GATE SOLVED PAPER
Civil Engineering
2014-1

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GATE SOLVED PAPER - CE

2014-1

General Aptitude

Q. 1 - Q. 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

Sol. 1 Correct option is (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

Sol. 2 Correct option is (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.

Sol. 3 Correct option is (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

Sol. 4 Correct option is (C).

Q. 5 A foundry has a fixed daily cost of ₹ 50000 whenever it operates and a variable cost of ₹ $800Q$, where Q is the daily production in tonnes. What is the cost of production in ₹ per tonne for a daily production of 100 tonnes?

Sol. 5 Correct answer is 1300.

Q. 6 - Q. 10 Carry two marks each.

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

(A) ALRVX (B) EPVZB

(C) ITZDF (D) OYEIK

Sol. 6 Correct option is (D).

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

Sol. 7 Correct option 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?

Sol. 8 Correct answer is 180.

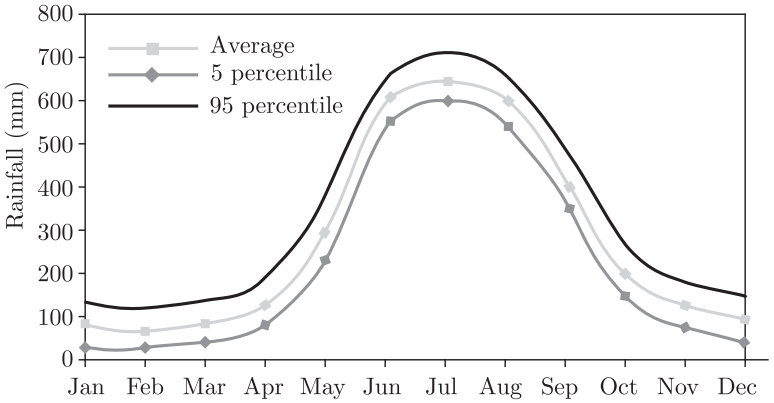
Q. 9 One percent of the people of country X are taller than 6 ft. Two percent of the people of country Y are taller than 6 ft. There are thrice as many people in country X as in country Y. Taking both countries together, what is the percentage of people taller than 6 ft?

(A) 3.0 (B) 2.5

(C) 1.5 (D) 1.25

Sol. 9 Correct option is (D).

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)

Sol. 10 Correct option is (B).

END OF THE QUESTION PAPER

Civil Engineering

Q. 1 - Q. 25 Carry one mark each.

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

(A) $-\infty$ (B) 0

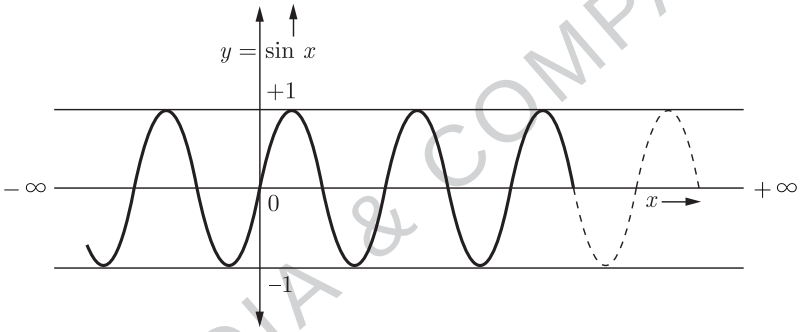
(C) 1 (D) ∞

Sol. 1 Correct option is (C).

Given $\lim\limits_{x\to\infty}\left(\dfrac{x+\sin x}{x}\right)$ can be written as

$$\lim_{x\to\infty}\left(\frac{x}{x}+\frac{\sin x}{x}\right)\Rightarrow\lim_{x\to\infty}\left(1+\frac{\sin x}{x}\right) \quad ...(1)$$

sin has a plot



$\sin x$ value remains b/w $+1$ to -1; for $x\in(-\infty,+\infty)$

So putting limits in (1)

$$1+\frac{\sin\infty}{\infty}=1+\frac{(\text{value b/w}+1\text{ to}-1)}{\infty}=1+0=1$$

Q. 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^TJK is _____.

Sol. 2 Correct answer is 23.

Given $$J=\begin{bmatrix}3&2&1\\2&4&2\\1&2&6\end{bmatrix}_{3\times3}\ \&\ K=\begin{bmatrix}1\\2\\-1\end{bmatrix}_{3\times1}$$

So $$K^T=\begin{bmatrix}1&2&-1\end{bmatrix}_{1\times3}$$

so matrix multiplication

$$K^TJK=\begin{bmatrix}1&2&-1\end{bmatrix}\begin{bmatrix}3&2&1\\2&4&2\\1&2&6\end{bmatrix}\begin{bmatrix}1\\2\\-1\end{bmatrix}$$

$$=\begin{bmatrix}6&8&-1\end{bmatrix}_{1\times3}\begin{bmatrix}1\\2\\-1\end{bmatrix}_{3\times1}$$

$$=6+16+1=23$$

Q. 3 The probability density function of evaporation E on any day during a year in a

watershed is given by

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

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

Sol. 3 Correct answer is 0.4 .

Given probability distribution

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

We have to find probability that E lies b/w 2 & 4 so, for 2 to 4.

$$f(E) = \frac{1}{5}$$

$$\text{Required probability } p = \int_2^4 f(E)\,dE = \int_2^4 \frac{1}{5}\,dE = \frac{1}{5}[E]_2^4 = \frac{4-2}{5}$$

$$= \frac{2}{5} = 0.4$$

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

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

(A) 915 (B) 1355

(C) 1640 (D) 2180

Sol. 4 Correct option is (A).

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

Sum of eigen values of a matrix is equal to the summation of its diagonal elements.

So Sum of eigen values is equal to $= 215 + 150 + 550 = 915$

Q. 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 $(x_3, y_3) = (4,3)$. The area of the triangle is equal to

(A) 3/2 (B) 3/4

(C) 4/5 (D) 5/2

Sol. 5 Correct option is (A).

Given co-ordinates of points $A(1,0)$, $B(2,2)$ & $C(4,3)$

So, by distance formula $a = AB = \sqrt{(2-0)^2 + (2-1)^2} = \sqrt{5}$

$$b = BC = \sqrt{(4-2)^2 + (3-2)^2} = \sqrt{5}$$

& $$c = CD = \sqrt{(3-0)^2 + (4-1)^2} = \sqrt{18} = 3\sqrt{2}$$

So by hero's formula area; $A = \sqrt{s(s-a)(s-b)(s-c)}$ ...(1)

where, $$s = \frac{a+b+c}{2} = \frac{\sqrt{5} + \sqrt{5} + 3\sqrt{2}}{2}$$

$$= \sqrt{5} + \frac{3\sqrt{2}}{2} \quad \text{...(2)}$$

From (1) & (2)

$$\text{area; } A = \sqrt{\left(\sqrt{5}+\frac{3\sqrt{2}}{2}\right)\left[\sqrt{5}+\frac{3\sqrt{2}}{2}-\sqrt{5}\right]\left[\left(\sqrt{5}+\frac{3\sqrt{2}}{2}\right)-\sqrt{5}\right]\left[\left(\sqrt{5}+\frac{3\sqrt{2}}{2}\right)-(3\sqrt{2})\right]}$$

$$= \sqrt{\left(\sqrt{5}+\frac{3\sqrt{2}}{2}\right)\left(\frac{3\sqrt{2}}{2}\right)\left(\frac{3\sqrt{2}}{2}\right)\left(\sqrt{5}-\frac{3\sqrt{2}}{2}\right)}$$

$$= \sqrt{\left(\frac{3\times\sqrt{2}}{2}\right)^2(\sqrt{5})^2-\left(\frac{3\sqrt{2}}{2}\right)^2} = \sqrt{\left(\frac{9\times 2}{4}\right)\times\left(5-\frac{9}{2}\right)}$$

$$= \sqrt{\left(\frac{9}{2}\right)\left(\frac{1}{2}\right)} = \frac{3}{2}$$

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

	Group-I		Group-II
P.	Factor to decreases 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

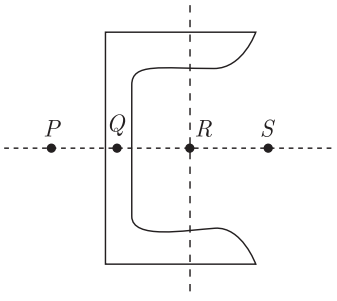
Sol. 6 Correct option is (C).

$$\text{Design strength} = \frac{\text{Ultimate strength of Material}}{\text{Partial safety factor}}$$

$$\text{Design Ultimate load} = \text{Working Load} \times \text{Load factor}$$

Statical method of ultimate load is also known as lower bound method, Kinematic method of ultimate load is also known as upper bound method.

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



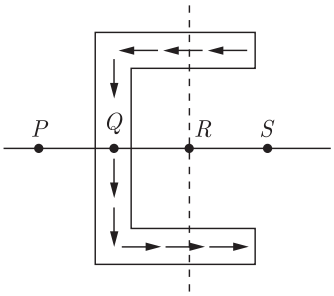
(A) P (B) Q

(C) R (D) S

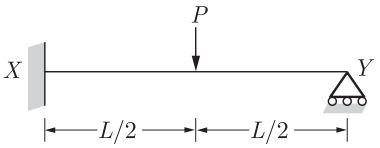
Sol. 7 Correct option is (A).

Shear centre is the point through which the internal flexural shear should pass. When external shear force due to loading passes through, the same point, no torsion is caused.

For section shown 'P' is the shear centre.



Q. 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

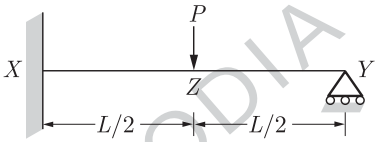


(A) $P = \dfrac{2M_p}{L}$ (B) $P = \dfrac{4M_p}{L}$

(C) $P = \dfrac{6M_p}{L}$ (D) $P = \dfrac{8M_p}{L}$

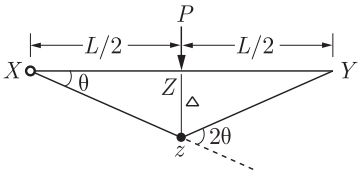
Sol. 8 Correct option is (C).

Given beam



For collapse mechanism to form, a plastic hinge should form at X and then below the load at Z. There is a real hinge at Y.

Given plastic moment capacity is M_P, So by kinematic method, Deflected shape



So $\Delta = \dfrac{\theta L}{2}$, Now external work = internal work

$\Rightarrow \quad P \times \Delta = M_P(\Sigma\theta)$

$\Rightarrow \quad P \times \Delta = M_P(\theta_X) + M_P(\theta_Z)$

$\Rightarrow \quad P \times \dfrac{\theta L}{2} = M_P(\theta) + M_P(2\theta)$

So $P = \dfrac{2 \times 3M_P}{L} = \dfrac{6M_P}{L}$

Q. 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 $\mathrm{N/mm^2}$) in limit state method of design as per IS:456-2000 is _ _ _ _ _ _ _ _ _ _

Sol. 9 Correct answer is 9.

As per IS -456-200 Clause 34.4

Bearing strength of concrete is $0.25f_{ck}$ (for working stress method)

& $0.45\, f_{ck}$ (For limit state Method)

So M20 is given; Therefore, $f_{ck} = 20\,\text{N/mm}^2$

For limit state method bearing strength will be

$$0.45f_{ck} = 0.45 \times 20 = 9\,\text{N/mm}^2$$

Q. 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

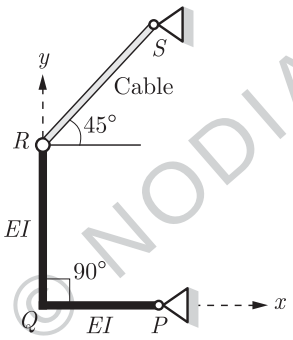
(A) $V > 0.6\,V_s$ (B) $V > 0.7\,V_s$

(C) $V > 0.8\,V_s$ (D) $V > 0.9\,V_s$

Sol. 10 Correct option is (A).

According to IS : 800-2007, for steel section subjected to combination of shear and bending action's, if applied shear force is V & shear capacity is V_s then for $V > 0.6\,V_s$. Shear force V is categorised as high.

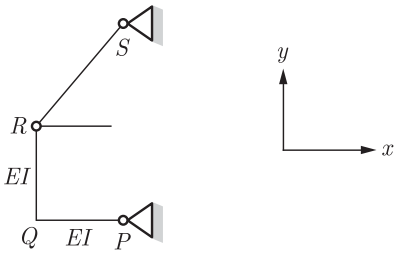
Q. 11 The degree of static indeterminacy of a rigid jointed frame PQR supported as shown in the figure is



(A) zero (B) one

(C) two (D) unstable

Sol. 11 Correct option is (A).



Internal indeterminacy for plane frames

$$\text{'}D_{si}\text{'} = 3C = 3 \times 0 = 0 \qquad \text{...(i)}$$

(C is total number of closed loops)

External indeterminacy 'D_{se}'

= Total no. of reactions – Available equilibrium equations

Total number of reaction 'R' $= 2$ at $P + 2$ at $S = 4$

$$\text{Equilibrium equations '}E\text{'} = 3(\Sigma X, \Sigma Y, \Sigma M_z = 0) + 1(\text{due to hinge at } R)$$
$$= 4$$

So $D_{se} = R - E = 4 - 4 = 0$ ...(ii)

Total static indeterminacy $D_s = D_{si} + D_{se} = 0$

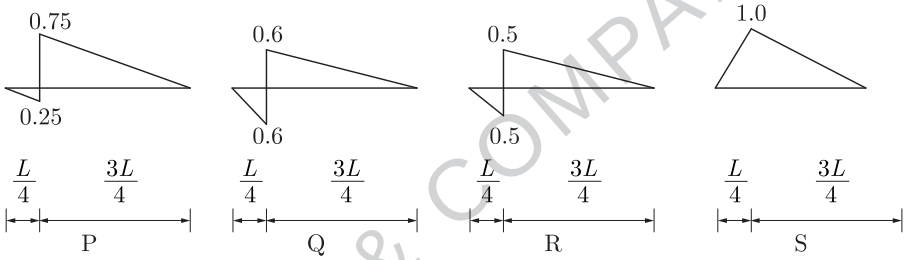
Alternatively

By formula of static indeterminacy for plane frame

$$D_s = 3m + r - r' - 3j$$
$$m = \text{(Total members)} = 3$$
$$r = \text{(available reactions)} = 2 + 2 = 4$$
$$r' = \text{(additional equilibrium equation)} = 1 \text{ (due to hing at } R)$$
$$j = \text{(Total number of joints)} = 4$$

So $D_s = 3 \times 3 + 4 - 1 - 3 \times 4 = 0$

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



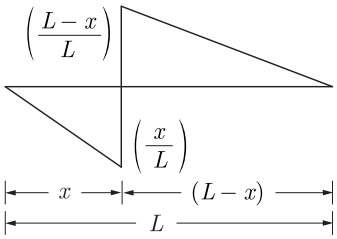
(A) P (B) Q

(C) R (D) S

Sol. 12 Correct option is (A).

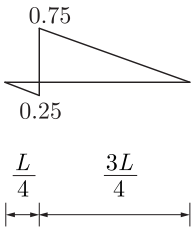
Influence line diagram is the variation of any forcing function at any point on the beam as a unit load moves across its length.

Influence line diagram of shear force for a beam at a section x for a beam of length L is given as



So here $x = \frac{L}{4}$

So influence line diagram



$$\left(\frac{x}{L}=\frac{L/4}{L}=0.25 \text{ \& } \frac{L-x}{L}=\frac{3L}{4L}=0.75\right)$$

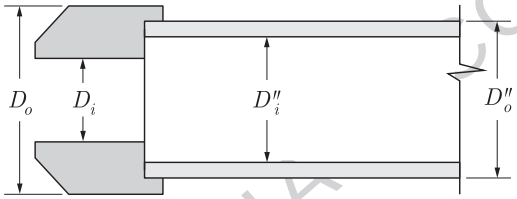
Q. 13 The degree of disturbance of the sample collected by the sampler is expressed by a term called the "area ratio". If the outer diameter and inner diameter of the sampler are D_o and D_i respectively, the area ratio is given by

(A) $\frac{D_o^2-D_i^2}{D_i^2}$ (B) $\frac{D_i^2-D_o^2}{D_i^2}$

(C) $\frac{D_o^2-D_i^2}{D_o^2}$ (D) $\frac{D_i^2-D_o^2}{D_o^2}$

Sol. 13 Correct option is (A).

Sampler is as shown below with its D_i & D_o



So Area ratio is $\frac{D_o^2-D_i^2}{D_i^2}$

inside clearance is $=\frac{D_i''-D_i}{D_i}$; out side clearance is $=\frac{D_o-D_o''}{D_o''}$

Q. 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

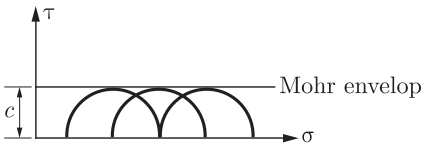
(B) Consolidated Undrained (CU) test

(C) Unconfined Compression (UC) test

(D) Unconsolidated Undrained (UU) test

Sol. 14 Correct option is (D).

For a unconsolidated undrained test on saturated cohesive soils, the mohr envelope is horizontal line parallel of σ axis.



Slope of mohr envelope is zero, ϕ is zero.

Q. 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

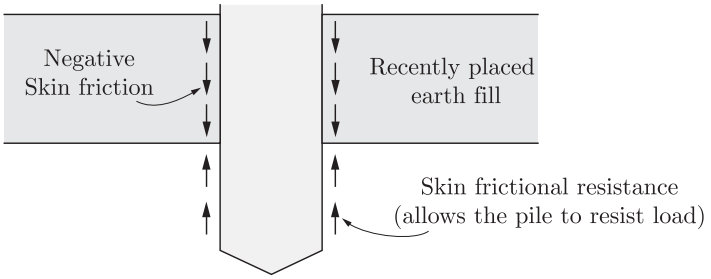
(C) maintain the working load on the pile

(D) reduce the settlement of the pile

Sol. 15 Correct option is (B).

Negative skin friction acts in the direction opposite to the frictional resistance, that allows the pile to resist load.

So it decreases the load bearing capacity.



Q. 16 A long slope is formed in a soil with shear strength parameters : $c' = 0$ and $\phi' = 34^\circ$. 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 $\gamma_{sat} = 18\,\text{kN/m}^3$ and $\gamma_w = 10\,\text{kN/m}^3$. 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

Sol. 16 Correct option is (D).

For a semi infinite stratum of noncohesive soil, factor of safety for slope is given as

$$F = \frac{\overline{\sigma}\tan\phi}{\sigma\tan i}$$

$$F = \frac{\gamma\tan\phi}{\gamma\tan i} = \frac{\tan\phi}{\tan i} \qquad (\phi = \text{friction angle},\ i = \text{slope angle})$$

but steady seepage is taking place parallel to the stratum,

So effective stress, $\overline{\sigma} = (\gamma_{sat} - \gamma_w)z = \gamma' z$ ($\gamma' =$ submerged weight)

So $$F = \frac{\gamma' z}{\gamma_{sat} z}\frac{\tan\phi}{\tan i} \Rightarrow F = \frac{\gamma'}{\gamma_{sat}}\frac{\tan\phi}{\tan i} \quad \text{...(i)}$$

So $F = 1.5;\quad \gamma' = (18 - 10) = 8;\quad \gamma_{sat} = 18;\quad \phi = 34^\circ$

So from (1)

$$\tan i = \frac{8}{18 \times 1.5}\tan 34 = 0.199$$

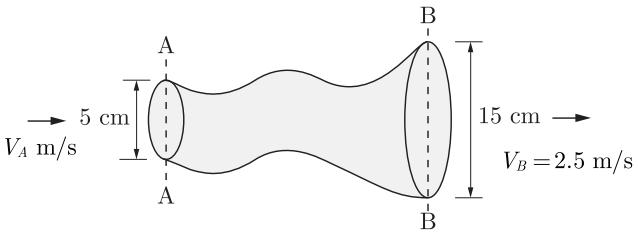
$$i = 11.30$$

Q. 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

– – – – – – –

Sol. 17 Correct answer is 22.5 .

Given a variable section of Diameters 15 cm & 5 cm at two sections as shown



Given velocity at B-B section is 2.5 m/s & velocity at section A-B is V_A m/s.
So by applying continuity equation at section A-A & B-B

$$V_A \times A_A = V_B \times A_B$$

$$V_A \times \frac{\pi}{4} \times (5)^2 = 2.5 \times \frac{\pi}{4} \times (15)^2$$

So $$V_A = 22.5\,\text{m/s}$$

Q. 18 A conventional flow duration curve is a plot between

(A) Flow and percentage time flow is exceeded

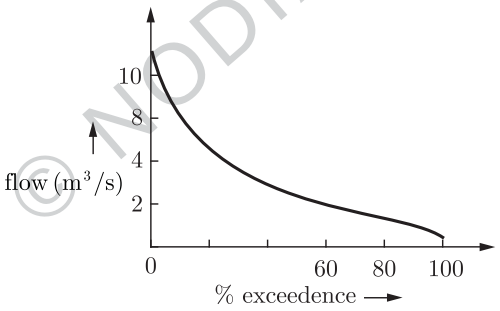
(B) Duration of flooding and ground level elevation

(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

Sol. 18 Correct option is (A).

Flow duration curve (FDC) are used in the design of Hydropower projects and it is a plot of flow and percentage times flow is exceeded, as shown.



Q. 19 In reservoirs with an uncontrolled spillway, the peak of the plotted outflow hydrograph

(A) lies outside the plotted inflow hydrograph

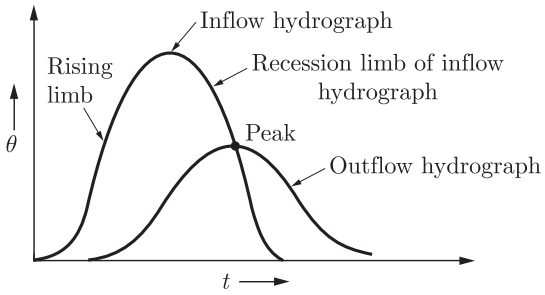
(B) lies on the recession limb of the plotted inflow hydrograph

(C) lies on the peak of the inflow hydrograph

(D) is higher than the peak of the plotted inflow hydrograph

Sol. 19 Correct option is (B).

For a reservoir with uncontrolled spillway the inflow and outflow hydrographs are



Q. 20 The dimension for kinematic viscosity is

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

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

Sol. 20 Correct option is (C).

Kinematic viscosity ν is the ratio of dynamic viscosity to the density of fluid.

dynamic viscosity μ has the relation $\tau = \mu\frac{dv}{dy}$

$\tau =$ Shear stress has dimension of

$$= \frac{\text{Force}}{\text{Area}} = \frac{\text{MLT}^{-2}}{\text{L}^2} = \text{ML}^{-1}\text{T}^{-2}$$

& $\frac{dv}{dy}$ has dimension $\frac{\text{LT}^{-1}}{\text{L}} = \text{T}^{-1}$

So Dimension of $\mu = \frac{\text{ML}^{-1}\text{T}^{-2}}{\text{T}^{-1}} = \text{ML}^{-1}\text{T}^{-1}$ $\left(\because \mu = \frac{\tau}{\left(\frac{d\nu}{dy}\right)}\right)$

Dimension of density. 'ρ' $= \frac{\text{M}}{\text{L}^3} = \text{ML}^{-3}$

So Dimension for, $\nu = \frac{\mu}{\rho} = \frac{\text{ML}^{-1}\text{T}^{-1}}{\text{ML}^{-3}} = \left(\frac{\text{L}^2}{\text{T}}\right)$

Q. 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

Sol. 21 Correct option is (D).

Toxic metals are the metals which have no known function in the body and are harmful in excess.

Eg.: Arsenic, lead, mercury, sodium, calcium, cadmium, chromium, selenium, copper etc.

Iron, manganese and magnesium are required by the body in small amount for metabolism. Therefor though they are present in water but are non-toxic.

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

Sol. 22 Correct answer is 2.75 .

Equation for oxidization of methane CH_4 is

$$\underset{(12+4)}{\text{CH}_4} + 2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \underset{(12+2\times16)}{\text{CO}_2}$$

(Atomic masses C = 12 g/mole; H = 1 g/mole; O = 16 g/mol)

So 16 g of CH_4 produces 44 g of CO_2

Let 1 kg of CH_4 oxidisation produce x kg of CO_2

So $$x = \frac{44 \times 1}{16} = 2.75\,\text{kg}$$

Q. 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

Sol. 23 Correct option is (C).

Peak hourly factor is defined as

$$\text{PHF} = \frac{\text{Hourly Volume}}{\text{Peak rate of flow with in the hour}}$$

If 15 minutes are taken for peak flow

$$\text{PHF} = \frac{\text{Hourly Volume}}{\text{Peak rate of flow for 15 min duration}}$$

$$= \frac{V}{4V_{15}}$$

PHF is used for designing traffic services based on traffic capacity and its value lies b/w 0.25 to 1 according to Highway capacity manual (HCM)

Q. 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

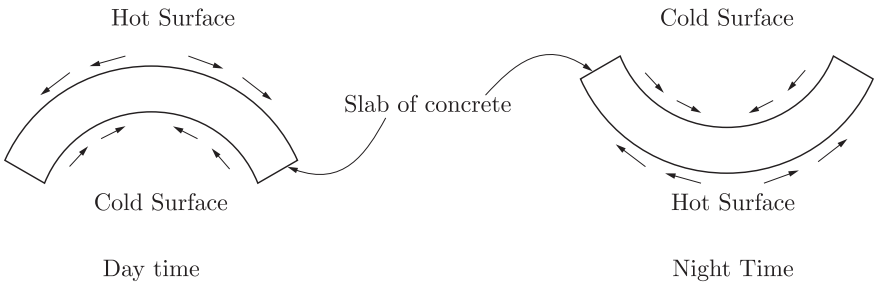
The TRUE statement(s) is (are)

(A) P only (B) Q only

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

Sol. 24 Correct option is (C).

The warping of the slab due to temperature changes is shown



But due to self weight opposite stresses are introduced i.e. compressive on top and tensile at bottom during day time, tensile on top and compressive at bottom during Night time.

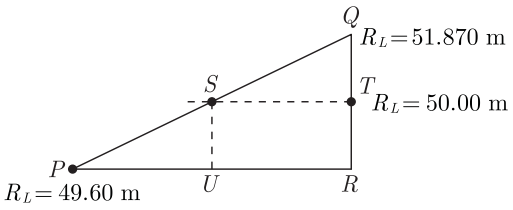
Q. 25 The Reduced Levels (RLs) of the points P and Q are $+49.600\,\text{m}$ and $+51.870\,\text{m}$ respectively. Distance PQ is $20\,\text{m}$. The distance (in m from P) at which the $+51.000\,\text{m}$ contour cuts the line PQ is

(A) 15.00 (B) 12.33

(C) 3.52 (D) 2.27

Sol. 25 Correct option is (B).

Reduce level (RL) of two points P & Q are given respectively 49.60 m & 51.870 m & Distance b/w $PQ = 20\,\text{m}$ as shown



SO distance $QR = 51.870 - 49.60 = 2.27\,\text{m}$

$SU = 50 - 49.60 = 1.40\,\text{m}$

So by similarity of Δ's PQR & PSU

$$\frac{PS}{SU} = \frac{PQ}{QR} \Rightarrow PS = \frac{20 \times 1.40}{2.27} = 12.33\,\text{m}$$

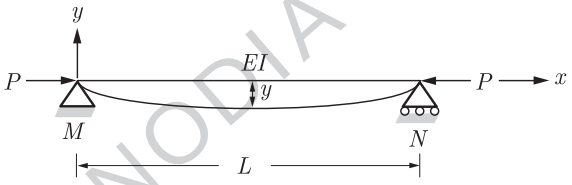
SO distance from P to point at which RL is 50 m i.e

$$PS = 12.33\,\text{m}$$

Q. 26 - Q. 55 Carry two marks each.

Q. 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 a is amplitude constant for y, then

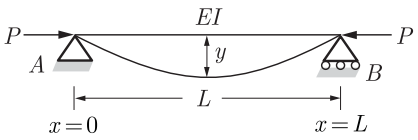
(A) $y = \frac{1}{P}\left(1 - a\cos\frac{2\pi x}{L}\right)$ (B) $y = \frac{1}{P}\left(1 - a\sin\frac{2\pi x}{L}\right)$

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

Sol. 26 Correct option is (C).

Given 2nd order differential equation

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



Solution of 2nd order differential equation of the form

$$\frac{d^2y}{dx^2} = -C^2y \text{ is}$$

$$y = a\sin Cx + b\cos Cx \quad (a \text{ \& } b \text{ are constants})$$

here $C^2 = \frac{P}{EI}$

So $y = a\sin\sqrt{\frac{P}{EI}}\,x + b\cos\sqrt{\frac{P}{EI}}\,x$ ...(i)

Putting boundary conditions at $x = 0;\ y = 0$

$$0 = a\sin 0 + b\cos 0$$

$$b = 0 \quad \text{...(ii)}$$

at $x = L;\ y = 0$

$$0 = a\sin\sqrt{\frac{P}{EI}}\,L$$

$$\sin\sqrt{\frac{P}{EI}}\,L = 0$$

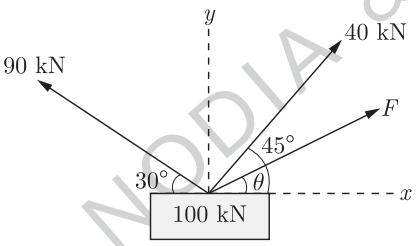
$$\sqrt{\frac{P}{EI}}\,L = n\pi (n = -3, -2, -1, 0, 1, 2, ...)$$

So $\sqrt{\frac{P}{EI}} = \frac{n\pi}{L}$ ...(iii)

From (i), (ii) & (iii)

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

Q. 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

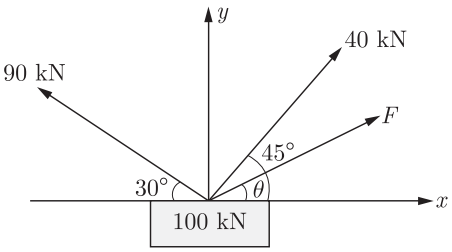


(A) $F = 56.389$ kN and $\theta = 28.28^\circ$ (B) $F = -56.389$ kN and $\theta = -28.28^\circ$

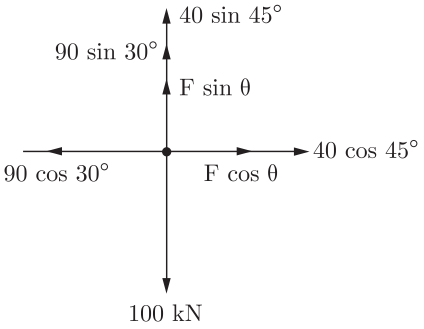
(C) $F = 9.055$ kN and $\theta = 1.414^\circ$ (D) $F = -9.055$ kN and $\theta = -1.414^\circ$

Sol. 27 Correct option is (A).

Given a box of 100 kN as shown



Making free body diagram of box and breaking forces into components in x & y direction.



Applying equilibrium equations for forces in x & y direction.

$\Sigma y = 0$ $\quad 40\sin 45^\circ + 90\sin 30^\circ + F\sin\theta = 100$

$$F\sin\theta = 26.71 \qquad \text{...(i)}$$

$\Sigma x = 0$ $\quad 40\cos 45^\circ + F\cos\theta = 90\cos 30^\circ \Rightarrow F\cos\theta = 49.65$

$\frac{(i)}{(ii)}$ gives $\quad \frac{F\sin\theta}{F\cos\theta} = \frac{26.71}{49.65}$

$$\tan\theta = 0.5379 \Rightarrow \theta = 28.28^\circ$$

Putting in (ii), we get $\quad F\cos 28.28^\circ = 49.65$

$$F = 56.379\ \text{kN}$$

Q. 28 A particle moves along a curve whose parametric equations are : $x = t^3 + 2t$, $y = -3e^{-2t}$ and $z = 2\sin(5t)$, 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 _____.

Sol. 28 Correct answer is 12.

Given equation of motion in 3 different direction

i.e. $\quad x = t^3 + 2t;\ y = -3e^{-2t};\ z = 2\sin 5t\ (\text{cm})$

So Velocity in x, y, z directions are

$$V_x = \frac{\partial x}{\partial t} = (3t^2 + 2)\boldsymbol{i};\ V_y = (6e^{-2t})\boldsymbol{j};\ V_z = (10\cos 5t)\boldsymbol{k}\ \text{cm/s}$$

Now accelerations in x, y, z directions are

$$a_x = \frac{\partial V_x}{\partial t} = (6t)\boldsymbol{i};\ a_y = \frac{\partial V_y}{\partial t} = (-12e^{-2t})\boldsymbol{j};$$

$$a_z = \frac{\partial V_z}{\partial t} = (-50\sin 5t)\boldsymbol{k}\ \text{cm}^2/\text{s}$$

at $t = 0$ accelerations are

$$a_x = 0\boldsymbol{i};\ a_y = -12\boldsymbol{j};\ a_z = 0\,\boldsymbol{k}$$

$$\text{Magnitude of acceleration} = \sqrt{a_x^2 + a_y^2 + a_z^2} = \sqrt{12^2} = 12\ \text{cm}^2/\text{s}$$

Q. 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 _____

Sol. 29 Correct answer is 0.265 .

We know in poisson's distribution probability of any event is given by

$$P(X = K) = \frac{e^{-\lambda}(\lambda)^K}{K!}$$

where X is random variable,

λ = mean no. of event in an interval

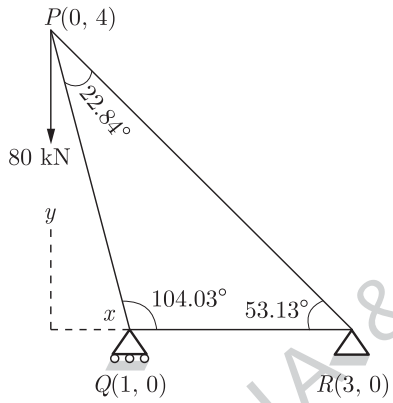
K = number of events in an interval

So here mean $\lambda = 5$ penalties

Probability of less than 4 penalties a day is to be found so

$$P = P(X=0)+P(X=1)+P(X=2)+P(X=3)$$
$$= \frac{e^{-5}5^0}{0!}+\frac{e^{-5}5^1}{1!}+\frac{e^{-5}5^2}{2!}+\frac{e^{-5}5^3}{3!}$$
$$= e^{-5}\left(1+5+\frac{25}{2}+\frac{125}{6}\right)=0.265$$

Q. 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

Sol. 30 Correct option is (A).

Given a truss with loadings as shown.

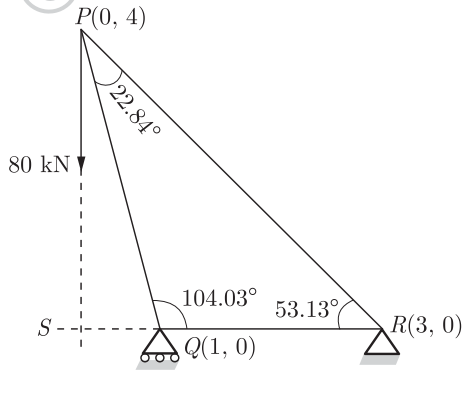


Fig. (1)

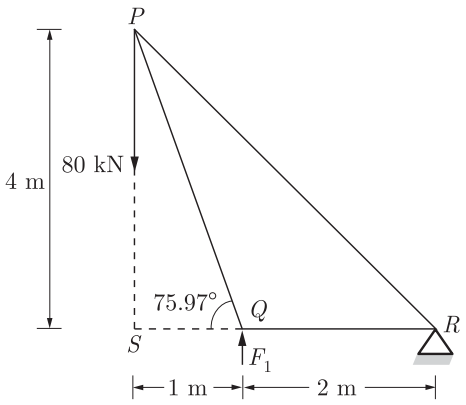


Fig. (2)

by distance formula $PQ = \sqrt{1^2+4^2} = 4.123\,\text{m}$;

$QR = \sqrt{(3-1)^2+0^2} = 2\,\text{m}$

$\angle PQS = 180^\circ - 104.03^\circ = 75.97^\circ$;

$SQ = PQ\cos 75.97^\circ = 1\,\text{m}$

$$PS = PQ\sin 75.97^\circ = 4\,\text{m}$$

Now in fig (2) Let reaction at Q be F_1 kN so $\Sigma M_R = 0$

$$80 \times (1+2) = F_1 \times 2$$

$$F_1 = 120\,\text{kN}$$

So reaction is 120 kN

Taking section as shown in fig(3), by method of section, equilibrium of right side $\Sigma M_P = 0$

$$120 \times 1 + F_{QR} \times 4 = 0$$

$$F_{QR} = -30\,\text{kN}$$

$-$ve means force is compressive, since it is opposite to the assumed tensile direction.

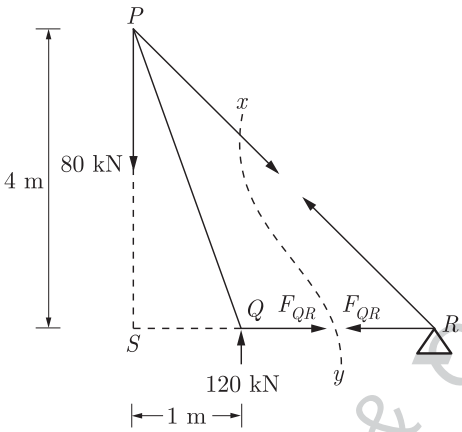
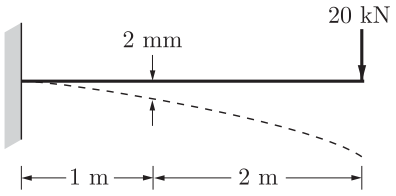


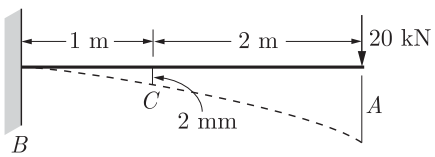
Fig. (3)

Q. 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 _ _ _ _ _ _ _ _ _

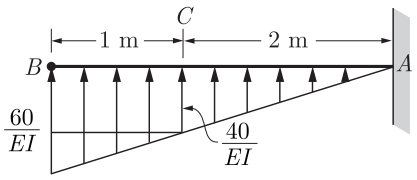


Sol. 31 Correct answer is 1.

Given A cantilever beam as shown with load at A



If flexural rigidity of beam be EI so conjugatae beam diagram of beam AB (i.e. M/EI diagram)

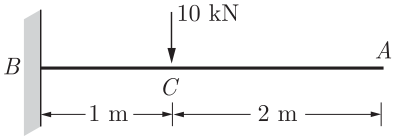


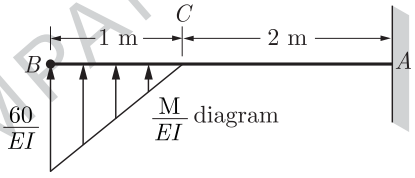
Deflection at C due to this loading is Bending moment of conjugate beam diagram at C, which is 2 mm (given)

i.e. $$2 = \left(\frac{40}{EI} \times 1\right) \times \frac{1}{2} + \frac{1}{2} \times \left(\frac{60}{EI} - \frac{40}{EI}\right) \times 1 \times \frac{2}{3}$$

$$EI = \frac{40}{3} \quad \text{...(i)}$$

Now load 10 kN is applied on Beam at C and maximum deflection will occur at free end, so conjugate beam diagram is as shown





So deflection at

A = Bending moment of conjugate Beam diagram

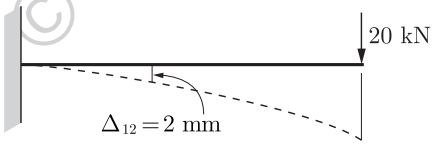
about

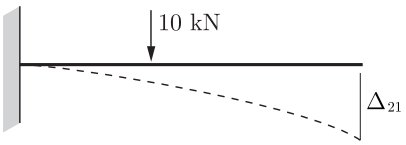
$$A = \frac{1}{2} \times 1 \times \left(\frac{10}{EI}\right) \times \left(2 + 1 \times \frac{2}{3}\right)$$

$$= \frac{10}{EI} \times \frac{4}{3} = \frac{10 \times 3}{40} \times \frac{4}{3} = 1 \text{ mm (using (i))}$$

Alternatively,

By Betti's law

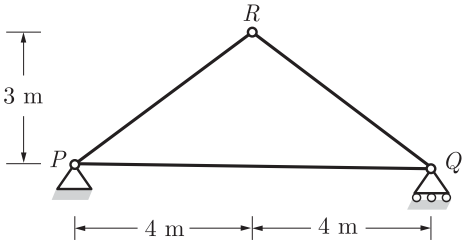




$$20 \times \Delta_{21} = \Delta_{12} \times 10$$

$$\Delta_{21} = \frac{2 \times 10}{20} = 1 \text{ mm}$$

Q. 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 _____.

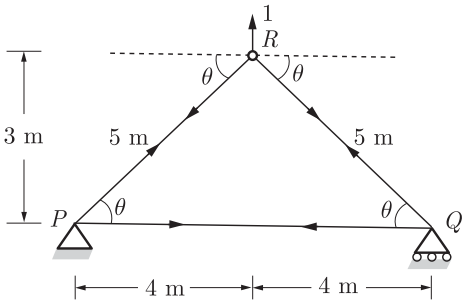


Sol. 32 Correct answer is 2.

Given, truss as shown and PQ is short by 3 mm

So $\lambda_{PQ} = -3\,\text{mm}$

Let unit load be applied at R, and finding out forces in members



by method of joints at R; $\Sigma F_x = 0$

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

$\Sigma F_y = 0 \Rightarrow \quad U_{PR}\sin\theta + U_{RQ}\sin\theta = 1$

$$2 \times U_{PR} \times \frac{3}{5} = 1$$

$$U_{PR} = \frac{5}{6}$$

at $P \quad \Sigma F_x = 0 \qquad U_{PR}\cos\theta + U_{PQ} = 0$

$$U_{PQ} = -\frac{5}{6} \times \left(\frac{4}{5}\right) = -\frac{2}{3}$$

So Deflection at $R = U_{PQ} \times \lambda_{PQ} = -\frac{2}{3} \times (-3) = 2\,\text{mm}$

It is +ve, therefore deflection is in the direction of applied unit load.

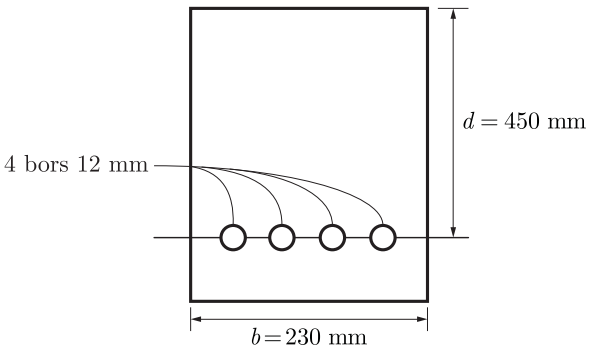
Q. 33 A rectangular beam of width (b) 230 mm and effective depth (d) 450 mm is reinforced with four bars of 12 mm diameter. The grade of concrete is M20 and grade of steel is Fe500. Given that for M20 grade of concrete the ultimate shear strength, $\tau_{uc} = 0.36\,\text{N/mm}^2$ for steel percentage, $p = 0.25$, and $\tau_{uc} = 0.48\,\text{N/mm}^2$ for $p = 0.50$. For a factored shear force of 45 kN, 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

Sol. 33 Correct option is (A).

Given a beam as shown



So percentage reinforcement

$$p = \frac{A_{st}}{bd} \times 100$$

$$= \frac{4 \times \frac{\pi}{4} \times (12)^2}{230 \times 450} \times 100 = 0.43\%$$

Given, for % reinforcement 0.25 design shear strength $\tau_C = 0.36\ \text{N/mm}^2$

for % reinforcement 0.50 design shear strength $\tau_C = 0.48\ \text{N/mm}^2$

by interpolation,for $p = 0.43$

$$\tau_C = 0.36 + \frac{(0.48 - 0.36)}{(0.50 - 0.25)}(0.43 - 0.25)$$

$$= 0.45\ \text{N/mm}^2$$

Given shear force $V = 45\ \text{kN} = 45000\ \text{N}$

$$\tau_V = \text{Nominal shear stress} = \frac{V}{bd} = \frac{45000}{230 \times 450} = 0.434\ \text{N/mm}^2$$

$$\tau_V < \tau_C$$

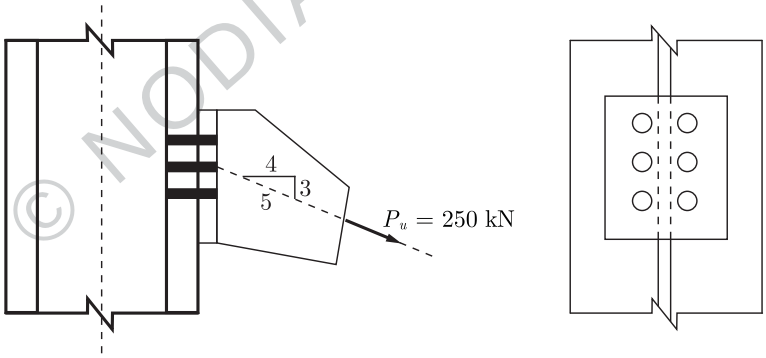
Nominal shear reinforcement will be provided with spacing S_V

So $\frac{A_{sv}}{b \times S_V} = \frac{0.4}{0.87 f_y}$ (A_{sv} is area of two legged shear reinforcement)

$$\frac{\left(2 \times \frac{\pi}{4} \times (d)^2\right)}{230 \times 375} = \frac{0.4}{0.87 \times 500}$$

$$d = 7.18\ \text{mm} \simeq 8\ \text{mm}$$

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

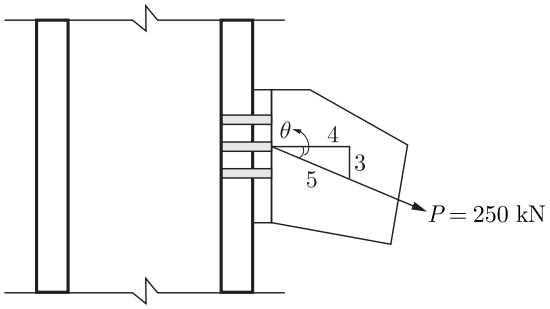


(A) 30.33 and 20.00 (B) 30.33 and 25.00

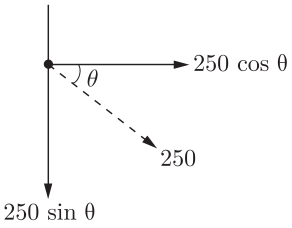
(C) 33.33 and 20.00 (D) 33.33 and 25.00

Sol. 34 Correct option is (D).

Given joint with 6 bolts and force acting as,



The FBD of joint is as shown



So Tension on joint is $250\cos\theta = 250 \times \frac{4}{5} = 200\,\text{kN}$

Tension on each bolt is $= \frac{200}{6} = 33.33\,\text{kN}$

So, Shear force on joint is $= 250\sin\theta = 250 \times \frac{3}{5} = 150\,\text{kN}$

Shear force on each bolt is $= \frac{150}{6} = 25\,\text{kN}$

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

Sol. 35 Correct answer is 2.

Given beam of width $b = 230\,\text{mm}$; depth $d = 500\,\text{mm}$; Rebars of yield strength $f_y = 500\,\text{N/mm}^2$ and diameter 12 mm are to be used.

According to IS : 456-2000, minimum tension reinforcement is A_{st}

So $$\frac{A_{st}}{bd} = \frac{0.85}{f_y}$$

Let n bars of 12 mm ϕ be used so

$$\frac{n \times \frac{\pi}{4} \times (12)^2}{230 \times 500} = \frac{0.85}{500} \Rightarrow n = 1.72$$

But number of bars $= 2$

Q. 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}

Sol. 36 Correct option is (C).

We know that equation of pure bending given

$$\frac{f}{y} = \frac{M}{I} = \frac{E}{R} \qquad \text{...(i)}$$

Given stress at extreme fibre

$$f = 5.8\,\text{N/mm}^2$$

distance of Neutral axis to extreme fiber

$$y = 58\,\text{mm}$$

$E =$ elastic module of concrete

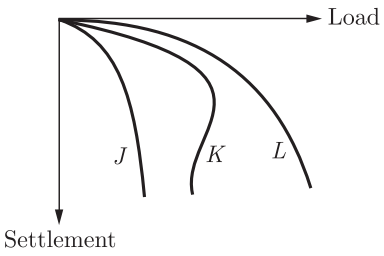
So $$E = 5000\sqrt{f_{cx}} = 5000\sqrt{25} = 25000 \qquad (M-25)$$

Curvature is $\frac{1}{R}$

So $\dfrac{f}{y} = \dfrac{E}{R}$ from (i)

$$\frac{5.8}{58} = \frac{25000}{R} \Rightarrow \frac{1}{R} = 4.0 \times 10^{-6}\,\text{mm}^{-1}$$

Q. 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

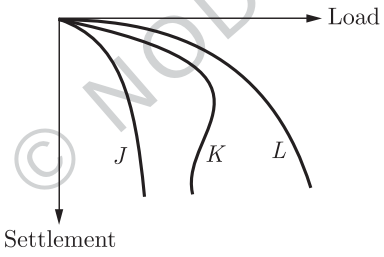


	Group I		Group II
P.	Curve J	1.	No apparent heaving of soil around the footing
Q.	Curve K	2.	Rankine's passive zone develops imperfectly
R.	Curve L	3.	Well defined slip surface extends to ground surface

(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

Sol. 37 Correct option is (A).



J curve is for punching shear failure and no heaving of soil takes place in this case
K is curve for general shear failure.
L is curve for local shear failure.

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

(A) 56.43 (B) 60.25

(C) 62.87 (D) 65.71

Sol. 38 Correct option is (D).

Given, soil with field properties

Bulk density $\rho = 1800\,\text{kg/m}^3$; water content, $w = 8\% = 0.08$

So dry density $\rho_d = \dfrac{\rho}{1+w} = \dfrac{1800}{1+0.08} = 1666.67\,\text{kg/m}^3$

So void ratio 'e' at field condition can be determined by relation

$$\rho_d = \frac{G\rho_w}{1+e} \Rightarrow e = \frac{G\rho_w}{\rho_d} - 1$$

$$= \frac{2.7 \times 1000}{1666.67} - 1$$

$$e = 0.62$$

So $e_{\max} = 0.85 \qquad e_{\min} = 0.50$

$$\text{relative density } I_d = \frac{e_{\max} - e}{e_{\max} - e_{\min}} \times 100$$

$$= \frac{(0.85 - 0.62)}{(0.85 - 0.50)} \times 100$$

$$I_d = 65.71$$

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

$$\sigma_o' = 175\,\text{kPa};\ e_o = 1.1;\ \sigma_o' + \Delta\sigma_o' = 300\,\text{kPa};\ e = 0.9$$

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

Sol. 39 Correct answer is 7.61 .

Coefficient of volume compressibility is ratio of change in volume of a soil per unit initial volume due to unit increase in effective stress. Denote by 'm_v'

So $$m_v = \frac{\Delta e}{1+e_0}\frac{1}{\Delta\overline{\sigma}_0}$$

Δe = change in void ratio

$= e_0 - e = 1.1 - 0.9 = 0.2$

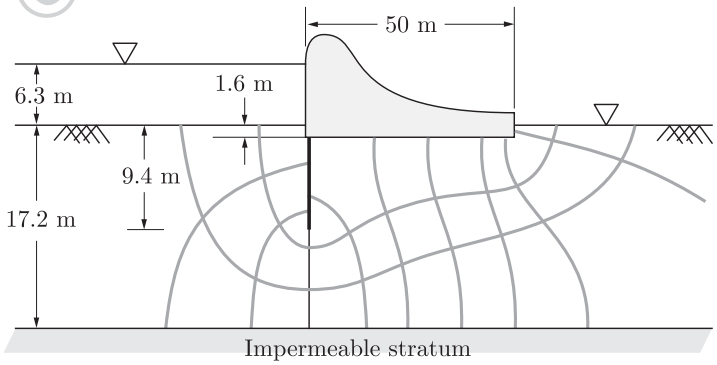
$e_0 = 1.1$

$\Delta\sigma_0$ = Change in effective stress

$\Delta\sigma_0 = 300 - 175 = 125\,\text{kPa}$

So $$m_v = \frac{0.2}{1+1.1} \times \frac{1}{125} = 7.61 \times 10^{-4}\,\text{m}^2/\text{kN}$$

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



Sol. 40 Correct answer is 7.18 .

Flow 'q' for a flow net under the dam is given by

$$q = KH \times \frac{N_f}{N_d}$$

N_f = number of flow channels = 3

N_d = number of equipotential drops = 10

H = Total head available b/w upstream & downstream = 6.3 m

K = Coefficient of permeability

$= 3.8 \times 10^{-6}\,\text{m/s}$

$= 3.8 \times 10^{-4}\,\text{cm/s}$

So flow per unit width, $q = 3.8 \times 10^{-4} \times 6.3 \times 10^2 \times \frac{3}{10}$

$= 0.0718\,\text{cm}^2/\text{s}$

Discharge $Q = 0.0718 \times 100 = 7.18\,\text{cm}^3/\text{s}$ $(Q = qb)$

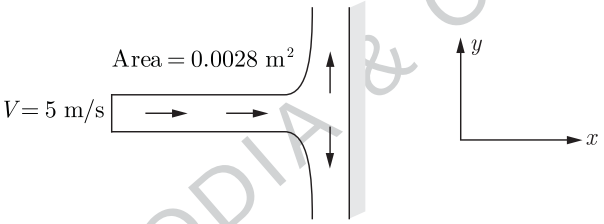
Q. 41 A horizontal jet of water with its cross-sectional area of $0.0028\,\text{m}^2$ hits a fixed vertical plate with a velocity of 5 m/s. After impact the jet splits symmetrically in a plane parallel to the plane of the plate. The force of impact (in N) of the jet on the plate is

(A) 90 (B) 80

(C) 70 (D) 60

Sol. 41 Correct option is (C).

The Jet impacts plate as shown



the velocity in x direction becomes zero after impact so using impulse momentum theorem

$$F = \rho_w Q_1 V_1 - \rho_w Q_2 V_2 = \rho_w Q(V_1 - 0)$$

$Q = AV = 0.0028 \times 5 = 0.014$ $\quad \rho_w = 1000\,\text{kg/m}^3$

So Force, $F = 1000 \times 0.014 \times (5 - 0)$

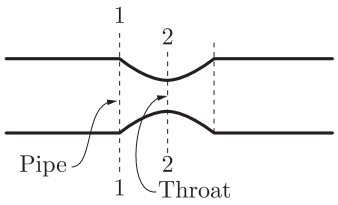
$= 70\,\text{N}$

Q. 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 $9.81\,\text{m/s}^2$, the the coefficient of discharge of the venturimeter (correct up to two places of decimal) is_____.

Sol. 42 Correct answer is 0.945 .

Discharge for venturimeter is given as

$$Q = \frac{C_d a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$$



$$a_1 = \frac{\pi}{4} \times (15 \times 10^{-2})^2 = 0.0176\ \text{m}^2$$

$$a_2 = \frac{\pi}{4} \times (7.5 \times 10^{-2})^2 = 0.0041\ \text{m}^2$$

Given head $h = 2.45\ \text{m}$ $q = 9.81\ \text{m/s}^2$

So if C_d is coefficient of discharge & $Q = 30\ \text{m}^3/\text{sec} = 30 \times 10^{-3}\ \text{m}^3/\text{s}$

So $$30 \times 10^{-3} = \frac{C_d \times (0.0176)(0.0041)}{\sqrt{(0.0176)^2 - (0.0041)^2}} \times \sqrt{2 \times 9.81 \times 2.45}$$

$$C_d = 0.945$$

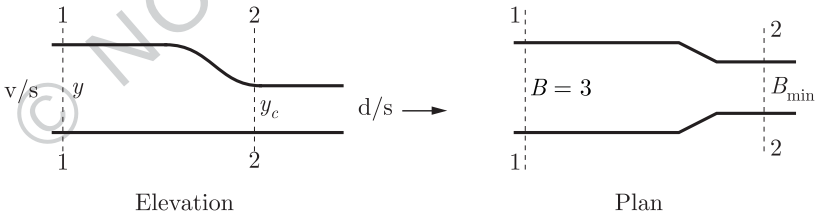
Q. 43 A rectangular channel having a bed slope of 0.0001, width 3.0 m and Manning's coefficient 'n' 0.015, carries a discharge of 1.0 m^3/s. Given that the normal depth of flow ranges between 0.76 m and 0.8 m. The minimum width of a throat (in m) that is possible at a given section, while ensuring that 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

Sol. 43 Correct option is (B).

If we keep on reducing the width of section down stream, the depth of section upstream will keep on increasing, till the depth at constriction reaches critical width.



We have find width of section 2-2 '$B_{\min}$' at which the depth reaches critical depth 'y_c' and specific energy is E_c

We know $$E_c = \frac{3}{2} y_c = \frac{3}{2} \times \left(\frac{q^2}{g}\right)^{1/3}$$ (q is discharge per unit width)

So $$E_c = \frac{3}{2} \times \left(\frac{\left(\frac{Q}{B_{\min}}\right)^{1/2}}{9.8}\right)^{1/3} = \frac{3}{2} \times \left(\frac{1}{B_{\min}}\right)^{2/3} \times \frac{1}{(9.8)^{1/3}}$$ ...(i)

(discharge is same at section 1-1 & 2-2 is same $Q = 1\ \text{m}^3/\text{s}$)

$$E = \text{Specific energy} = \frac{V^2}{2g} + y = y + \frac{q^2}{2gy^2}$$ ...(ii)

By Manning's formula

$$Q = \text{discharge} = \frac{1}{N}(r)^{2/3}(s)^{1/2} \times A = 1\ \text{m}^3/\text{s}$$

($r =$ wetted perimeter, $s =$ slope)

$$\frac{1}{0.015} \times \left(\frac{3y}{3+2y}\right)^{2/3} \times (0.0001)^{1/2} \times (3y) = 1$$

$$y = 0.78\,\text{m}$$

Putting in (ii)

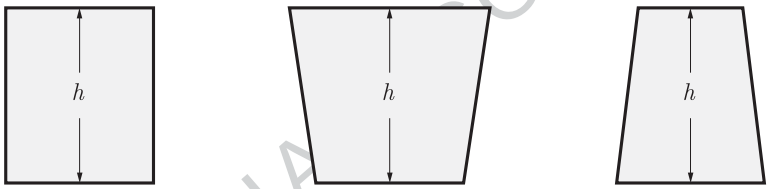
$$E = 0.78 + \frac{\left(\frac{1}{3}\right)^2}{2 \times 9.81 \times (0.78)^2} = 0.789 \qquad \text{...(iii)}$$

Equating (1) & (3)

$$E_c = E \Rightarrow 0.700\left(\frac{1}{B_{\min}}\right)^{2/3} = 0.789$$

$$B_{\min} = 0.8356$$

Q. 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 same base area

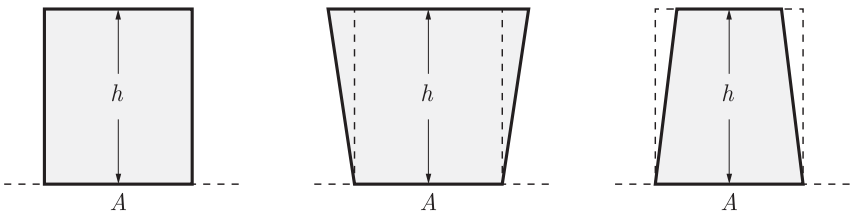
(1) (2) (3)

(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 $F_1 = F_2 = F_3$

Sol. 44 Correct option is (D).

Given 3 buckets with same height 'h' and same base area A as shown



(1) (2) (3)

Clearly volume of (2) is largest, then (1) & at last (3).

So weight of water in bucket = Volume of bucket $\times$ unit weight of water

$$= V \times \gamma_W$$

γ_W is constant, so weight of (2) is largest then (1) & thereafter 3 i.e. $W_2 > W_1 > W_3$

Now pressure at section X-X for buckets

$$P_{(1)} = \gamma_W h;\ P_{(2)} = \gamma_W h;\ P_{(3)} = \gamma_W h$$

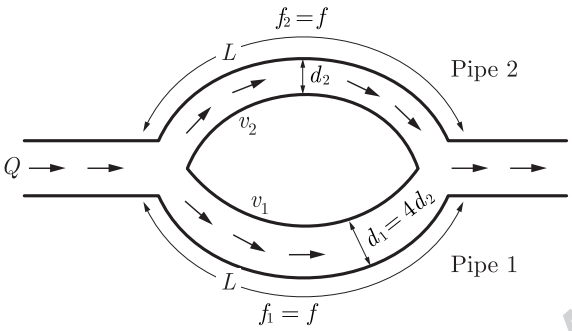
Force $F_1 = P_1 \times A_1 = \gamma_W ha;\ F_2 = P_2 A_2 = \gamma_W hA;\ F_3 = \gamma_W hA$

$$F_1 = F_2 = F_3$$

So pressure at any section depends only upon the height of water column above it but not the shape or inclination.

Q. 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 _ _ _ _ _ _ _

Sol. 45 Correct answer is 2.



Let the velocity in upper pipe be V_2 & in lower pipe be V_1, Q is the original discharge.

Given diameters of two pipes are d_1 & d_2 respectively with $d_1 = 4d_2$

The pipes are in parallel, so head loss in both pipes will be equal, So

$$\frac{f_1 L_1 V_1^2}{2gd_1} = \frac{f_2 L_2 V_2^2}{2gd_2}$$

$$\frac{f \times L \times V_1^2}{2 \times g \times 4d_2} = \frac{f\, L V_2^2}{2 \times g \times d_2}$$

$$\left(\frac{V_1}{V_2}\right)^2 = 4$$

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

Q. 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

Sol. 46 Correct option is (A).

If 'n' is the dilution coefficient

So $$C^n \times t = A$$

C = Concentration of disinfectant in kg/m^3

t = time taken by disinfectant to remove microorganism

A = Constant

So for same level of disinfection

$$C_1^n t_1 = C_2^n t_1 \quad \text{...(1)}$$

$$n = 1$$

So
$$C_1 = \frac{M_1}{Q_1} = \frac{32}{16 \times 10^{-3} \times 10^6} = 2 \times 10^{-3}\ \text{kg/m}^3$$

$$C_2 = \frac{M_2}{Q_2} = \frac{M_2}{22 \times 10^3}\ \text{kg/m}^3$$

(Where M_2 is the require amount of chlorine per day)

$$t_1 = \frac{\text{length of pipe}}{\text{Velocity of water}}$$

$$= \frac{2.5}{Q_1/A_6} = \frac{2.5 \times 10^3}{.16 \times 10^3/\left(\frac{\pi}{4} \times (.45)^2\right)} = 0.024\ \text{day}$$

$$t_2 = \frac{\text{length of pipe}}{\text{velocity of water}}$$

$$= \frac{2.5 \times 10^3}{Q_2/A} = \frac{2.5 \times 10^3}{22 \times 10^3/(\frac{\pi}{4} \times (.45)^2)} = 0.018\ \text{day}$$

So using (i)

$$2 \times 10^{-3} \times 0.024 = \frac{M_2}{22 \times 10^3} \times 0.018$$

$$M_2 = 58.66 \simeq 60.50$$

Q. 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

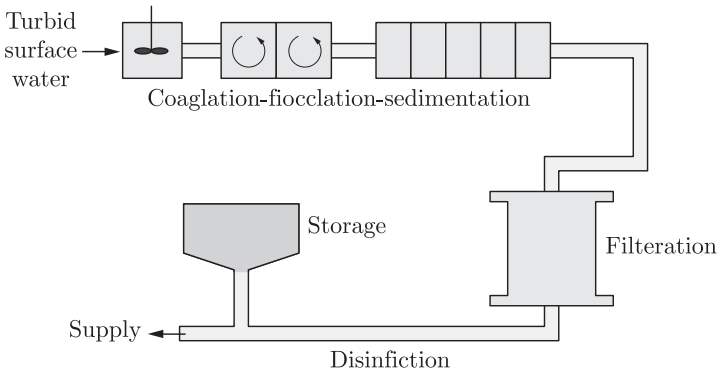
(B) Turbid surface water → Disinfection → Flocculation → Sedimentation → Filtration → Coagulation → Storage & Supply

(C) Turbid surface water → Filtration → Sedimentation → Disinfection → Flocculation → Coagulation → Storage & Supply

(D) Turbid surface water → Sedimentation → Flocculation → Coagulation → Disinfection → Filtration → Storage & Supply

Sol. 47 Correct option is (A).

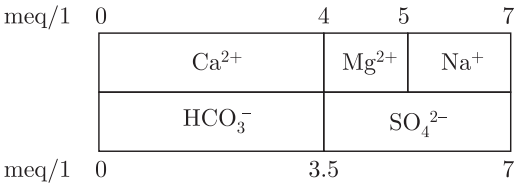
The treatment process for turbid water is as shown



Turbid water is coagulated by adding agents like Alum etc to water after which they form flocks of colloids which are heavy enough to sink. Therefore sedimentation is carried out after that. Further, the water is filtrated and made free of microorganism by disinfection process.

Q. 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

Sol. 48 Correct option is (B).

From the given composition

$$\text{Concentration of } Ca^{2+} = 4\,\text{meq/Lt};\ Mg^{2+} = (5-4) = 1\,\text{meq/Lt}$$

$$HCO_3^- = 3.5\,\text{meq/Lt}$$

$$\text{Molar mass of } CaCO_3 = 40 + 12 + 16 \times 3 = 100\,\text{g};$$

$$\text{equivalent per mole} = 2$$

Carbonate hardness is lesser of the total hardness or Alkalinity

$$TH = \text{Total Hardness}$$

$$= [Ca^{2+}]_{\text{meq/Lt}} \times [CaCO_3]_{\text{mg/meq}} + [Mg^{2+}]_{\text{meq/Lt}} \times [CaCO_3]_{\text{mg/meq}}$$

$$= (4) \times \left(\frac{100}{2}\right) + 1 \times \left(\frac{100}{2}\right)$$

$$= 250\,\text{mg/Lt (as } CaCO_3)$$

$A = \text{Alkalinity} = \text{Presence of carbonate } (CO_3^{2-}) \text{ \& bicarbonate } (HCO_3^-) \text{ ions}$

$$A = (3.5)\,\text{meq/Lt} \times \left(\frac{100}{2}\right) = 175\,\text{mg/Lt}$$

$$\text{Carbonate Hardness} = \text{Lessor of} = (\text{TH, A}) = 175\,\text{mg/Lt}$$

$$\text{Non carbonate Hardness} = \text{TH} - \text{Alkalinity}$$

$$= 250 - 175 = 75\,\text{mg/Lt} \quad (\text{as } CaCO_3)$$

Q. 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 _____.

Sol. 49 Correct answer is 4.8 .

Given allowable discharge

$$'Q' = 0.21\,m^3/s \text{ \& Velocity} = 0.75\,m/s$$

So area of pipe of diameter $d_{(m)}$ is $\frac{\pi}{4} \times d^2$

$$Q = VA$$

$$0.21 = 0.75 \times \frac{\pi}{4} \times (d)^2$$

$$d = 0.597\,m$$

Now for flowing without any difficulty, the pipe should have gradient equal to

head lost in friction.

$$\frac{f\,l\,V^2}{2gd} = h_f \qquad (f = 0.01;\ g = 9.81;\ L = 100\,\text{m})$$

$$h_f = \frac{0.01 \times 100 \times 0.75^2}{2 \times 9.81 \times 0.597}$$

$$= 0.048\,\text{m} = 4.8\,\text{cm}$$

So $\text{gradient} = \frac{4.8\,\text{cm}}{100\,\text{m}}$ length of pipe

Q. 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 _ _ _ _ _ _ _ _ _

Sol. 50 Correct answer is 309.

Vehicle damage factor (VDF) is a multiplier for converting the number of commercial vehicle of different axle loads and axle configuration to number of standard axle load repetition

Given

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

So vehicle damage factor can be calculated by "fourth power rule" and taking standard axle load $= 8160\,\text{kg} \simeq 8.2$ tonnes

$$\text{So} \qquad \text{VDF} = .10\left(\frac{18}{8.2}\right)^4 + .20\left(\frac{14}{8.2}\right)^4 + .35\left(\frac{10}{8.2}\right)^4 + .15\left(\frac{8}{8.2}\right)^4 + .20\left(\frac{6}{8.2}\right)^4$$

$$= 4.988$$

Given, Design life $n = 15$ years; growth rate $r = 7.5\% = 0.075$

Average daily traffic $A = 5000$; Distribution factor $D = 1$;

VDF $= 4.988$; load safety factor, $F = 1.3$

$$\text{So} \qquad \text{Design traffic} = \frac{365 \times A \times ((1+r)^n - 1) \times D \times VDF \times F}{r}$$

$$= \frac{365 \times 5000 \times ((1+0.075)^{15} - 1) \times 1 \times 4.988 \times 1.3}{0.075}$$

$$= 309085511 \text{ standard axle}$$
$$= 309 \text{ Million standard Axle (MSA)}$$

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

Sol. 51 Correct answer is 3.159 .

Given

longitudinal friction coefficient $f = 0.35$

$$\text{SSD} = 170\,\text{m};\ g = 9.81\,\text{m/s}^2;\ V = 90\,\text{kmph}$$

or $$V = 90 \times \frac{5}{18} = 25\,\text{m/s}$$

So let perception time be t sec

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

$$170 = 25 \times t + \frac{25^2}{2 \times 9.81 \times 0.35}$$

$$t = 3.159\,\text{sec}$$

Q. 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 _____.

Sol. 52 Correct answer is 1750.

Given speed density relation

$$u = 70 - 0.7k$$

v = speed in km/hr & k = density in veh/km

We know relation b/w volume & density is

$$q = ku$$

q = volume of vehicle (veh/hr)

So $$q = 70k - 0.7k^2 \quad \text{...(1)}$$

maximum volume is the traffic capacity so differentiating (1)

$\frac{dq}{dk} = 0 \Rightarrow$ $$70 - 1.4k = 0 \Rightarrow k = 50\,\text{veh/km}$$

So capacity 'q' at $$(k = 50) = 70 \times 50 - 0.7 \times 50^2$$
$$= 1750\,\text{veh/hr}$$

Q. 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 _____

Sol. 53 Correct answer is 92.

Given 3 phase signal

Optimum cycle length for phased signal is given by webster method

$$C_0 = \frac{1.5L + 5}{1 - \Sigma y}$$

Σy = Summation of ratio of flow in a phase to saturation flow
$= 0.20 + 0.25 + 0.3 = 0.75$

L = total time lost in all phases $= 4 \times 3 = 12\,\text{sec}$

So $$C_0 = \frac{1.5 \times 12 + 5}{1 - 0.75} = 92 \text{ sec}$$

Q. 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, then RL (in m) of R is

(A) 103.355 (B) 103.155

(C) 101.455 (D) 100.355

Sol. 54 Correct option is (C).

Staff Station	BS	IS	FS	RL	HI
P.	1.655 m			100 m	101.65
Q.	−0.950 m		−1.50	103.155 m	102.205
R.			0.750		

$$\text{RL of P} = 100 \text{ m}$$

$$\text{Height of instrument HI} = \text{RL} + \text{BS} \Rightarrow \text{RL} = \text{HI} - \text{FS}$$

So $$\text{HI at P} = 100 + 1.65 = 101.65$$

$$\text{RL at Q} = \text{HI} - \text{FS} = 101.65 - (-1.50) = 103.155$$

$$\text{HI at Q} = RL + BS = 103.155 - (-0.955) = 102.205$$

$$\text{RL at R} = 102.205 - 0.750 = 101.455 \text{ m}$$

Noting changing of station take place once.

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

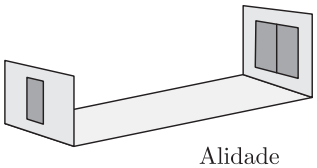
	Group I		Group II
P.	Alidade	1.	Chain surveying
Q.	Arrow	2.	Levelling
R.	Bubble tube	3.	Plain table surveying
S	Stadia hair	4.	Theodolite surveying

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

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

Sol. 55 Correct option is (D).

Alidade is used in plane table surveying to draw a line in the direction of a point on map.



Alidade

Arrow

Arrow is used in chain surveying for making points on the ground during survey.

Bubble tube is used to check the horizontality of the levelling instrument, stadia hair is present in the eye-piece of theodolite.

****

ANSWER KEY

General Aptitude									
1	2	3	4	5	6	7	8	9	10
(A)	(B)	(D)	(C)	(1300)	(D)	(B)	(180)	(D)	(B)

Civil Engineering									
1	2	3	4	5	6	7	8	9	10
(C)	(23)	(0.4)	(A)	(A)	(C)	(A)	(C)	(9)	(A)
11	12	13	14	15	16	17	18	19	20
(A)	(A)	(A)	(D)	(B)	(D)	(22.5)	(A)	(B)	(C)
21	22	23	24	25	26	27	28	29	30
(D)	(2.75)	(C)	(C)	(B)	(C)	(A)	(12)	(0.265)	(A)
31	32	33	34	35	36	37	38	39	40
(1)	(2)	(A)	(D)	(2)	(C)	(A)	(D)	(7.61)	(7.18)
41	42	43	44	45	46	47	48	49	50
(C)	(0.945)	(B)	(D)	(2)	(A)	(A)	(B)	(4.8)	(309)
51	52	53	54	55					
(3.159)	(1750)	(92)	(C)	(D)					