical earth retaining wall retains a dry granular backfill with angle of internal friction of 30° and unit weight of $20kN/m^3$. If the wall is prevented from yielding (no movement), the total horizontal thrust (in kN per unit length) on the wall is

(A) 0 (B) 30 (C) 45 (D) 270

Key: **(C)**

Exp:

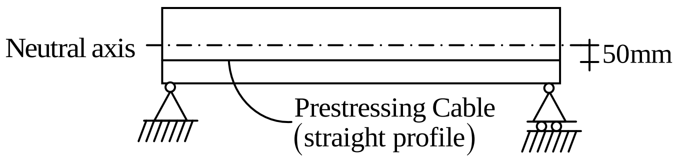


Wall is prevented from yielding (no movement) i.e wall is at rest

$K_0 = 1 - \sin\phi = 1 - \sin 30 = 0.5$

$F_H = \frac{1}{2}\times 3\times 30 = 3\times 15 = 45\text{ kN/m length.}$

31. A 6 m long simply supported beam is prestressed as shown in the figure.



The beam carries a uniformly distributed load of 6kN/m over its entire span. If the effective flexural rigidity $EI=2\times10^4 kNm^2$ and the effective prestressing force is 200kN, the net increase in length of the prestressing cable (in mm, up to two decimal places) is _______

Key: **(0.12)**

Exp: Given,

span, $\ell = 6m$ w, udl = 6**KN/m. and e, eccentricity =50mm**

Prestressing force P=200KN

(a) slope of the beam due to p – force $\theta_1 = \frac{Pe\ell}{8EI}$

$$= \frac{200\times10^3\times50\times6000}{2\times2\times10^{13}} = 1.5\times10^{-3}\,(\text{upward})$$

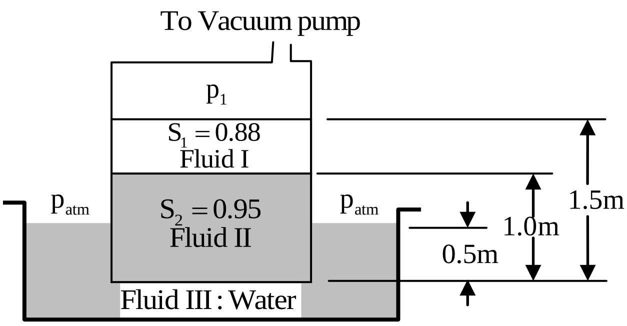
(b) slope of the beam due to UDL

$$\theta_2 = \frac{w\ell^3}{24EI} = \frac{6\times(6000)^3}{24\times2\times10^{13}} = 2.7\times10^{-3}$$

(c) Net slope of beam

$$\theta = \theta_1 + \theta_2$$
$$= (-)1.5\times10^{-3} + 2.7\times10^{-3}$$
$$= 1.2\times10^{-3} = 2e\theta = 2\times50\times1.2\times10^{-3} = 0.12mm$$

32. A three fluid system (immiscible) is connected to a vacuum pump. The specific gravity values of the fluids (S_1, S_2) are given in the figure.



Unit weight of water, $\gamma_w = 9.81 kN/m^3$
Atmospheric Pressure, $p_{atm} = 95.43 kPa$

The gauge pressure value (in kN/m^2. Up to two decimal places) of p_1 is _____

Key: (–8.73)

Exp: Balancing the pressure force at datum level below fluid II:

$$P_A = P_1 + \underset{(\text{Fluid I})}{S_1 \times \rho_w \times g \times 0.5} + S_2 \times \rho_w \times g \times 1$$

$$1000 \times 9.81 \times 0.5 = P_1 + 0.88 \times 1000 \times 9.81 \times 0.5 + 0.95 \times 9.81 \times 1 \times 1000$$

$$\Rightarrow P_1 = -8.73 KN/m^2$$

33. The value (up to two decimal places) of a line integral $\int \vec{F}(\vec{r}).d\vec{r}$, for $\vec{F}(\vec{r}) = x^2\vec{i} + y^2\vec{j}$ along C which is a straight line joining (0,0) to (1,1) is ______

Key: (0.67)

Exp: $\int_C \bar{F}(\bar{r}).d\bar{r} = \int_C x^2dx + y^2dy$

straight line joining $(0,0)$ to $(1,1)$ is $y = x$

$$\Rightarrow dy = dx$$

$$\therefore \int_C x^2dx + y^2dy = \int_{x=0}^{1} x^2dx + x^2dx = \int_{x=0}^{1} 2x^2dx$$

$$= 2\frac{x^3}{3}\Big|_0^1 = \frac{2}{3} \simeq 0.67$$

34. A singly reinforced rectangular concrete beam of width 300mm and effective depth 400 mm is to be designed using M25 grad concrete and Fe500 grade reinforcing steel. For the beam to be under reinforced, the maximum number of 16mm diameter reinforcing bars that can be provided is

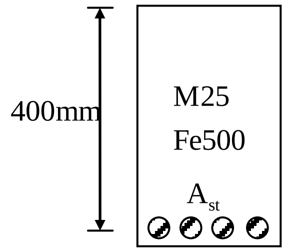
(A) 3 (B) 4 (C) 5 (D) 6

Key: (C)

Exp: For Fe500

$$x_{u,max} = 0.46d = 0.46 \times 400 = 184 mm$$

For under reinforced section $x_u < x_{u,\,max}$



C=T

$0.36f_{ck}\ b\ x_u = 0.87\ f_y\ A_{st}$

$0.36\times 25\times 300\times (184) = 0.87\times 500\times n\times \frac{\pi}{4}16^2$

$n = \frac{0.36\times 25\times 300\times 184\times 4}{0.87\times 500\times \pi\times 16^2} = 5.68$

5.68 no.f bars will be used for balanced section for under reinforced section no.of bars should be less than that of balanced section and maximum value is 5.

35. In a 5m wide rectangular channel, the velocity u distribution in the vertical direction y is given by $u = 1.25y^{\frac{1}{6}}$. The distance y is measured from the channel bed. If the flow depth is 2m, the discharge per unit width of the channel is

(A) 2.40m^3/s/m (B) 2.80 m^3/s/m (C) 3.27 m^3/s/m (D) 12.02 m^3/s/m

Key: **(A)**

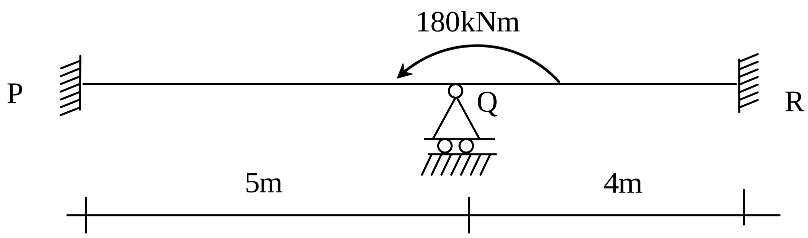
Exp: $q = \int_0 u.d_y$

$= \int_0^2 1.25y^{1/6}d_y$

$= 1.25\left.\frac{y^{7/6}}{7/6}\right|_0^2 = 1.25.\frac{2^{7/6}}{7/6}$

$= 2.40\,m^3/s/m$ width

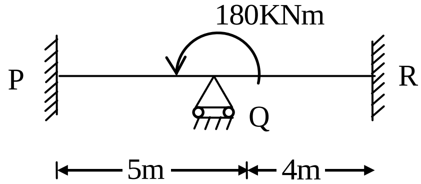
36. A prismatic beam P-Q-R of flexural rigidity EI=1×10^4kNm^2 is subjected to a moment of 180kNm at Q as shown in the figure.



The rotation at Q (in rad, up to two decimal places) is _______

Key: **(0.01)**

Exp:



Using slope deflection equation

$$M_{QP} = \frac{2EI}{5}(2\theta_{QP})$$

$$M_{QR} = \frac{2EI}{4}(2\theta_{QR})$$

using equilibrium;

$$\because M_{QP} + M_{QP} = 180$$

$$\Rightarrow \frac{2EI}{5} \times 2\theta_{QP} + \frac{4EI\theta_{QR}}{4} = 180$$

or, $0.8EI(\theta_{QP}) + EI\theta_{QR} = 180$

or, $1.8EI\theta_Q = 180$

or, $\theta_Q = \frac{100}{EI} = \frac{100}{1\times10^4} = 0.01\text{ radian}$

37. A 7.5 m wide two lane road on a plain terrain is to be laid along a horizontal curve of radius 510m. For a design speed of 100kmph, super elevation is provided as per IRC: 73-1980. Consider acceleration due to gravity as $9.81 m/s^2$. The level difference between the inner and outer edges of the road (in m, up to three decimal places) is ________

Key: (0.525m)

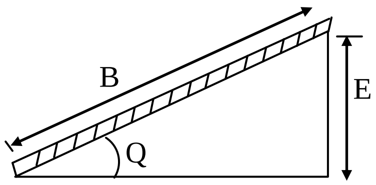
Exp: $B = 7.5m,\ R = 510m$

Design speed, V=100 kmph

$g = 9.81 m/s^2$

We know,

super elevation, $e = \tan\theta = \sin\theta = \frac{E}{B}$



$\therefore E = eB$

For mixed traffic condition

$$e = \frac{V^2}{225R} = \frac{(100)^2}{225\times510} = 0.087 > 0.07$$

$$\therefore \text{restrict } e = 0.07 \text{ for which } f = \frac{V^2}{127R} - 0.07$$

$$= \frac{(100)^2}{127\times510} - 0.07 = 0.084 < 0.15$$

$$\therefore E = 7.50\times0.070 = 0.525m$$

38. The Laplace transform F(s) of the exponential function, f(t) = e^{at} when $t \geq 0$, where a is a constant and (s-a) > 0, is

(A) $\frac{1}{s+a}$ (B) $\frac{1}{s-a}$ (C) $\frac{1}{a-s}$ (D) ∞

Key: (B)

Exp: $L[e^{at}] = \frac{1}{s-a}$

39. An aerial photograph of a terrain having an average elevation of 1400m is taken at a scale of 1:7500. The focal length of the camera is 15cm. The altitude of the flight above mean sea level (in m, up to one decimal place) is ____________

Key: **(2525.0)**

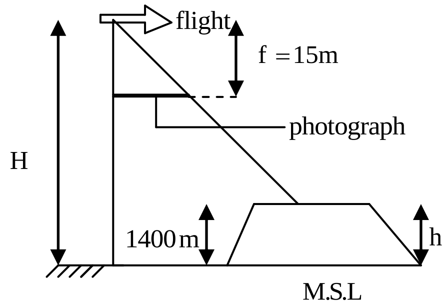
Exp: Let altitude of the flight above MSL be H

$h = 1400\text{ m}$

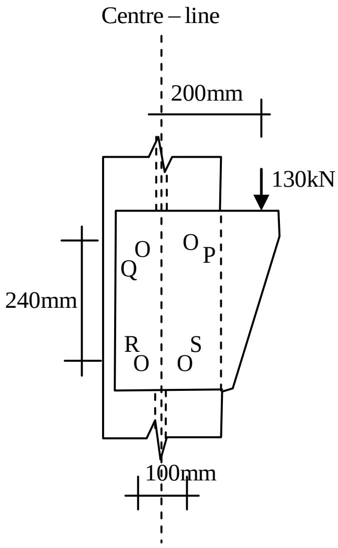
$s = \frac{1}{7500}$

$\Rightarrow \frac{1}{7500} = \frac{f}{H-h}$

$\Rightarrow H - 1400 = 7500(0.15) \Rightarrow H = 2525\text{m}$



40. Four bolts P, Q, R and S of equal diameter are used for a bracket subjected to a load of 130 kN as shown in the figure.



The force in bolt P is

(A) 32.50kN (B) 69.32kN (C) 82.50kN (D) 119.32kN

Key: **(B)**

Exp: Direct force, $F_1 = \frac{P}{4} = \frac{130}{4} = 32.5\text{kN}$

Force due to moment, $F_2 = \frac{Per_n}{\Sigma r^2}$

$r_n = \sqrt{(50)^2 + (120)^2} = 130\text{mm}$

$\Sigma r^2 = 4 \times (130)^2 = 520 \times 130 = 67600$

$\therefore F_2 = \frac{130 \times 0.20 \times 130 \times 1000}{67600} = 50\text{kN}$

$\cos\theta = \frac{50}{\sqrt{(50)^2 + (120)^2}} = \frac{50}{130} = 0.385$

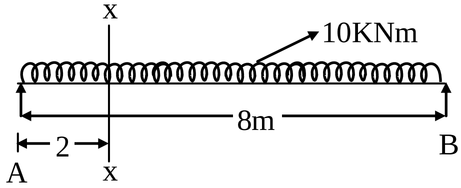
Resultant force, $F_n = \sqrt{(32.5)^2 + (50)^2 + 2 \times 32.5 \times 50 \times 0.385}$

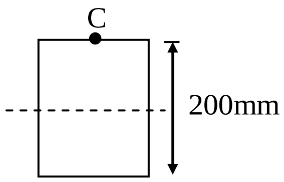
$\Rightarrow F_n = 69.32\text{kN}$

41. An 8 m long simply supported elastic beam of rectangular cross section (100mm × 200mm) is subjected to a uniformly distributed load of 10kN/m over its entire span. The maximum principal stress (in MPa, up to two decimal places) at a point located at the extreme compression edge of a cross section and at 2m from the support is _______

Key: **(90.00)**

Exp:





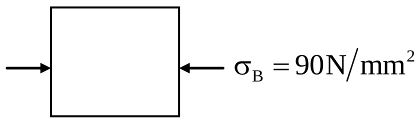
??

$$M_x = V_A \times 2 - 10 \times 2 \times 1$$

$$= \frac{10 \times 8}{2} \times 2 - 20 = 60\text{KNm}$$

$$\therefore \sigma_b = \frac{M}{I} y_{max} = \frac{60 \times 10^6 \times 12}{(100)(200)^3} \times 100 = 90\, \text{N/mm}^2 \, (\text{compressre})\, \text{atC.}$$

τ at top compression edge $= 0$

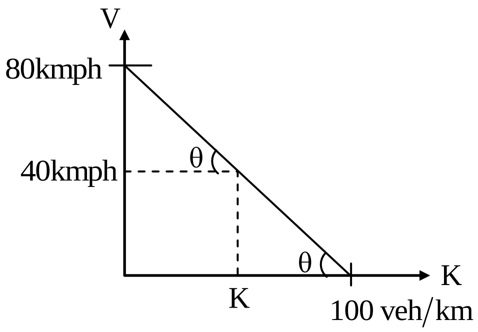


$$\therefore \sigma_1 = \frac{\sigma_b}{2} + \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2} = \sigma_b = 90\text{N/mm}^2 = 90.00\text{MPa.}$$

42. The space mean speed (kmph) and density (vehicles/km) of a traffic stream are linearly related. The free flow speed an jam density are 80kmph and 100 vehicles/km respectively. The traffic flow (in vehicles/h, up to one decimal place) corresponding to a speed of 40kmph is ______

Key: **(2000)**

Exp:

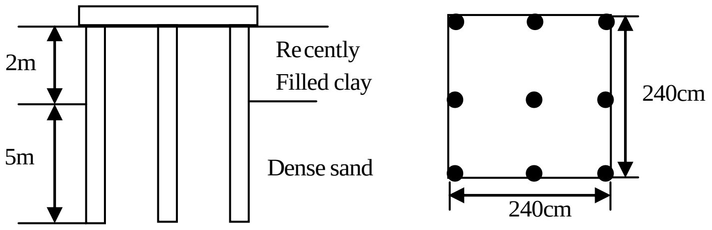


$$\tan\theta = \frac{80 - 40}{k} = \frac{80}{100}$$

$$\frac{40}{k} = \frac{80}{100} \Rightarrow k = \frac{4000}{80} = 50 \text{ veh/km}$$

$$q = kv = 40 \times 50 = 2000 \text{ veh/hr}$$

43. A group of nine piles in a 3×3 square pattern is embedded in a soil strata comprising dense sand underlying recently filled clay layer, as shown in the figure. The perimeter of an individual pile is 126cm. The size of pile group is 240 cm×240cm. The recently filled clay has undrained shear strength of 15kPa and unit weight of 16kN/m^3.



The negative frictional load (in kN, up to two decimal places) acting on the pile group is ______

Key: **(472.32kN)**

Exp: Single action

$F_{ng} = nF_n = nCN_C p_s L$

$= 9 \times 15 \times 1.26 \times 2$

$= 340.20$ kN

Group pile action

$F_{ng} = c_u p_g L + \gamma D_n A_g$

$= 15 \times 4 \times 2.4 \times 2 + 16 \times 2 \times (2.4)^2 = 472.32\text{kN}$

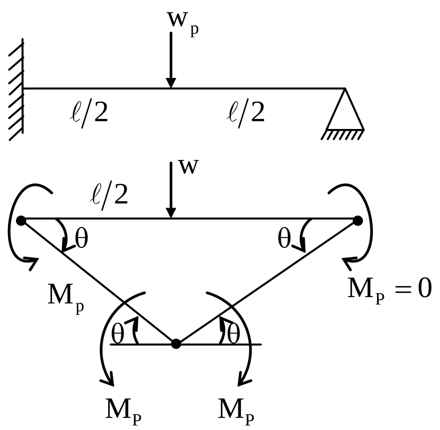
$\therefore$ Negative frictional load $= 472.32$kN

(whichever is greater)

44. A prismatic propped cantilever beam of span L and plastic moment capacity M_p is subjected to a concentrated load at its mid span. If the collapse load of the beam is $\alpha \frac{M_p}{L}$, the value of α is __________

Key: **(6)**

Exp: By upper bound theorem



$M_p\theta + M_p\theta + M_p\theta + 0 = w\frac{\ell}{2}\theta$

$3m_p\theta = \frac{w\ell}{2}\theta$

$w = \frac{6M_p}{\ell} \Rightarrow \alpha = 6$

45. The matrix $\begin{bmatrix} 2 & -4 \\ 4 & -2 \end{bmatrix}$ has

(A) real eigenvalues and eigenvectors
(B) real eigenvalues but complex eigenvectors
(C) complex eigenvalues but real eigen vectors
(D) complex eigenvalues and eigen vectors

Key: (D)

Exp: Let $A = \begin{bmatrix} 2 & -4 \\ 4 & -2 \end{bmatrix}$

Characteristic equation of A is $\lambda^2 - (\text{trace of } A)\lambda + |A| = 0$

$$\Rightarrow \lambda^2 - 0 + 12 = 0$$
$$\Rightarrow \lambda = \pm 2\sqrt{3}\,i$$

and corresponding eigen vectors are

$$\begin{bmatrix} \frac{1}{2} + \frac{\sqrt{3}}{2}i \\ 1 \end{bmatrix} \begin{bmatrix} \frac{1}{2} - \frac{\sqrt{3}}{2}i \\ 1 \end{bmatrix}$$

46. A flocculation tank contains 1800m^3 of water, which is mixed using paddles at an average velocity gradient G of 100/s. The water temperature and the corresponding dynamic viscosity are 30°C and 0.798×10^{-3} Ns/m^2, respectively. The theoretical power required to achieve the stated value of G (in kW, up to two decimal places) is _______

Key: (14.36)

Exp: Given,

$V = 1800\text{m}^3$

$G = 100\,S^{-1}$

$\mu = 0.798 \times 10^{-3}\ \text{Ns/m}^2$

$\therefore$ Theoretical power, $P = G^2 V \mu$

$$= (100)^2 \times 1800 \times 0.798 \times 10^{-3}$$
$$= 14364 \text{ watt} = 14.36 \text{ kwatt}$$

47. The total horizontal and vertical stresses at a point X in a saturated sandy medium are 170 kPa and 300kPa, respectively. The static pore water pressure is 30 kPa. At failure, the excess pore water pressure is measured to be 94.50kPa, and the shear stresses on the vertical and horizontal planes passing through the point X are zero. Effective cohesion is 0kPa and effective angle of internal friction is 36°. The shear strength (in kPa, up to two decimal places) at point X is _________

Key: (52.449)

Exp: $\alpha = 45 + \frac{\phi}{2}$

$\phi = 36^0$

$$\alpha = 45 + \frac{\phi}{2} = 45 + \frac{36}{2} = 45 + 18 = 63^0$$

$$\bar{\sigma}_1 - \sigma - u = 300 - (30 + 94.50) = 175.5$$

$$\bar{\sigma}_3 = \sigma - u = 170 - (30 + 94.50) = 45.5$$

$$\bar{\sigma}_n = \frac{\bar{\sigma}_1 + \bar{\sigma}_3}{2} + \frac{\bar{\sigma}_1 - \bar{\sigma}_3}{2}\cos 2\alpha$$

$$= \frac{175 + 45.5}{2} + \frac{175 - 45.5}{2}\cos(2 \times 63)$$

$$= 110.25 + 64.75$$

$$= 110.25 - 3805$$

$$= 72.19$$

$$\text{shear strength}(\tau) = c + \bar{\sigma}_n \tan\phi$$

$$= 0 + 72.19 \tan 36$$

$$= 52.449\,\text{kPa}$$

48. The total rainfall in a catchment of area $1000 km^2$, during a 6h storm, is 19cm. The surface runoff due to this storm computed from triangular direct runoff hydrograph is $1 \times 10^8 m^3$. The ϕ_{index} for this storm (in cm /h, up to one decimal place) is __________

Key: **(1.5)**

Exp: Catchment area $= 1000\ km^2 = 1000 \times 10^6 m^2$

$$\text{ra inf all}(p) = 19cm$$

$$\text{duration}(t) = 6hrs$$

$$\text{surface runoff } = 1 \times 10^8 m^3$$

$$\text{runoff } = \frac{1 \times 10^8}{1000 \times 10^6} = \frac{1}{10} m = 0.1m = 10\ cm$$

$$\phi - \text{index} = \frac{p - R}{t} = \frac{19 - 10}{6h} = \frac{9}{6} = 1.5 cm/hr$$

49. A rough pipe of 0.5m diameter, 300m length and roughness height of 0.25mm. carries water (kinematic viscosity=$0.9 \times 10^{-6} m^2/s$) with velocity of 3m/s. Friction factor (f) for laminar flow is given by f=64/Re, and for turbulent flow it is given by $\frac{1}{\sqrt{f}} = 2\log_{10}\left(\frac{r}{k}\right) + 1.74$, where, Re=Reynolds number, r=radius of pipe, k=roughness height and $g=9.81 m/s^2$. The head loss (in m, up to three decimal places) in the pipe due to friction is ______.

Key: **(4.594)**

Exp: Reynolds number

$$(R_e) = \frac{\rho VD}{\mu} = \frac{VD}{\gamma} = \frac{3(m/s) \times 0.5m}{0.9 \times 10^{-6}}$$

$$= 1.6667 \times 10^6 > 2000$$

Flow is turbulent

For Turbulent flow

$$\frac{1}{\sqrt{f}} = 2\log_{10}\left(\frac{r}{K}\right) + 1.74$$

$$\frac{1}{\sqrt{f}} = 2.\log_{10}\left(\frac{0.25\times10^{-3}}{0.25}\right) + 1.74$$

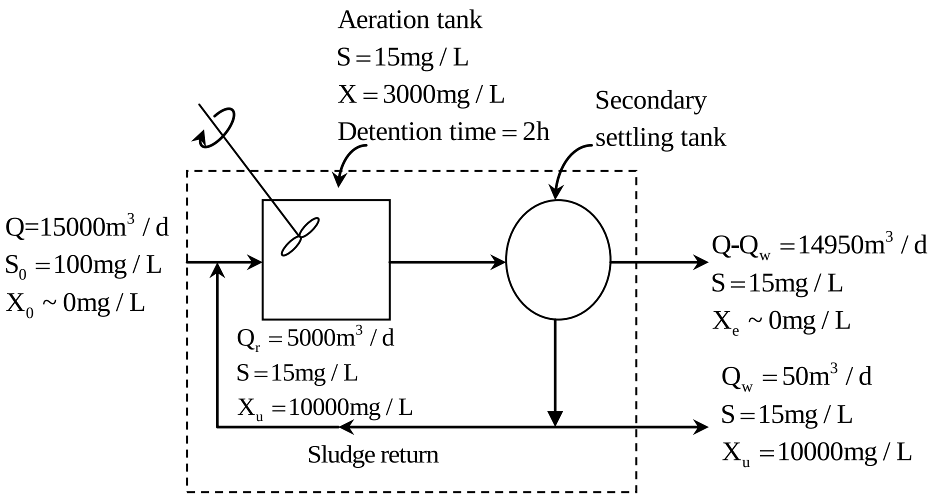
$$\frac{1}{\sqrt{f}} = 2\times3\log_{10}10 + 1.74$$

$$\frac{1}{\sqrt{f}} = 7.74 \Rightarrow f = 0.01669$$

$$\text{head loss due to friction}\left(h_f\right) = \frac{fLV^2}{2gd} = \frac{0.01669\times300\times3^2}{2\times9.81\times0.5}$$

$$= 4.594\text{m}$$

50. A schematic flow diagram of a completely mixed biological reactor with provision for recycling of solids is shown in the figure.



S_0, S=readily biodegradable soluble BOD, mg/L

Q, Q_r, Q_w=flow rates, m^3/d

X_0, X, X_e, X_u= microorganism concentrations (mixed – liquor volatile suspended solids or MLVSS), mg/L

The mean cell residence time (in days, up to one decimal place) is _______.

Key: (7.5)

Exp: Mean cell residence time $\left(\theta_c\right) = \dfrac{\text{mass of MLSS in creation tank}}{\text{mass of MLSS wasted/day}}$

$$\theta_c = \frac{V.X}{Q_wX_u + Q_eX_e} = \frac{VX}{Q_wX_u + \left(Q - Q_w\right)X_e}$$

$$Q - Q_w = 14950$$

$$Q = 14950 + Q_w$$

$$= 14950 + 50 = 15000\,m^3/\text{day}$$

$Q_e = Q - Q_w = 15000 - 50 = 14950\ m^3/day$

Detention time = 2hr

$\frac{Volume}{Q} = 2hrs$

$volume = 2hr \times 15000\ m^3/day$

$= \frac{2\times15000}{24} = \frac{30000}{24} m^3 = 1250m^3$

$Q_c = \frac{V.X}{Q_w X_w + Q_e X_e}$

$= \frac{1250\times3000}{50\times10000} = 7.5 days$

51. A car follows a slow moving truck (travelling at a speed of 10m/s) on a two lane two way highway. The car reduces its speed to 10m/s and follows the truck maintaining a distance of 16m from the truck. On finding a clear gap in the opposing traffic stream, the car accelerates at an average rate of $4m/s^2$, overtakes the truck and returns to its original lane. When it returns to its original lane, the distance between the car and the truck is 16m. The total distance covered by the car during this period (from the time it leaves its lane and subsequently returns to its lane after overtaking) is

(A) 64m (B) 72m (C) 128 m (D) 144m

Key: **(B)**

Exp: $d_2 = V_B T + (S_1 + S_2)$

$S_1 = S_2 = 16m$

$T = \sqrt{\frac{2(S_1+S_2)}{a}} = \sqrt{\frac{2(16+16)}{4}} = \sqrt{\frac{2\times32}{4}} = 4$

$d_2 = 10\times4 + 16 + 16$

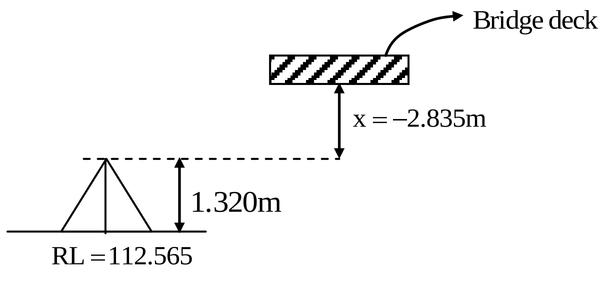
$= 40 + 32 = 72m$

52. A level instrument at a height of 1.320 m has been placed at a station having a Reduced Level (RL) of 112.565m. The instrument reads-2.835m on a levelling staff held at the bottom of a bridge deck. The RL (in m) of the bottom of the bridge deck is

(A) 116.720 (B) 116.080 (C) 114.080 (D) 111.050

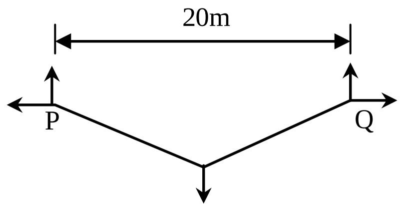
Key: **(A)**

Exp:



$RL = 112.565 + 1.320 + 2.835 = 116.72\,m$

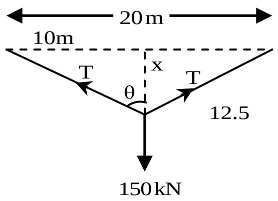
53. A cable PQ of length 25m is supported at two ends at the same level as shown in the figure. The horizontal distance between the supports is 20m. A point load of 150kN is applied at point R which divides it into two equal parts.

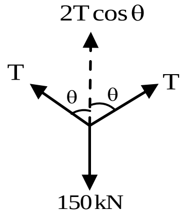


Neglecting the self weight of the cable. The tension (in kN. In integer value) in the cable due to the applied load will be ___________.

Key: **(125)**

Exp:





$$x^2 + 10^2 = 12.5^2$$
$$x^2 = 12.5^2 - 10^2$$
$$x = 7.5\,\text{m}$$
$$\cos\theta = \frac{7.5}{12.5}$$

$$2T\cos\theta = 150\,\text{kN}$$
$$T = \frac{150}{2\cos\theta} = \frac{150}{2\times\frac{7.5}{12.5}}$$
$$= 125\,\text{kN}$$

54. At a small water treatment plant which has 4 filters, the rates of filtration and back washing are $200\text{m}^3/\text{d}/\text{m}^2$ and $1000\text{m}^3/\text{d}/\text{m}^2$, respectively. Backwashing is done for 15min per day. The maturation, which occurs initially as the filter is put back into service after cleaning, takes 30min. It is proposed to recover the water being wasted during backwashing and maturation. The percentage increase in the filtered water produced (up to two decimal places) would be __.

Key: **(7.528)**

Exp: % increase in filtered water $= \dfrac{\text{volume of water used in back washing}}{\text{volume of filtered water}} \times 100$

$$= \frac{\text{volume of water used in}\left(\text{back washing} + \text{maturation}\right)}{\text{volume of filtered water}} \times 100$$

$$= \frac{\text{ROB} \times \text{DOB} \times \text{Area of filter} + \text{ROM} \times \text{DOM} \times \text{Area}}{\text{ROF} \times \text{DOF} \times \text{Area of filter}} \times 100$$

$$= \frac{1000 \times \frac{15\,\text{min}}{24 \times 60\,\text{min}} + 200 \times \frac{30\,\text{min}}{24 \times 60\,\text{min}}}{200 \times \frac{(24 - 0.75)\,\text{hr}}{24\text{hr}}} \times 100$$

$$= \frac{10.42 + 4.167}{193.75} \times 100 = 7.528\%$$

55. The rank of the following matrix is

$$\begin{bmatrix} 1 & 1 & 0 & -2 \\ 2 & 0 & 2 & 2 \\ 4 & 1 & 3 & 1 \end{bmatrix}$$

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

Key: **(B)**

Exp: $\begin{bmatrix} 1 & 1 & 0 & -2 \\ 2 & 0 & 2 & 2 \\ 4 & 1 & 3 & 1 \end{bmatrix}$

Reducing into Echelon form

$R_2 \to R_2 - 2R_1$
$R_3 \to R_3 - 4R_1$ $\sim \begin{bmatrix} 1 & 1 & 0 & -2 \\ 0 & -2 & 2 & 6 \\ 0 & -3 & 3 & 9 \end{bmatrix}$

$R_3 \to 2R_3 - 3R_2$ $\sim \begin{bmatrix} 1 & 1 & 0 & -2 \\ 0 & -2 & 2 & 6 \\ 0 & 0 & 0 & 0 \end{bmatrix}$

Rank = No of non-zero rows
= 2