Q. No. 1 – 5 Carry One Mark Each

Q.1 A student is required to demonstrate a high level of comprehension of the subject, especially in the social sciences.

The word closest in meaning to comprehension is

(A) understanding (B) meaning (C) concentration (D) stability

Answer: (A)

Q.2 Choose the most appropriate word from the options given below to complete the following sentence.

One of his biggest ______ was his ability to forgive.

(A) vice (B) virtues (C) choices (D) strength

Answer: (B)

Q.3 Rajan was not happy that Sajan decided to do the project on his own. On observing his unhappiness, Sajan explained to Rajan that he preferred to work independently.

Which one of the statements below is logically valid and can be inferred from the above sentences?

(A) Rajan has decided to work only in a group.

(B) Rajan and Sajan were formed into a group against their wishes.

(C) Sajan had decided to give in to Rajan's request to work with him.

(D) Rajan had believed that Sajan and he would be working together.

Answer: (D)

Q.4 If $y = 5x^2 + 3$, then the tangent at $x = 0, y = 3$

(A) passes through $x = 0, y = 0$ (B) has a slope of +1

(C) is parallel to the x-axis (D) has a slope of -1

Answer: (C)

Exp: $y = 5x^2 + 3, \frac{dy}{dx} = 10x$

$$\text{Slope of tangent} = \left(\frac{dy}{dx}\right)_{x=0,\, y=3} = 10 \times 0 = 0$$

Slope = 0 $\Rightarrow$ tangent is parallel to x-axis.

Q.5 A foundry has a fixed daily cost of Rs 50,000 whenever it operates and a variable cost of Rs 800Q, where Q is the daily production in tonnes. What is the cost of production in Rs per tonne for a daily production of 100 tonnes?

Answer: 1300 to 1300

Exp: Fixed cost = Rs. 50,000

Variable cost = Rs. 800Q

Q = daily production in tones

For 100 tonnes of production daily, total cost of production = 50,000+800×100 = 130,000

So, cost of production per tonne of daily production

$$= \frac{130,000}{100} = \text{Rs.}\,1300.$$

Q. No. 6 – 10 Carry One Mark Each

Q.6 Find the odd one in the following group: ALRVX, EPVZB, ITZDF, OYEIK

(A) ALRVX (B) EPVZB (C) ITZDF (D) OYEIK

Answer: (D)

Exp: ALRVX→only one vowel
EPVZB→only one vowel
ITZDF→only one vowel
OYEIK→three vowels

Q.7 Anuj, Bhola, Chandan, Dilip, Eswar and Faisal live on different floors in a six-storeyed building (the ground floor is numbered 1, the floor above it 2, and so on). Anuj lives on an even-numbered floor. Bhola does not live on an odd numbered floor. Chandan does not live on any of the floors below Faisal's floor. Dilip does not live on floor number 2. Eswar does not live on a floor immediately above or immediately below Bhola. Faisal lives three floors above Dilip. Which of the following floor-person combinations is correct?

	Anuj	Bhola	Chandan	Dilip	Eswar	Faisal
(A)	6	2	5	1	3	4
(B)	2	6	5	1	3	4
(C)	4	2	6	3	1	5
(D)	2	4	6	1	3	5

Answer: (B)

Exp: (a) Anuj: Even numbered floor (2,4,6)
(b) Bhola: Even numbered floor (2,4,6)
(c) Chandan lives on the floor above that of Faisal.
(d) Dilip: not on 2nd floor.
(e) Eswar: does not live immediately above or immediately below Bhola
From the options its clear, that only option (B) satisfies condition (e).
So, correct Ans is (B).

Q.8 The smallest angle of a triangle is equal to two thirds of the smallest angle of a quadrilateral. The ratio between the angles of the quadrilateral is 3:4:5:6. The largest angle of the triangle is twice its smallest angle. What is the sum, in degrees, of the second largest angle of the triangle and the largest angle of the quadrilateral?

Answer: 180 to 180

Exp: Let the angles of quadrilateral are 3x, 4x, 5x, 6x
So, 3x+4x+5x+6x = 360
x = 20
Smallest angle of quadrilateral = 3×20 = 60°

Smallest angle of triangle = $\frac{2}{3}\times 60° = 40°$

Largest angle of triangle = 2×40° = 60°
Three angles of triangle are 40°, 60°, 80°
Largest angle of quadrilateral is 120°
Sum (2nd largest angle of triangle + largest angle of quadrilateral)
= 60°+120°=180°.

Q.9 One percent of the people of country X are taller than 6 ft. Two percent of the people of country Y are taller than 6 ft. There are thrice as many people in country X as in country Y. Taking both countries together, what is the percentage of people taller than 6 ft?

(A) 3.0 (B) 2.5 (C) 1.5 (D) 1.25

Answer: (D)

Exp: Let number of people in country y = 100

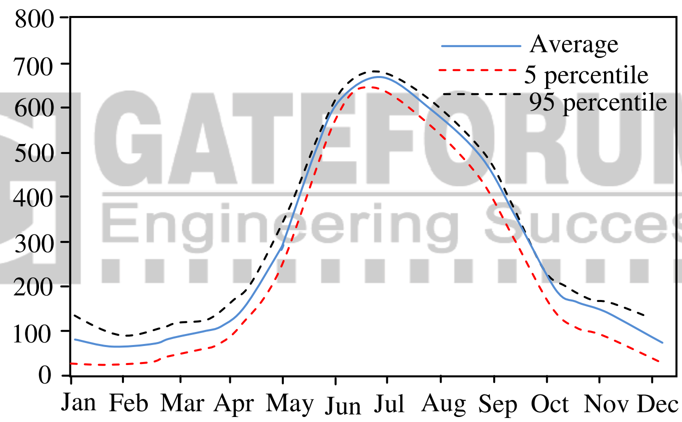
So, number of people in country x = 300

Total number of people taller than 6ft in both the countries

$$= 300\times\frac{1}{100}+100\times\frac{2}{100}=5$$

% of people taller than 6ft in both the countries $=\frac{5}{400}\times 100 = 1.25\%.$

Q.10 The monthly rainfall chart based on 50 years of rainfall in Agra is shown in the following figure. Which of the following are true? (k percentile is the value such that k percent of the data fall below that value)



(i) On average, it rains more in July than in December

(ii) Every year, the amount of rainfall in August is more than that in January

(iii) July rainfall can be estimated with better confidence than February rainfall

(iv) In August, there is at least 500 mm of rainfall

(A) (i) and (ii) (B) (i) and (iii) (C) (ii) and (iii) (D) (iii) and (iv)

Answer: (B)

Exp: In the question the monthly average rainfall chart for 50 years has been given.

Let us check the options.

(i) On average, it rains more in July than in December $\Rightarrow$ correct.

(ii) Every year, the amount of rainfall in August is more than that in January.

$\Rightarrow$ may not be correct because average rainfall is given in the question.

(iii) July rainfall can be estimated with better confidence than February rainfall.

$\Rightarrow$ From chart it is clear the gap between 5 percentile and 95 percentile from average is higher in February than that in July $\Rightarrow$ correct.

(iv) In August at least 500 mm rainfall

$\Rightarrow$ May not be correct, because its 50 year average.

So correct option (B) (i) and (iii).

Q. No. 1 – 25 Carry One Mark Each

1. $\lim\limits_{x\to\infty}\left(\dfrac{x+\sin x}{x}\right)$ equals to

(A) $-\infty$ (B) 0 (C) 1 (D) ∞

Answer: (C)

Exp. $\lim\limits_{x\to\infty}\left(\dfrac{x+\sin x}{x}\right) = \lim\limits_{x\to\infty}\left(1+\dfrac{\sin x}{x}\right)$

$=1+0=1.$

2. Given the matrices $J=\begin{bmatrix}3 & 2 & 1\\ 2 & 4 & 2\\ 1 & 2 & 6\end{bmatrix}$ and $K=\begin{bmatrix}1\\ 2\\ -1\end{bmatrix}$, the product $K^T JK$ is _________

Answer: 23 to 23

Exp. $K^T JK = \begin{bmatrix}1 & 2 & -1\end{bmatrix}\begin{bmatrix}3 & 2 & 1\\ 2 & 4 & 2\\ 1 & 2 & 6\end{bmatrix}\begin{bmatrix}1\\ 2\\ -1\end{bmatrix}$

$=\begin{bmatrix}6 & 8 & -1\end{bmatrix}\begin{bmatrix}1\\ 2\\ -1\end{bmatrix} = 23$

3. The probability density function of evaporation on any day during a year in a watershed is given by

$$f(E)=\begin{cases}\dfrac{1}{5} & 0\le E\le 5\,\text{mm/day}\\ 0 & \text{otherwise}\end{cases}$$

The probability that E lies in between 2 and 4 mm/day in a day in the watershed is (in decimal) ___________

Answer: 0.4 to 0.4

Exp. $P(2<E<4) = \int_2^4 f(E)\,dE$

$=\int_2^4 \frac{1}{5}dE = \frac{1}{5}E\Big|_2^4$

$=\frac{1}{5}(4-2) = \frac{2}{5} = 0.4$

4. The sum of Eigen values of the matrix, [M] is

$$\text{where}\left[M\right]=\begin{bmatrix}215 & 650 & 795\\ 655 & 150 & 835\\ 485 & 355 & 550\end{bmatrix}$$

(A) 915 (B) 1355 (C) 1640 (D) 2180

Answer: (A)

Exp. Sum of the eigen values = Trace of the matrix

$$= 215 + 150 + 550$$

$$= 915$$

5. With reference to the conventional Cartesian (x, y) coordinate system, the vertices of a triangle have the following coordinates: $(x_1, y_1) = (1, 0)$; $(x_2, y_2) = (2, 2)$; and $(x3, y_3) = (4, 3)$. The area of the triangle is equal to

(A) $\frac{3}{2}$ (B) $\frac{3}{4}$ (C) $\frac{4}{5}$ (D) $\frac{5}{2}$

Answer: (A)

Exp. Area of triangle $= \frac{1}{2}\begin{vmatrix}x_1 & x_2 & x_3\\ y_1 & y_2 & y_3\\ 1 & 1 & 1\end{vmatrix} = \frac{1}{2}\begin{vmatrix}1 & 2 & 4\\ 0 & 2 & 3\\ 1 & 1 & 1\end{vmatrix}$

$$=\frac{1}{2}\left|1(2-3)-2(0-3)+4(0-2)\right|$$

$$=\frac{1}{2}\left|-3\right| = \frac{3}{2}$$

6. Match the information given in Group – I with those in Group II.

Group - I	Group - II
(p) Factor to decrease ultimate strength to design strength	(1) Upper bound on ultimate load
(q) Factor to increase working load to ultimate load for design	(2) Lower bound on ultimate load
(r) Statical method of ultimate load analysis	(3) Material partial safety factor
(s) Kinematical mechanism method of ultimate load analysis	(4) Load factor

(A) P – 1; Q – 2; R – 3; S – 4 (B) P – 2; Q – 1; R – 4; S - 3

(C) P – 3; Q – 4; R – 2; S – 1 (D) P – 4; Q – 3; R – 2; S – 1

Answer: (C)

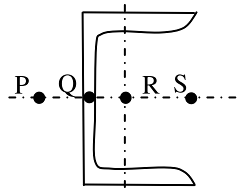
Exp. Static method → Upper bound method of ultimate load analysis

Kinematic method → Lower bound on ultimate load

$Q_{Design} = Q_w \times \text{load factor}$

$M_0 = M_u \times \gamma_m,\ \gamma_m = \text{material partial safety factor}$

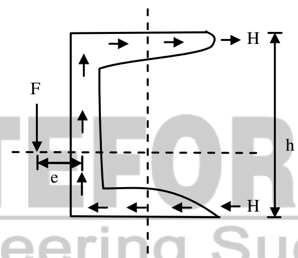
7. The possible location of shear centre of the channel section, shown below, is



(A) P (B) Q (C) R (D) S

Answer: (A)

Exp.

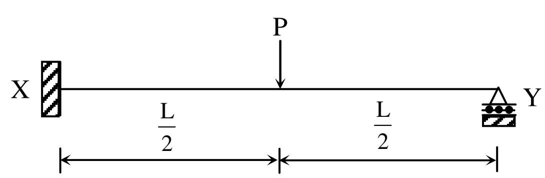


$F.e = H \times h$

$\Rightarrow F = \dfrac{H \times h}{e}$

Only possible location is P

8. The ultimate collapse load (P) in terms of plastic moment M_p by kinematic approach for a propped cantilever of length L with P acting at its mid-span as shown in the figure, would be



(A) $P = \dfrac{2M_P}{L}$ (B) $P = \dfrac{4M_P}{L}$ (C) $P = \dfrac{6M_P}{L}$ (D) $P = \dfrac{8M_P}{L}$

Answer: (C)

Exp. $D_s = 1$

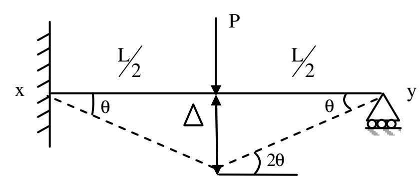
So, no. of plastic hinges = $D_s + 1 = 2$

External work done $= P.\Delta = P.\left(\dfrac{L}{2}.\theta\right)$

Internal work done $M_p.\theta + M_p.2\theta = 3M_p.\theta$

By principal of virtual work

$= P.\dfrac{L}{2}.\theta = 3M_p.\theta \Rightarrow P = \dfrac{6M_p}{L}$



9. While designing, for a steel column of Fe250 grade, a base plate resting on a concrete pedestal of M20 grade, the bearing strength of concrete (in N/mm^2) in limit state method of design as per IS:456-2000 is ____________

Answer: 9 to 9

Exp. Permissible bearing strength $= 0.45f_{ck}$

$$= 0.45\times20 = 9N/mm^2$$

10. A steel section is subjected to a combination of shear and bending actions. The applied shear force is V and the shear capacity of the section is V_s. For such a section, high shear force (as per IS:800-2007) is defined as

(A) $V > 0.6V_S$ (B) $V > 0.7V_S$

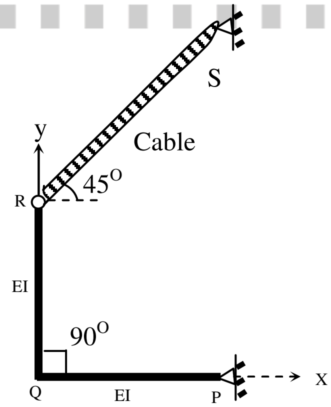
(C) $V > 0.8V_S$ (D) $V > 0.9V_S$

Answer: (A)

Exp. As per clause 9.2.1 (IS: 800-2007) for combined shear and bending: Factored value of applied shear force is greater than or equal to shear strength for high shear.

i.e., $V > 0.6V_s$

11. The degree of static indeterminacy of a rigid jointed frame PQR supported as shown in the figure is



(A) Zero (B) One (C) Two (D) Unstable

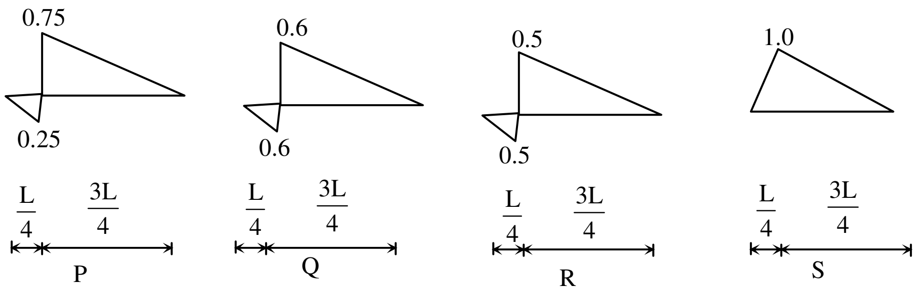
Answer: (A)

Exp. $D_s = D_{se} + D_{si}$

$= (r_e - 3) + 3c - r_r$

$= (4-3) + 3\times0 - 1 = 0$

12. In a beam of length L, four possible influence line diagrams for shear force at a section located at a distance of $\frac{L}{4}$ of from the left end support (marked as P, Q, R and S) are shown below. The correct influence line diagram is



(A) P (B) Q (C) R (D)

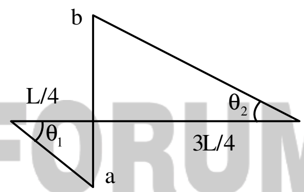
Answer: (A)

Exp. $\theta_1 = \theta_2$

So, $\frac{a}{L/4} = \frac{b}{3L/4} \Rightarrow b = 3a$

Also $a + b = 1 \Rightarrow a = 1/4 = 0.25$

$\Rightarrow b = 3/4 = 0.75$



13. The degree of disturbance of the sample collected by the sampler is expressed by a term called the "area ratio". If the outer diameter and inner diameter of the sampler are D_o and D_i respectively, the area ratio is given by

(A) $\frac{D_0^2 - D_i^2}{D_i^2}$ (B) $\frac{D_i^2 - D_0^2}{D_t^2}$ (C) $\frac{D_0^2 - D_i^2}{D_0^2}$ (D) $\frac{D_i^2 - D_0^2}{D_0^2}$

Answer: (A)

14. For a saturated cohesive soil, a triaxial test yields the angle of internal friction (φ) as zero. The conducted test is

(A) Consolidated Drained (CD) test (B) Consolidated Undrained (CU) test

(C) Unconfined Compression (UC) test (D) Unconsolidated Undrained (UU) test

Answer: (D)

Exp. Unconsolidated undrained test is used for completely saturated cohesive soil. In this test, no drainage is permitted during the first state as well as in the second stage.

15. The action of negative skin friction on the pile is to

(A) increase the ultimate load on the pile (B) reduce the allowable load on the pile

(C) maintain the working load on the pile (D) reduce the settlement of the pile

Answer: (B)

16. A long slope is formed in a soil with shear strength parameters: c' = 0 and $\phi' = 34^{O}$. A firm stratum lies below the slope and it is assumed that the water table may occasionally rise to the surface, with seepage taking place parallel to the slope. Use $\gamma_{mt} = 18 kN/m^3$ and $\gamma_w = 10 kN/m^3$. The maximum slope angle (in degrees) to ensure a factor of safety of 1.5, assuming a potential failure surface parallel to the slope, would be

(A) 45.3 (B) 44.7 (C) 12.3 (D) 11.3

Answer: (D)

Exp. $c' = 0, \phi' = 34°$

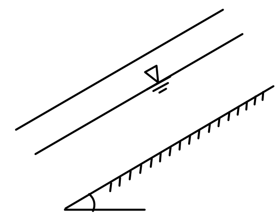
$\gamma_{sat} = 18 k\ N/m^3$

$\gamma_w = 10 kN/m^3$

F.O.S = 1.5

$\gamma_{sub} = \gamma_{sat} - \gamma_w$

When water table rises to surface $= 18 - 10 = 8 kN/m^3$



$$\text{F.O.S} = \frac{\gamma_{sub}}{\gamma_{sat}} \frac{\tan\phi}{\tan\beta}$$

$$\Rightarrow 1.5 = \frac{8}{18} \times \frac{\tan 34°}{\tan\beta}$$

$$\Rightarrow \tan\beta = 0.199 \Rightarrow \beta = 11.30°$$

17. An incompressible homogeneous fluid is flowing steadily in a variable diameter pipe having the large and small diameters as 15 cm and 5 cm, respectively. If the velocity at a section at the 15 cm diameter portion of the pipe is 2.5 m/s, the velocity of the fluid (in m/s) at a section falling in 5 cm portion of the pipe is ___________

Answer: 22 to 23

Exp. By continuity equation between two sections

$$A_1V_1 = A_2V_2$$

$$\Rightarrow \frac{\pi}{4} \times (d_1)^2 . V_1 = \frac{\pi}{4}(d_2)^2 . V_2$$

$$\Rightarrow (15)^2 \times 2.5 = (5)^2 \times V_2$$

$$\Rightarrow V_2 = \frac{225 \times 2.5}{25} = 22.5 m/s$$

18. A conventional flow duration curve is a plot between

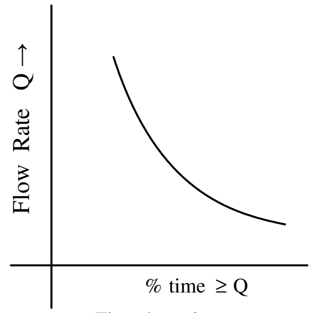
(A) Flow and percentage time flow is exceeded

(B) Duration of flooding and ground level elevation

(C) Duration of water supply in a city and proportion of area receiving supply exceeding this duration

(D) Flow rate and duration of time taken to empty a reservoir at that flow rate

Answer: (A)

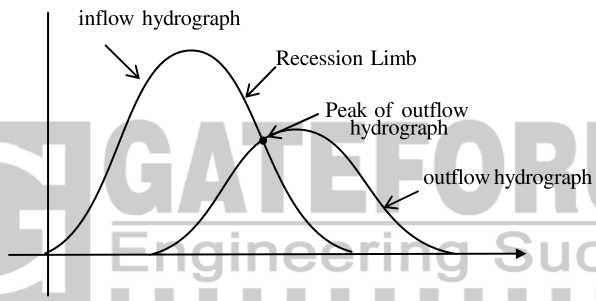


Flow duaration curve

19. In reservoirs with an uncontrolled spillway, the peak of the plotted outflow hydrograph
(A) lies outside the plotted inflow hydrograph
(B) lies on the recession limb of the plotted inflow hydrograph
(C) lies on the peak of the inflow hydrograph
(D) is higher than the peak of the plotted inflow hydrograph

Answer: (B)

Exp.



20. The dimension for kinematic viscosity is

(A) $\frac{L}{MT}$ (B) $\frac{L}{T^2}$ (C) $\frac{L^2}{T}$ (D) $\frac{ML}{T}$

Answer: (C)

Exp. Kinematic viscosity $(V) \rightarrow cm^2/s : \frac{L^2}{T}$

21. Some of the nontoxic metals normally found in natural water are
(A) arsenic, lead and mercury (B) calcium, sodium and silver
(C) cadmium, chromium and copper (D) iron, manganese and magnesium

Answer: (D)

22. The amount of CO_2 generated (in kg) while completely oxidizing one kg of CH_4 to the end products is __________

Answer: 2.7 to 2.8

Exp. $\underset{16\,g}{CH_4} + 2O_2 \rightarrow \underset{44\,g}{CO_2} + 2H_2O$

When completely oxidized, 16g CH_4 liberates = 44g CO_2

So, 1 kg. CH_4 will liberate $= \frac{44}{16} \times 1 = 2.75\,kg$

23. The minimum value of 15 minute peak hour factor on a section of a road is

(A) 0.10 (B) 0.20 (C) 0.25 (D) 0.33

Answer: (C)

Exp. 15 minute peak hour factor is used to design traffic intersections

$$PHF = \frac{\left(V/4\right)}{V_{15}}$$

Where V= peak hour volume (veh/hr)

V_{15} = Maximum 15 minimum volume within the peak hour.

Minimum value is 0.25

24. The following statements are related to temperature stresses developed in concrete pavement slabs with free edges (without any restraint):

(P) The temperature stresses will be zero during both day and night times if the pavement slab is considered weightless

(Q) The temperature stresses will be compressive at the bottom of the slab during night time if the self-weight of the pavement slab is considered

(R) The temperature stresses will be compressive at the bottom of the slab during day time if the self-weight of the pavement slab is considered

The TRUE statement(s) is(are)

(A) P only (B) Q only (C) P and Q only (D) P and R only

Answer: (C)

Exp. Temperature stress = 0 if pavement is weightless

Temperature stress = Tensile at bottom of slab in day time

= Compressive at bottom of slab in night time

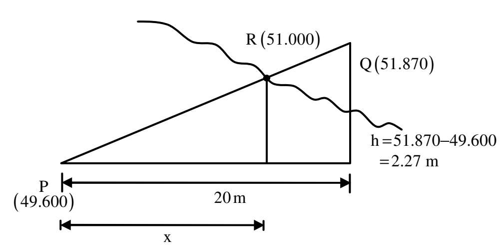
25. The Reduced Levels (RLs) of the points P and Q are +49.600 m and +51.870 m respectively. Distance PQ is 20 m. The distance (in m from P) at which the +51.000 m contour cuts the line PQ is

(A) 15.00 (B) 12.33 (C) 3.52 (D) 2.27

Answer: (B)

Exp. $$\frac{h}{20} = \frac{51-49.6}{x}$$

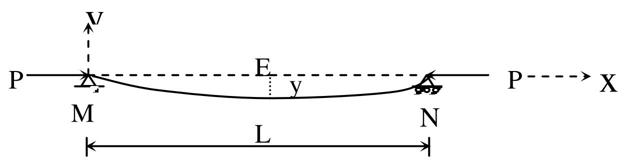
$$\Rightarrow x = \frac{1.4\times 20}{2.27} = 12.33\,m$$



Q. No. 26 – 55 Carry Two Marks

26. If the following equation establishes equilibrium in slightly bent position, the mid-span deflection of a member shown in the figure is

$$\frac{d^2y}{dx^2}+\frac{P}{EI}y=0$$



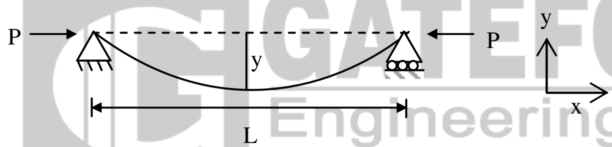
If α is amplitude constant for y, then

(A) $y=\frac{1}{P}\left(1-\alpha\cos\frac{2\pi x}{L}\right)$ (B) $y=\frac{1}{P}\left(1-\alpha\sin\frac{2\pi x}{L}\right)$

(C) $y=\alpha\sin\frac{n\pi x}{L}$ (D) $y=\alpha\cos\frac{n\pi x}{L}$

Answer: (C)

Exp.



$$\frac{d^2y}{dx^2}=\frac{-P}{EI}.y=-K^2.y$$

Solution of this differential equation is

$y=a\sin kx+b\cos kx$

at $x=0,\ y=0\ \Rightarrow\ b=0$

at $x=L,\ y=0\ \Rightarrow\ 0=a\sin KL$

$\Rightarrow KL=n\pi \Rightarrow K=\frac{n\pi}{L}$

$\therefore\ y=a\sin\frac{n\pi}{L}x$

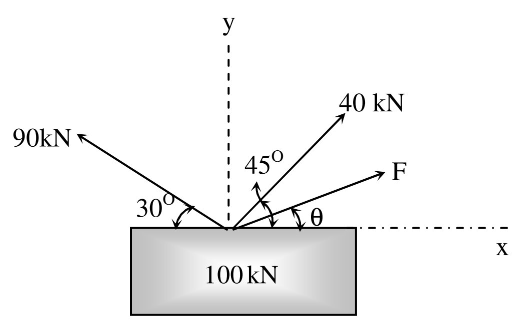
27. A box of weight 100 kN shown in the figure is to be lifted without swinging. If all forces are coplanar, the magnitude and direction (θ) of the force (F) with respect to x-axis should be

(A) F = 56.389 kN and θ = 28.28°

(B) F = -56.389 kN and θ = - 28.28°

(C) F = 9.055 kN and θ = 1.414°

(D) F = -9.055 kN and θ = -1.414°



Answer: (A)

Exp. For no swinging, $\Sigma F_H = 0$

$$\Rightarrow 90\cos 30° = F\cos\theta + 40\cos 45°$$

$$\Rightarrow F\cos\theta = 49.658 \text{ ....(i)}$$

Also, $\Sigma F_v = 0$

$$\Rightarrow 100 = 90\sin 30° + 40\sin 45° + F\sin\theta$$

$$\Rightarrow F\sin\theta = 26.715 \text{ ....(ii)}$$

solving (i) and (ii)

$F = 56.389$ kN, $\theta = 28.28°$

28. A particle moves along a curve whose parametric equations are: $x = t^3 + 2t, y = -3e^{-2t}$ and z = 2sin(5t), where x, y and z show variations of the distance covered by the particle (in cm) with time t (in s). The magnitude of the acceleration of the particle (in cm/s^2) at t = 0 is ________

Answer: 12 to 12

Exp. $x = t^3 + 2t,\ y = -3^{e^{-2t}},\ z = 2\sin(5t)$

$$a_x = \frac{\partial^2 x}{\partial t^2} = 6t$$

$$a_y = \frac{\partial^2 y}{\partial t^2} = -12.e^{-2t}$$

$$a_z = \frac{\partial^2 z}{\partial t^2} = -50\sin 5t$$

$$a = a_x\hat{i} + a_y\hat{j} + a_z\hat{k} = (6t)\hat{i} - (12e^{-2t})\hat{j} - (50\sin 5t)\hat{k}$$

$$a(t=0) = -12\hat{j}$$

$$\text{so, } |a|_{t=0} = 12\,\text{cm/s}^2$$

29. A traffic office imposes on an average 5 number of penalties daily on traffic violators. Assume that the number of penalties on different days is independent and follows a Poisson distribution. The probability that there will be less than 4 penalties in a day is __________

Answer: 0.26 to 0.27

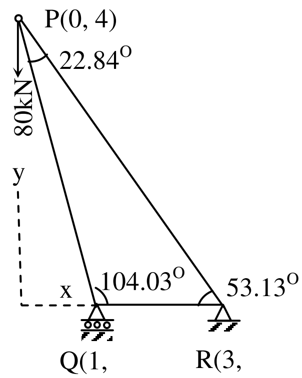
Exp. $P(x) = \dfrac{e^{-\lambda}\lambda^x}{x!}, \lambda = 5$

$$P(x<4) = P(x=0) + P(x=1) + P(x=2) + P(x=3)$$

$$= \frac{e^{-5}5^0}{\lfloor 0} + \frac{e^{-5}5^1}{\lfloor 1} + \frac{e^{-5}5^2}{\lfloor 2} + \frac{e^{-5}5^3}{\lfloor 3}$$

$$= e^{-5}\left[1 + 5 + \frac{25}{2} + \frac{125}{6}\right] = 0.265$$

30. Mathematical idealization of a crane has three bars with their vertices arranged as shown in the figure with a load of 80 kN hanging vertically. The coordinates of the vertices are given in parentheses. The force in the member QR, F_{QR} will be



(A) 30 kN Compressive

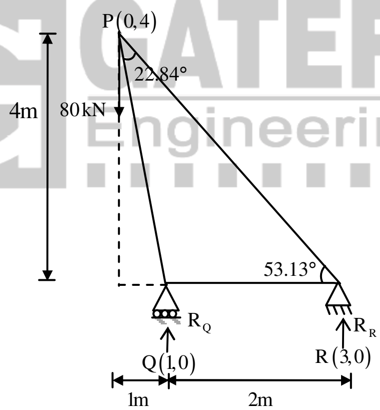
(B) 30 kN Tensile

(C) 50 kN Compressive

(D) 50 kN Tensile

Answer: A

Exp.



$\Sigma F_v = 0 \Rightarrow R_Q + R_R = 80$..................(i)

Taking moment about Q=0

$\Rightarrow 80\times1 + R_R\times2 = 0$

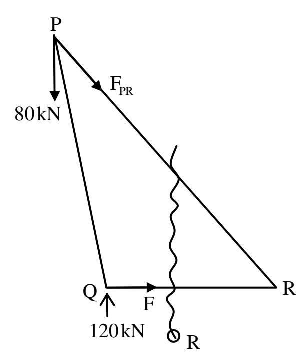
$\Rightarrow R_R = -40\,kN$

From (i), we get $R_Q = 120\,kN$

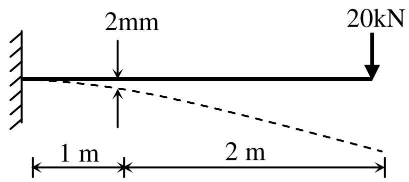
Taking moment about P = 0

$F_{QR}\times4 + 120\times1 = 0$

$\Rightarrow F_{QR} = -30\,kN$ (−) means compressive

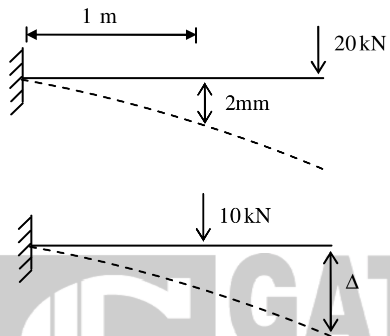


31. For the cantilever beam of span 3 m (shown below), a concentrated load of 20 kN applied at the free end causes a vertical displacement of 2 mm at a section located at a distance of 1 m from the fixed end. If a concentrated vertically downward load of 10 kN is applied at the section located at a distance of 1 m from the fixed end (with no other load on the beam), the maximum vertical displacement in the same beam (in mm) is



Answer: 1 to 1

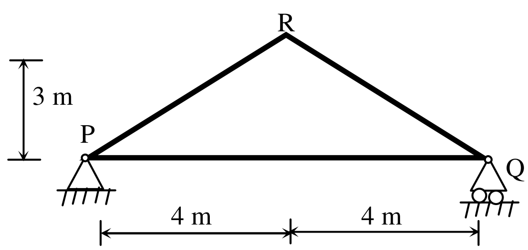
Exp.



By Bettis theorem,

$20 \times \Delta = 10 \times 2 \Rightarrow \Delta = 1\text{mm}.$

32. For the truss shown below, the member PQ is short by 3 mm. The magnitude of vertical displacement of joint R (in mm) is ______________



Answer: 1.0 to 2.5

Exp. Since deflection at R is required. So, let us apply a virtual unit load at point R in upwards direction.

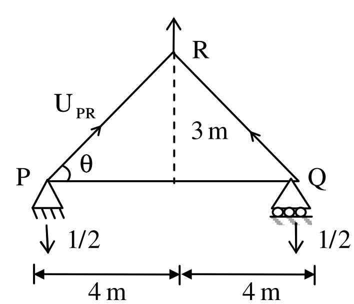
At point P $\Sigma F_V = 0 \Rightarrow U_{PR} \sin\theta = \frac{1}{2}$

$\Sigma F_H = 0 \Rightarrow U_{PR} \cos\theta + U_{PQ} = 0$

$\Rightarrow U_{PQ} = -U_{PR} \cos\theta$

$= -\frac{1}{2\sin\theta} . \cos\theta$

$= -\frac{1}{2} \times \frac{1}{\tan\theta} = -\frac{1}{2} \times \frac{4}{3} = -2/3$



$\tan\theta = \frac{3}{4}$

$\delta_R = U_{PQ} \times \lambda_{PQ}$

$= \frac{-2}{3} \times (-3)\ [\because PQ \text{ is 3mm short}] = 2\,mm$

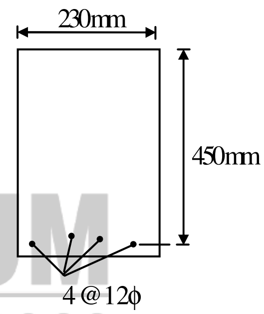
So, deflection at R = 2mm (upwards)

33. A rectangular beam of width (*b*) 230 mm and effective depth (*d*) 450mm is reinforced with four bars of 12 mm diameter. The grade of concrete is M20 and grade of steel is Fe500. Given that for M20 grade of concrete the ultimate shear strength, $\tau_{\infty} = 0.36 N/mm^2$ for steel percentage, p = 0.25, and $\tau_{\infty} = 0.48 N/mm^2$ for *p* = 0.50. For a factored shear force of 45kN, the diameter (in mm) of Fe500 steel two legged stirrups to be used at spacing of 375 mm, should be

(A) 8 (B) 10 (C) 12 (D) 16

Answer: (A)

Exp. $\tau_V = \frac{V_U}{bd} = \frac{45\times1000}{230\times450} = 0.434\ N/mm^2$



% tensile reinforcement (p) = $\frac{4\times\frac{\pi}{4}\times(12)^2}{230\times450}\times100 = 0.437\%$

$\tau_c = 0.36 + \frac{0.12}{0.25}\times(0.437-0.25) = 0.45\,N/mm^2$

$\tau_v < \tau_c$

So, minimum shear reinforcement is required

Minimum shear reinforcement

$\frac{A_{sv}}{b\times S_v} = \frac{0.4}{0.87 f_y}$

$\Rightarrow A_{sv} = \frac{0.4\times b\times S_v}{0.87\times f_y}$

$\Rightarrow 2\times\frac{\pi}{4}\times\phi^2 = \frac{0.4\times230\times375}{0.87\times500} \Rightarrow \phi = 7.10\,mm$

So, adopt $\phi = 8mm$

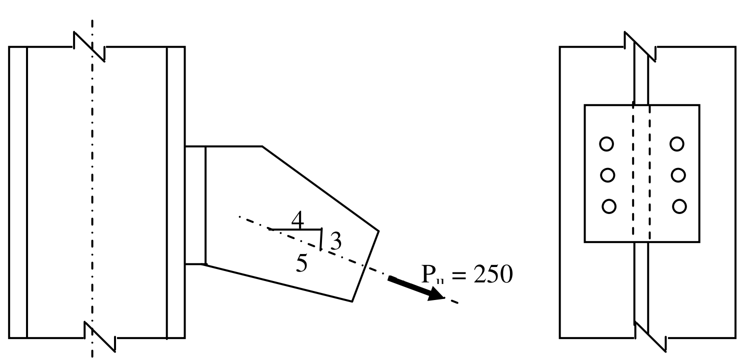
34. The tension and shear force (both in kN) in each bolt of the joint, as shown below, respectively are

(A) 30.33 and 20.00

(B) 30.33 and 25.00

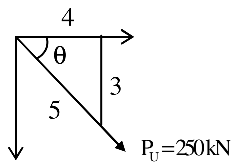
(C) 33.33 and 20.00

(D) 33.33 and 25.00



Answer: (D)

Exp. $\sin\theta = \frac{3}{5}, \cos\theta = \frac{4}{5}$



$$P_U \cos\theta = \frac{4}{5}.P_U$$

$$P_U \sin\theta = \frac{3}{5}.P_U$$

$$\text{Tension in each bolt} = \frac{P_U \cos\theta}{6} = \frac{4P_U}{5\times6} = \frac{4}{30}\times250 = 33.33\text{kN}$$

$$\text{Shear in each bolt} = \frac{P_U \sin\theta}{6} = \frac{3}{5}\times\frac{P_U}{6} = \frac{3}{5\times6}\times250 = 25\text{ kN}$$

35. For a beam of cross-section, width = 230 mm and effective depth = 500 mm, the number of rebars of 12 mm diameter required to satisfy minimum tension reinforcement requirement specified by IS:456-2000 (assuming grade of steel reinforcement as Fe500) is ___________

Answer: 2 to 2

Exp.

$$\frac{(A_{st})_{min}}{bd} = \frac{0.85}{f_y}$$

$$\Rightarrow (A_{st})_{min} = \frac{0.85}{500}\times230\times500 = 195.5\,mm^2$$

$$n\times\frac{\pi}{4}d^2 = 195.5 \Rightarrow n=1.73$$

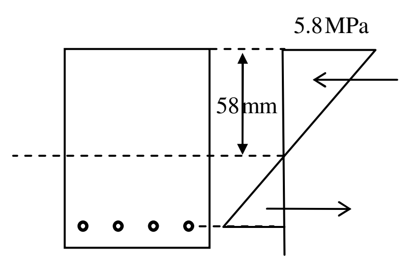
So, take $n=2$

36. In a reinforced concrete section, the stress at the extreme fibre in compression is 5.80 MPa. The depth of neutral axis in the section is 58 mm and the grade of concrete is M25. Assuming linear elastic behavior of the concrete, the effective curvature of the section (in per mm) is

(A) 2.0×10^{-6} (B) 3.0×10^{-6} (C) 4.0×10^{-6} (D) 5.0×10^{-6}

Answer: (C)

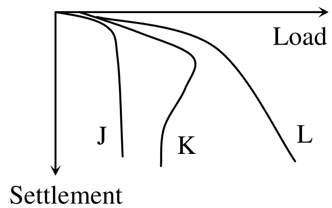
Exp. $E=5000\sqrt{f_{ck}} = 5000\times\sqrt{25} = 25000\,N/mm^2$



$$\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$$

$$\text{curvature, } \frac{1}{R} = \frac{f}{yE} = \frac{5.8}{58\times25000} = 4\times10^{-6}\text{ per mm}$$

37. Group I contains representative load-settlement curves for different modes of bearing capacity failures of sandy soil. Group II enlists the various failure characteristics. Match the load-settlement curves with the corresponding failure characteristics.



Group I	Group II
(p) Curve J	(1) No apparent heaving of soil around the footing
(q) Curve K	(2) Rankine's passive zone develops imperfectly
(r) Curve L	(3) Well defined slip surface extends to ground surface

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

Answer: (A)

Exp. K $\rightarrow$ General shear failure
L $\rightarrow$ Local shear failure
J $\rightarrow$ Punching shear failure

General shear failure (Q) : Well define failure pattern(3)
Local shear failure (L) : Rankine passive zone developes(2)
Punching shear failure: No heaving of soil around footing

38. A given cohesionless soil has $e_{max} = 0.85$ and $e_{max} = 0.50$. In the field, the soil is compacted to a mass density of 1800 kg/m^3 at a water content of 8%. Take the mass density of water as 1000kg/m^3 and G, as 2.7.The relative density (in %) of the soil is

(A) 56.43 (B) 60.25 (C) 62.87 (D) 65.7

Answer: (D)

Exp. $e_{max} = 0.85,\ e_{min} = 0.5\ \rho_{field} = 1800\,kg/m^3$

$w = 8\%,\ \rho_w = 1000\,kg/m^3,\ G_s = 2.7$

$$\rho = \frac{G(1+w)}{1+e}\rho_w$$

$$\Rightarrow 1+e = G(1+w)\frac{\rho_w}{\rho} = \frac{2.7(1+.08)}{1800}\times 1000$$

$$\Rightarrow e = 0.62$$

$$\text{Relative Density} = \frac{e_{max}-e}{e_{max}-e_{min}}\times 100 = \frac{0.85-0.62}{0.85-0.5}\times 100 = 65.71\%$$

39. The following data are given for the laboratory sample.

$$\sigma_0' = 175\text{kPa};\ e_0 = 1.1;\ \sigma_0' + \Delta\sigma_{0'} = 300\text{kPa};\ e = 0.9$$

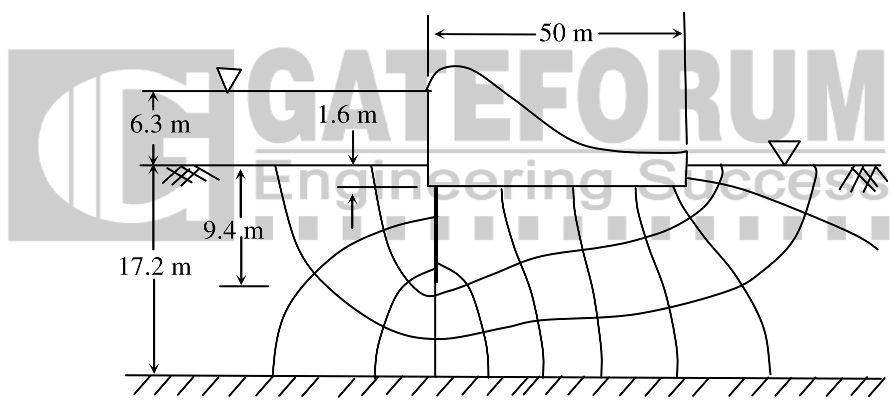
If thickness of the clay specimen is 25mm, the value of coefficient of volume compressibility is ________ $\times 10^{-4}\,\text{m}^2/\text{kN}$

Answer: 7.6 to 8.0

Exp. Volume compressibility, $m_v = \dfrac{a_v}{\Delta\bar{\sigma}} = \dfrac{\dfrac{\Delta e}{1+e_0}}{\Delta\bar{\sigma}}$

$$= \frac{0.2}{1+1.1} \times \frac{1}{125} = 7.62 \times 10^{-4}\,\text{m}^2/\text{kN}$$

40. The flow net constructed for the dam is shown in the figure below. Taking the coefficient of permeability as 3.8×10^{-6} m/s, the quantity of flow (in cm^3/s) under the dam per meter of dam is ____________



Impermeable stratum

Answer: 7.10 to 7.85

Exp. $Q = K.H.\dfrac{N_f}{N_d}$

N_f = No. of flow channels = 3

N_d = No. of equipotential drops = 10

$K = 3.8\times10^{-4}\,\text{s/m}$

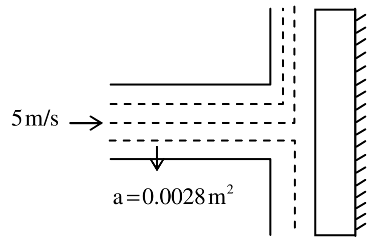
H = 6.3m

$$Q = 3.8\times10^{-6} \times 6.3 \times \frac{3}{10} = 7.182 \times 10^{-6}\,\text{m}^3/\text{s/m} = 7.182\,\text{cm}^3/\text{s/m}$$

41. A horizontal jet of water with its cross-sectional area of 0.0028 m^2 hits a fixed vertical plate with a velocity of 5 m/s. After impact the jet splits symmetrically in a plane parallel to the plane of the plate. The force of impact (in N) of the jet on the plate is

(A) 90 (B) 80 (C) 70 (D) 60

Answer: (C)

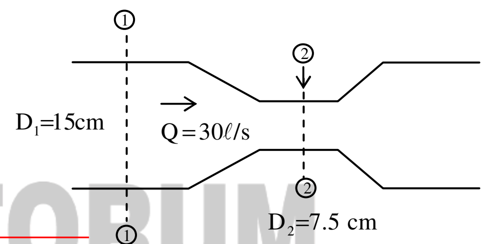


Exp. Force on plate, $F = \rho . a . v^2$

$= 1000 \times 0.0028 \times 5^2 = 70\,N$

42. A venturimeter, having a diameter of 7.5 cm at the throat and 15 cm at the enlarged end, is installed in a horizontal pipeline of 15 cm diameter. The pipe carries an incompressible fluid at a steady rate of 30 litres per second. The difference of pressure head measured in terms of the moving fluid in between the enlarged and the throat of the venturimeter is observed to be 2.45 m. Taking the acceleration due to gravity as 9.81 m/s^2, the coefficient of discharge of the venturimeter (correct up to two places of decimal) is ____________

Answer: 0.93 to 0.96



Exp. $Q = \dfrac{cd . a_1 a_2}{\sqrt{a_1^2 - a_2^2}} . \sqrt{2gh}$

$a_1 = \dfrac{\pi}{4} \times (.15)^2 = 0.0176\,m^2$

$a_2 = \dfrac{\pi}{4} \times (.075)^2 = 0.0044\,m^2$

$\Rightarrow 30 \times 10^{-3} = C_d . \dfrac{0.0176 \times 0.0044}{\sqrt{(0.0176)^2 - (0.0044)^2}} \times \sqrt{2 \times 9.81 \times 2.45}$

$\Rightarrow C_d = 0.95$

43. A rectangular channel having a bed slope of 0.0001, width 3.0 m and Manning's coefficient 'n' 0.015, carries a discharge of 1.0 m^3/s. Given that the normal depth of flow ranges between 0.76 m and 0.8 m. The minimum width of a throat (in m) that is possible at a given section, while ensuring that the prevailing normal depth is not exceeded along the reach upstream of the contraction, is approximately equal to (assume negligible losses)

(A) 0.64 (B) 0.84 (C) 1.04 (D) 1.24

Answer: (B)

Exp. $n = 0.015, \quad Q = 1\,m^3/s, \quad B = 3.0\,m$

Normal depth of flow ranges between 0.76m to 0.8 m

If prevailing normal depth of flow is not exceeded, there must not be choking of the section or it should be at boundary condition of choking.

So, width of section should be such that there should be critical flow corresponding to the prevailing specific energy.

i.e. $\dfrac{3}{2}\left(\dfrac{q^2}{g}\right)^{1/3} = E_c = E_{initial}$

$q = \dfrac{Q}{B_{min}}$, So $\dfrac{3}{2}\left[\dfrac{\left(\dfrac{Q}{B_{min}}\right)^2}{g}\right]^{1/3} = E_{initial}$

$$E_{initial} = y + \frac{q^2}{2gy^2}$$

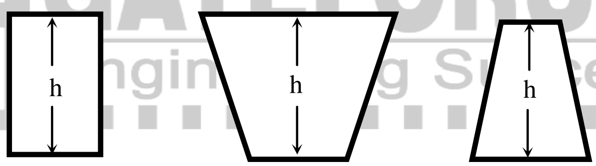
$$Q = \frac{1}{n}.A.R^{2/3}S^{1/2} \Rightarrow 1 = \frac{1}{0.015}.(B.y).\left(\frac{B.y}{B+2y}\right).S^{1/2}$$

$$\Rightarrow 1 = \frac{1}{0.015}.(3y).\left(\frac{3y}{3+2y}\right).(0.0001)^{1/2} \Rightarrow y = 0.78\text{ m}$$

$$\text{So, } E_{initial} = 0.78 + \frac{\left(\frac{1}{3}\right)^2}{2\times 9.81\times (0.78)^2} = 0.789\text{ m}$$

$$\text{So, } \frac{3}{2}\left(\frac{Q}{g.(B_{min})^2}\right)^{1/3} = 0.789 \Rightarrow B_{min} = 0.84\text{ m}$$

44. Three rigid buckets, shown as in the figures (1), (2) and (3), are of identical heights and base areas. Further, assume that each of these buckets have negligible mass and are full of water. The weights of water in these buckets are denoted as W_1, W_2, and W_3 respectively. Also, let the force of water on the base of the bucket be denoted as F_1, F_2, and F_3 respectively. The option giving an accurate description of the system physics is



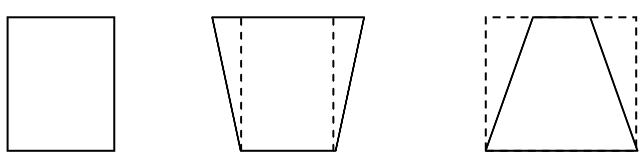
ALL THREE BUCKETS HAVE THE SAME BASE AREA

(1) (2) (3)

(A) $W_2 = W_1 = W_3$ and $F_2 > F_1 > F_3$
(B) $W_2 > W_1 > W_3$ and $F_2 > F_1 > F_3$
(C) $W_2 = W_1 = W_3$ and $F_1 = F_2 = F_3$
(D) $W_2 > W_1 > W_3$ and $F_1 = F_2 = F_3$

Answer: (D)

Exp.



Force on base of Bucket, $F = \gamma_w .h.A_{base}$

$\because$ Base area of all buckets is same.

So, $F_1 = F_2 = F_3$

Weight of water, $W = \gamma_w .V$

Since $V_2 > V_1 > V_3$

so, $W_2 > W_1 > W_3$

45. An incompressible fluid is flowing at a steady rate in a horizontal pipe. From a section, the pipe divides into two horizontal parallel pipes of diameters d_1 and d_2 (where $d_1 = 4d_2$) that run for a distance of L each and then again join back to a pipe of the original size. For both the parallel pipes, assume the head loss due to friction only and the Darcy-Weisbach friction factor to be the same. The velocity ratio between the bigger and the smaller branched pipes is ________

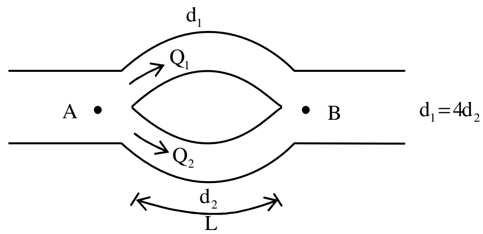
Answer: 2 to 2

Exp. Since pipes are in parallel,
so, head loss will be same

$$\frac{fL}{d_1}\cdot\frac{V_1^2}{2g} = \frac{fL}{d_2}\cdot\frac{V_2^2}{2g}$$

$$\Rightarrow \frac{V_1^2}{d_1} = \frac{V_2^2}{d_2} \Rightarrow \frac{V_1^2}{V_2^2} = \frac{d_1}{d_2} = 4$$

$$\Rightarrow \frac{V_1}{V_2} = 2$$



46. 16 MLD of water is flowing through a 2.5 km long pipe of diameter 45 cm. The chlorine at the rate of 32 kg/d is applied at the entry of this pipe so that disinfected water is obtained at the exit. There is a proposal to increase the flow through this pipe to 22 MLD from 16 MLD. Assume the dilution coefficient, n = 1. The minimum amount of chlorine (in kg per day) to be applied to achieve the same degree of disinfection for the enhanced flow is

(A) 60.50 (B) 44.00 (C) 38.00 (D) 23.27

Answer: (A)

Exp. For disinfection, we have $tc^n = K$

Where t = time required to kill all organisms
c= concentration of disinfectant
n = dilution coefficient
k = constant

So, $t_1 c_1^n = t_2 c_2^n$

here, n=1

$t_1 c_1 = t_2 c_2$

$t_1 = \frac{L}{V_1}$; L = length of pipe, V_1 = velocity of flow

$= \frac{L}{Q_1/A} = \frac{L.A}{Q_1}$; Q_1 = discharge per day

$C_1 = \frac{W_1}{Q_1}$, W_1 = weight of disinfectant per day

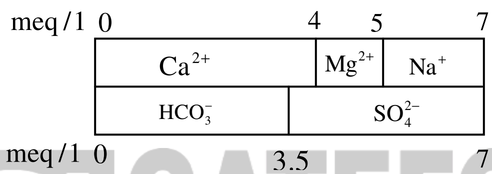
so, $\frac{LA}{Q_1}\cdot\frac{W_1}{Q_1} = \frac{LA}{Q_2}\cdot\frac{W_2}{Q_2}$

$$W_2 = \left(\frac{Q_2}{Q_1}\right)^2 . W_1 = \left(\frac{22}{16}\right)^2 \times 32 = 60.5\,kg/d$$

47. The potable water is prepared from turbid surface water by adopting the following treatment sequence.
(A) Turbid surface water → Coagulation → Flocculation → Sedimentation → Filtration → Disinfection → Storage & Supply
(B) Turbid surface water → Disinfection → Flocculation → Sedimentation → Filtration → Coagulation → Storage & Supply
(C) Turbid surface water → Filtration → Sedimentation → Disinfection → Flocculation → Coagulation → Storage & Supply
(D) Turbid surface water → Sedimentation → Flocculation → Coagulation → Disinfection → Filtration . Storage & Supply

Answer: (A)

48. For a sample of water with the ionic composition shown in the figure below, the carbonate and non-carbonate hardness concentrations (in mg/l as $CaCO_3$), respectively are:



(A) 200 and 50 (B) 175 and 75 (C) 75 and 175 (D) 50 and 200

Answer: (B)

Exp. Carbonate hardness $CH = 3.5 \times 50\ mg/\ell$ as $CaCO_3 = 175\,mg/\ell$

Non Carbonate hardness, NCH = Total Hardness – Carbonate hardness

$= 50 \times 50 - 175$

$= 75\ mg/\ell$ as $CaCO_3$

49. A straight 100 m long raw water gravity main is to carry water from an intake structure to the jack well of a water treatment plant. The required flow through this water main is 0.21 m^3/s. Allowable velocity through the main is 0.75 m/s. Assume f = 0.01, g = 9.81 m/s^2. The minimum gradient (in cm/100 m length) to be given to this gravity main so that the required amount of water flows without any difficulty is ___

Answer: 4.7 to 4.9

Exp. $Q = 0.21 m^3/s$

$V_a = 0.75\ m/s,\ f = 0.01,\ g = 9.81 m/s^2$

$A = \frac{Q}{V} \Rightarrow \frac{\pi}{4}.d^2 = \frac{0.21}{0.75}$

$\Rightarrow d = 0.60\,m$

$$h_f = \frac{f \times L}{d} \times \frac{V^2}{2g} = \frac{0.01 \times 100 \times (0.75)^2}{0.60 \times 2 \times 9.81} = 0.047\,m = 4.7\,cm$$

$$\text{Minimum gradient} = \frac{h_f}{L} = \frac{4.7cm}{100\,m}$$

50. A traffic survey conducted on a road yields an average daily traffic count of 5000 vehicles. The axle load distribution on the same road is given in the following table:

Axle load (tonnes)	Frequency of traffic (%)
18	10
14	20
10	35
8	15
6	20

The design period of the road is 15 years, the yearly traffic growth rate is 7.5% and the load safety factor (LSF) is 1.3. If the vehicle damage factor (VDF) is calculated from the above data, the design traffic (in million standard axle load, MSA) is

Answer: 307 to 310

Exp. Vehicle damage factor

$$VDF = \frac{V_1 \times \left(\frac{W_1}{W_s}\right)^4 + V_2 \cdot \left(\frac{W_2}{W_s}\right)^4 + \ldots\ldots\ldots V_s\left(\frac{W_s}{W_s}\right)^4}{V_1 + V_2 + V_3 + V_4 + V_5}$$

$$= \frac{10\times\left(\frac{18}{8.2}\right)^4 + 20\times\left(\frac{14}{8.2}\right)^4 + 35\times\left(\frac{10}{8.2}\right)^4 + 15\times\left(\frac{8}{8.2}\right)^4 + 20\times\left(\frac{16}{8.2}\right)^4}{10+20+35+15+20} = 4.99$$

$$N = \frac{365 \times A\left[(1+r)^n - 1\right]}{r} \times VDF$$

$$= \frac{365 \times 5000 \times \left[(1.075)^n - 1\right]}{0.075} \times 4.99 = 237.785\ MSA$$

So, Design traffic $= 237.785 \times 1.3 = 309.21$ MSA

51. The perception-reaction time for a vehicle travelling at 90 km/h, given the coefficient of longitudinal friction of 0.35 and the stopping sight distance of 170 m (assume g = 9.81 m/s^2), is __________ seconds.

Answer: 3.1 to 3.2

Exp.

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

$$170 = \left(90 \times \frac{5}{18}\right) + \frac{\left(90 \times \frac{5}{18}\right)^2}{2 \times 9.81 \times 0.35} \Rightarrow t = 3.15s$$

52. The speed-density (u-k) relationship on a single lane road with unidirectional flow is u = 70 – 0.7k, where u is in km/hr and k is in veh/km. The capacity of the road (in veh/hr) is ________

Answer: 1750 to 1750

Exp.

$$U = 70 - 0.7K$$

$$\text{capacity} = \frac{U_f \times K_j}{4} \qquad U_f = \text{free velocity}, \quad K_j = \text{jam density}$$

$$\text{At } K_j, U = 0$$

$$\text{So } K_j = \frac{70}{7} = 100 \text{ veh/km}$$

$$\text{At } K = 0, U = U_f = 70 \text{ km/hr}$$

$$\text{So, capacity} = \frac{70 \times 100}{4} = 1750 \text{ veh/hr}$$

53. An isolated three-phase traffic signal is designed by Webster's method. The critical flow ratios for three phases are 0.20, 0.30, and 0.25 respectively, and lost time per phase is 4 seconds. The optimum cycle length (in seconds) is ___________

Answer: 90 to 95

Exp. Total time lost in a cycle, $L = 4 \times 3 = 12 \text{sec}$

$$C = \frac{1.5L + 5}{1 - y} = \frac{1.5 \times 12 + 5}{1 - (0.2 + 0.3 + 0.25)} = 92\text{s}$$

54. A levelling is carried out to establish the Reduced Levels (RL) of point R with respect to the Bench Mark (BM) at P. The staff readings taken are given below.

Staff Station	BS	IS	FS	RL
P	1.655 m			100.000 m
Q	-0.950 m		-1.500 m	
R			0.750 m	?

If RL of P is +100.000 m, them RL (in m) of R is

(A) 103.355 (B) 103.155 (C) 101..455 (D) 100.355

Answer: (C)

Exp.

$$\text{RL of P} = 100.00 \text{m}$$

$$\text{RL of Q} = 100 + 1.655 + 1.5 = 103.155 \text{m}$$

$$\text{RL of R} = 103.155 - (0.95 + 0.75) = 101.455 \text{m}$$

55. Group I lists tool/instrument while Group II lists the method of surveying. Match the tool/instrument with the corresponding method of surveying.

Group I	Group II
(p) Alidade	(1) Chain surveying
(q) Arrow	(2) Levelling
(r) Bubble tube	(3) Plain table surveying
(s) Stadia hair	(4) Theodolite surveying

(A) P – 3; Q – 2; R – 1; S – 4
(B) P – 2; Q – 4; R – 3; S – 1
(C) P – 1; Q – 2; R – 4; S – 3
(D) P – 3; Q – 1; R – 2; S – 4

Answer: (D)

Exp.
Alidade → used in plane table surveying
Arrow → chain surveying
Bubble tube → leveling
Stadia hair → Theodolite surveying