## Section - I (Civil Engineering)

### One Mark Questions

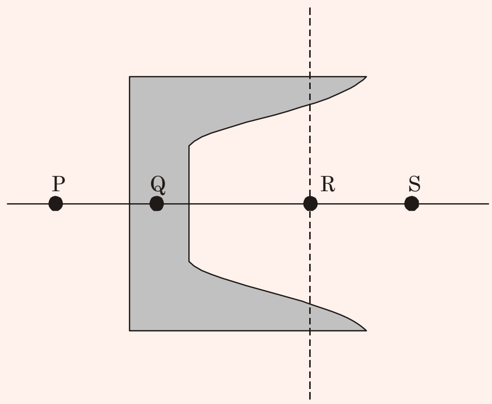
**Q.1** For a saturated cohesive soil, a tri-axial test yields the angle of interval friction ($\phi$) as zero. The conducted test is

(a) Consolidated Drained (CD) test
(b) Consolidated undrain (CU) test
(c) Unconfined compression (UC) test
(d) Unconsolidated undrain (UU) test

**Ans. (d)**

End of Solution

**Q.2** The possible location of shear centre of the channel section shown below is




(a) P (b) Q
(c) R (d) S

**Ans. (a)**

End of Solution

**Q.3** $\lim_{x\to\infty}\left(\frac{x+\sin x}{x}\right)$ is equal to

(a) $-\infty$ (b) 0
(c) 1 (d) $\infty$

**Ans. (c)**

Put $x = \frac{1}{h}$ as $x\to\infty \Rightarrow h\to 0$

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

$$= \lim_{h \to 0} 1 + \left( \frac{\sin \frac{1}{h}}{\frac{1}{h}} \right) = 1$$

End of Solution

**Q.4** A conventional flow duration curve is a plot between

(a) Flow and % time flow is exceeded
(b) Duration of flooding and ground level elevation
(c) Duration of water supply in a city and proportion of area recurring supply exceeding this duration.
(d) Flow rate and duration of time taken to empty of a reservoir at that flow rate.

**Ans.** **(a)**

End of Solution

**Q.5** A steel section is subjected to a combination of shear and bending action. The applied shear force is V and 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) $V > 0$

**Ans.** **(a)**

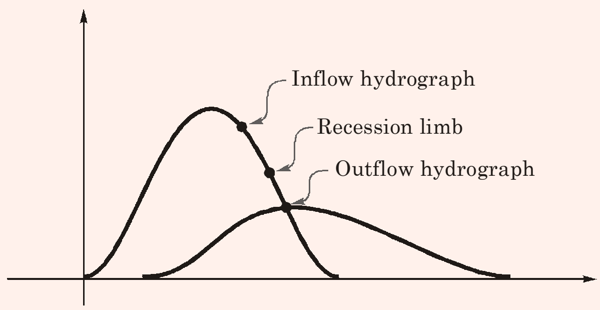
Clause 9.2.1 IS 800:2007.

End of Solution

**Q.6** In reservoir 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 peak of the plotted inflow hydrograph.

**Ans.** **(b)**




End of Solution

**Q.7** If $y = 5x^2 + 3$ than the tangent at x = 0 and y = 3

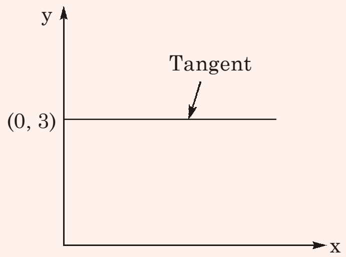
(a) passes through x = 0, y = 0
(b) has a slope +1
(c) is parallel to x-axis
(d) has a slope of –1

**Ans. (c)**

$$y = 5x^2 + 3$$

$$\frac{dy}{dx} = 10\,x$$

$$\Rightarrow \quad \left.\frac{dy}{dx}\right|_{(0,3)} = 10 \times 0 = 0$$




⇒ **tangent is parallel to x-axis.**

End of Solution

**Q.8** The dimension for kinematic viscosity is

(a) $\frac{L}{MT}$
(b) $\frac{L}{T^2}$
(c) $\frac{L^2}{T}$
(d) $\frac{ML}{T}$

**Ans. (c)**

The SI unit of kinamatic viscosity is $m^2/sec$.

∴ dimension of kinamatic viscosity [v] = $\mathbf{L^2/T}$.

End of Solution

**Q.9** The following statements are related to temperature stress developed in concrete pavement slab with four edge (without any restrain)

P : The temperature stress will be zero during both day and night time if the pavement slab is considered weight less.

Q. : The temperature stress 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 stress 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

**Ans. (c)**

The temperature stress will be tensile at the bottom of the slab during the day time if the self weight of the pavement slab is considered.

End of Solution

**Q.10** An incompressible homogeneous fluid flowing steadily in a variable dia pipe having the large and small dia as 15 cm and 5 cm respectively. If velocity at the section of 15 cm dia portion of the pipe is 2.5 m /sec, the velocity of fluid (in m/s) at section falling in 5 cm portion of the pipe is ________.

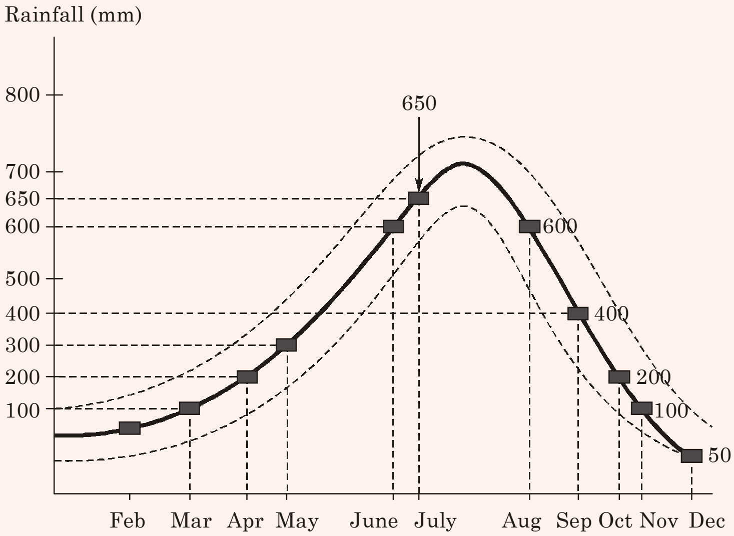
**Sol.**

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

$$\Rightarrow \quad V = 2.5 \times 9 = \mathbf{22.5\ m/s}$$

End of Solution

**Q.11** 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 % of data fall below that value)




(i) On average it rains more in July than in Dec.

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



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(iii) July rainfall can be estimated with better confidence than Feb. rainfall.
(iv) In Aug, there is at least 500 mm of rainfall.

(a) (i) and (ii)
(b) (i) and (iii)
(c) (ii) and (iii)
(d) (iii) and (iv)

**Ans. (b)**

End of Solution

**Q.12** The potable water is prepared from turbid surface water by adopting the foil treatment square.

(a) Turbid surface water → Coagulation → Flocculation → Sedimentation → Filtration → Disinfection → Storage and supply

(b) Turbid surface water → Disinfection → Flocculation → Sedimentation → Filteration → Coagulation → Storage and supply

(a) Turbid surface water → Filteration → Sedimentation→ Disinfection → Flocculation → Coagulation

(a) Turbid surface water → Sedimentation → Flocculation → Coagulation → Disinfection → Filteration

**Ans. (a)**

End of Solution

**Q.13** The minimum value of 15 minutes peak hour factor on a section of a road is

(a) 0.1
(b) 0.2
(c) 0.25
(d) 0.33

**Ans. (c)**

15 min. peak hr factor is used for traffic intersection design

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

$$V = \text{Peak hourly volume}\left(\text{in}\,\frac{\text{veh.}}{\text{hr.}}\right)$$

$V_{15}$ = Maximum 15 minimum volume within the peak hr. (veh.)

Maximum value is 1.0 and minimum value is 0.25

Normal range is 0.7 – 0.98 = **0.25**

End of Solution

**Q.14** Some of the non-toxic metal normally found in natural water are

(a) Arsenic, Lead, Mercury
(b) Calcium, Sodium, Silver
(c) Cadmium, curomium, copper
(d) Iron, Mangnese, Magnesium

**Ans. (d)**

End of Solution

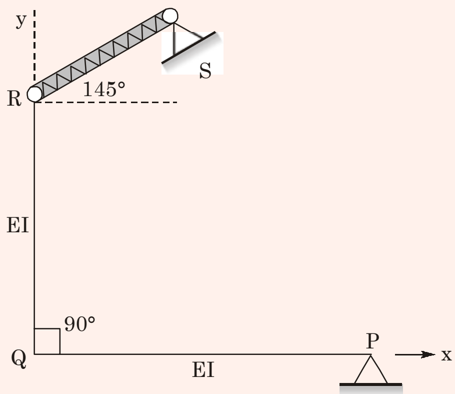
**Q.15** The degree of disturbances of a sample collected by sampler is expressed by a term called the area ratio. If outer diameter and inner dia of sample are $D_0$ and $D_i$ respecgively, the area ratio is

(a) $\frac{D_0^2 - D_i^2}{D_i^2}$
(b) $\frac{D_i^2 - D_0^2}{D_i^2}$
(c) $\frac{D_0^2 - D_i^2}{D_0^2}$
(d) $\frac{D_i^2 - D_0^2}{D_0^2}$

**Ans. (a)**

End of Solution

**Q.16** The degree of static indeterminacy of a rigid jointed frame PQR supported as shown is




(a) 0
(b) 1
(c) 2
(d) 3

**Ans. (a)**

$$D_s = D_{Se} + D_{si}$$
$$= (r_e - 3) + 3C - r_r$$
$$= (4 - 3) + 3 \times 0 - 1$$
$$= \mathbf{0}$$

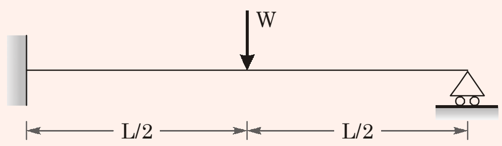
End of Solution

**Q.17** The action of negative 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

**Ans. (b)**

End of Solution

**Q.18** The ultimate collapse load ($W_u$) in terms of plastic moment $M_p$ by kinematic approach for a propped cantilever of length L with W acting at its mid span as shown in fig would be



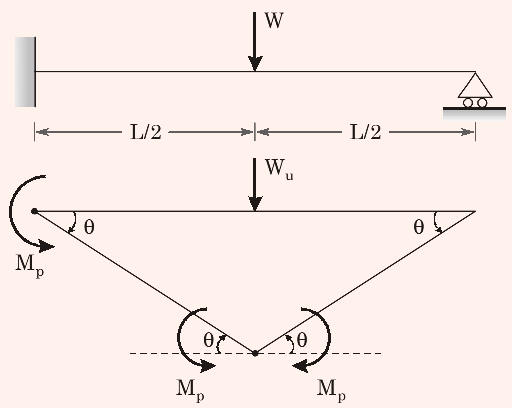

(a) $\frac{2M_p}{L}$

(b) $\frac{4M_p}{L}$

(c) $\frac{6M_p}{L}$

(d) $\frac{8M_p}{L}$

**Ans. (c)**




From principal of virtual work

$$-M_p\theta - M_p\theta - M_p\theta + W_u\frac{L}{2}\theta = 0$$

$$\Rightarrow \quad W_u = \frac{6M_p}{L}$$

End of Solution

**Q.19** Match the following:

| | Group I | | Group II |
|---|---|---|---|
| **P.** | Alidade | **1.** | Chain Survey |
| **Q.** | Arrow | **2.** | Levelling |
| **R.** | Bubble tube | **3.** | Plant table surveying |
| **S.** | Stedia hair | **4.** | Theodolite |

(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

**Ans. (d)**

P – 3, Q – 1, R – 2, S – 4

End of Solution

**Q.20** The sum of eigen value matrix [M] is

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

(a) 915
(b) 1355
(c) 1640
(d) 2180

**Ans. (a)**

Sum of eigen values = trace of matrix

= 215 + 150 + 550 = **915**

End of Solution

**Q.21** The probability density function of evaporation E on any day during a year in watershed is given by

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

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

**Sol.**

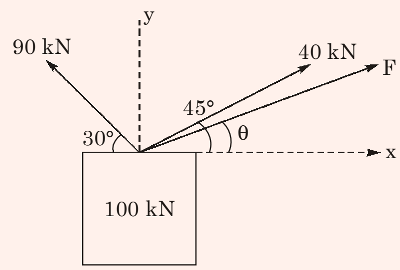
$$f(E) = \begin{cases} \frac{1}{5} & 0 \le E \le \text{mm/day} \\ 0 & \text{Otherwise} \end{cases}$$

$$P\ (2 < E < 4) = \int_2^4 f(E)\,dE = \int_2^4 \frac{1}{5}\,dE = \frac{1}{5}[E]_2^4$$

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

End of Solution

**Q.22** A box of weight 100 kN shown in the figure to be lifted without swinging. If all the forces are coplanar, the magnitude and direction (θ) of force F w.r.t. x axis is ________.




(a) F = 56.389 kN and θ = 28.28°

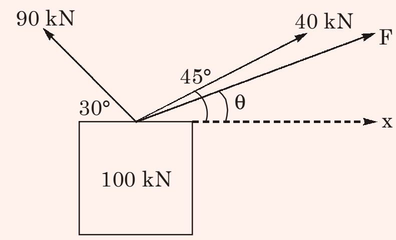
(b) F = –56.389 kN and θ = –28.28°

(c) F = 9.055 kN and θ = 1.1414°

(d) F = –9.055 kN and θ = –1.1414°

**Ans.** **(a)**

For no swinging $\Sigma F_{horizontal} = 0$




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

$$49.658 = F \cos \theta$$

F cos θ from **option (a)** = 56.389 cos 28.28° = **49.658 kN**

End of Solution

**Q.23** The amount of $CO_2$ generated in kg while completely oxidizing one kg of $CH_4$ is ________.

**Sol.**

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

$\Rightarrow$ 16 g of $CH_4$ when completely oxidized leads to 44 g of $CO_2$

$\Rightarrow$ 1 kg of $CH_4$ when completely oxidized leads to $\frac{44}{16} \times 1 = \mathbf{2.75\,kg\,CO_2}$

End of Solution

**Q.24** While designing for a steel column of Fe250 grade the base plate resting on a concrete pedestal of M20 grade, the bearing strength of concrete ($N/mm^2$) in LSM of design as per IS 456: 2000 is ..........

**Sol.**

$$\text{Permissible bearing stress} = 0.45\ f_{ck}$$
$$= 0.45 \times 20 = \mathbf{9\ N/mm^2}$$

End of Solution

**Q.25** Given $J = \begin{bmatrix} 3 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 6 \end{bmatrix}$ and $K = \begin{bmatrix} 1 \\ 2 \\ -1 \end{bmatrix}$ then product $K^T JK$ is _______.

**Sol.**

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

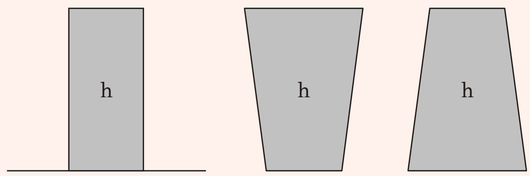
$$K^T JK = \begin{bmatrix} 1 & 2 & -1 \end{bmatrix} \begin{bmatrix} 3 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 6 \end{bmatrix} \begin{bmatrix} 1 \\ 2 \\ -1 \end{bmatrix}$$

$$= \begin{bmatrix} 6 & 8 & -1 \end{bmatrix} \begin{bmatrix} 1 \\ 2 \\ -1 \end{bmatrix} = 6 + 16 + 1 = \mathbf{23}$$

End of Solution

## Two Marks Questions

**Q.26** Three rigid bucket are of identical height and base area. Further assume that each of these buckets have negligible mass and are full of water. The weight of water in these bucket are denoted by $W_1$, $W_2$, $W_3$ respectively. Which of the following option are correct.




(a) $W_2 = W_1 = W_3$ and $F_2 > F_1 > F_2$

(b) $W_2 > W_1 > W_3$ and $F_2 > F_1 > F_3$

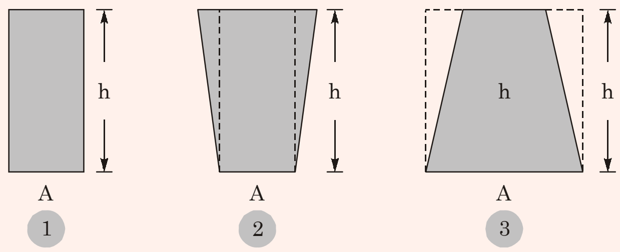
(c) $W_2 = W_1 = W_3$ and $F_1 = F_2 = F_3$

(d) $W_2 > W_1 > W_3$ and $F_2 = F_1 = F_3$

**Ans. (d)**

Bucket → identical height

→ identical base area




⇒ $W_2 > W_1 > W_3$

Force on the base in each case will be equal to $= \gamma_w h A$

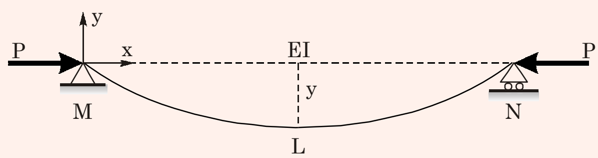
Hence, $\mathbf{F_1 = F_2 = F_3}$

End of Solution

**Q.27** If the following equation establishes equilibrium in slightly bent position.

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

the mid-span deflection of a member shown in figure is




[a is the amplitude constant for y]

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

(d) $y' = \frac{a\cos n\pi x}{L}$

**Ans. (c)**

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

$$= -m^2y$$

$\therefore$ Solution of above differential equation is

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

at $x = 0,\ y = 0$

$\Rightarrow$ $b = 0$

at $x = L,\ y = 0$

$\Rightarrow$ $0 = \sin mL$

$\Rightarrow$ $mL = n\pi$

$\Rightarrow$ $m = \dfrac{n\pi}{L}$

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

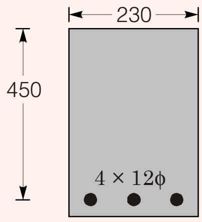
End of Solution

**Q.28** A rectangular beam of 230 mm width and effective depth = 450 mm, is reinforced with 4 bars of 12 mm diameter. The grade of concrete is M 20, grade of steel is Fe 500. Given that for M 20 grade of concrete, the ultimate shear strength $\tau_{uc}$ = 0.36 N/mm$^2$ for steel percentage of = 0.25, and $\tau_{uc}$ = 0.48 N/mm$^2$ for steel percentage = 0.5. For a factored shear force of 45 kN, the diameter (mm) of Fe 500 steel 2 legged stirrups to be used at spacing of 325 mm should be

(a) 8 (b) 10

(c) 12 (d) 16

**Ans. (a)**




$$\tau_{uc} = 0.36 \text{ N/mm}^2 \text{ [For M20] for } \frac{A_{st}}{bd}\times 100 = 0.25$$

$$\tau_{uc} = 0.48 \text{ N/mm}^2 \text{ [For M20] for } \frac{A_{st}}{bd}\times 100 = 0.5$$

Factored SF = 45 kN = $V_u$



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We have to calculate the dia of Fe 500 2-L egged stirrup to be used at a spacing of 325 mm c/c

$$\tau_v = \frac{V_u}{bd} = \frac{45\times1000}{230\times450} = 0.4348 \text{ N/mm}^2$$

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

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

Since $\tau_v - \tau_c < 0$

$\Rightarrow$ Min shear reinforcement is required

$\Rightarrow$ Min shear reinforcement is given by

$$\frac{A_{sv}}{bS_v} = \frac{0.4}{0.87 f_y}$$

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

Since we limit $f_y$ to 415 N/mm² hence,

$$A_{sv} = 2\times\frac{\pi}{4}(\phi)^2 = \frac{0.4\times325\times230}{0.87\times415} = 82.814 \text{ mm}^2$$

$$\phi = 7.26 \text{ mm}$$

adopt $\phi$ = **8 mm**

*End of Solution*

**Q.29** 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. These is a proposal to increase the flow through the 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) 60.5
(b) 4.4
(c) 38
(d) 23.27

**Ans. (a)**

In the disinfection process we have the relationship,

$$tC^n = K$$

where t = time required to kill all organism c = concentration of disinfectant

n = dilution coefficient

k = constant

$$\Rightarrow \quad t_1 C_1^n = t_2 C_2^n$$

in our case n = 1

$$\Rightarrow \quad t_1 C_1 = t_2 C_2$$

$$t_1 = \frac{L}{v_1}$$

L = length of pipe ; $V_1$ = velocity of flow

$$t_1 = \frac{L}{Q_1 / A}$$

$$t_1 = \frac{LA}{Q_1}$$

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

$$\Rightarrow \quad \frac{LA}{Q_1} \times \frac{W_1}{Q_1} = \frac{LA}{Q_2} \times \frac{W_2}{Q_2}$$

$$\Rightarrow \quad W_2 = \frac{Q_2^2}{Q_1^2} \times W_1 = \left(\frac{22}{16}\right)^2 \times 32 \text{ kg/day} = \mathbf{60.5 \text{ kg/day}}$$

*End of Solution*

**Q.30** A rectangular channel flow have bed slope of 0.0001 width = 3 m coefficient n = 0.015, Q = 1 m$^3$/sec given that normal depth of flow ranges between 0.76 m and 0.8 m. The minimum width of throat (in m) that is possible at a given section while ensuring that the prevailing normal depth does not exceed along the reach upstream of the concentration is approximately, equal to (assume negligible loss)

(a) 0.64 (b) 0.84

(c) 1.04 (d) 1.24

**Ans. (b)**

n = 0.015

Q = 1 m$^3$/s

Normal depth of flow between 0.76 m to 0.8 m.

If prevailing normal depth of flow is not exceeded, there must not be chocking of the section or there must be just chocking.

Thus the width of the section should be such that for the prevailing specific energy there should be critical flow at the contracted section

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

$$\Rightarrow \quad \frac{3}{2}\left[\frac{\left(\frac{Q}{B_{min}}\right)^2}{g}\right]^{1/3} = E_{initial}$$

Let is now calculate $E_{initial}$

$$Q = \frac{1}{2} AR^{2/3} S_0^{1/2}$$

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

$$\Rightarrow \quad y = 0.78 \text{ m}$$

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

$$= 0.78 + \frac{\left(\frac{1}{3}\right)^2}{2 \times 9.81 \times (0.78)^2} = 0.7893 \text{ m}$$

$$\Rightarrow \quad \frac{3}{2}\left[\frac{\left(\frac{Q}{B_{min}}\right)^2}{g}\right]^{1/3} = 0.7893$$

$$\Rightarrow \quad \frac{3}{2}\frac{(1)^{2/3}}{g^{1/3}(B_{min})^{2/3}} = 0.7893$$

$$B_{min} = \mathbf{0.836 \text{ m}}$$

*End of Solution*

**Q.31** A levelling is carried out to established the reduced level (RL) of point R with respect to the bench mark (BM) at P. The staff reading taken are given below

| Staff station | BS | IS | FS | RL |
|---|---|---|---|---|
| P | 1.655 | – | – | – |
| Q | –0.95 | – | –1.5 | – |
| R | – | – | 0.75 | – |

If RL of P is + 100 m, then RL (m) of R is

(a) 103.355
(b) 103.155
(c) 101.455
(d) 100.355

**Ans. (c)**

$$HI = RL + BS$$

and
$$RL = HI - FS$$

| Staff station | BS | IS | FS | RL | HI | RL |
|---|---|---|---|---|---|---|
| P | 1.655 | – | – | – | 101.655 | 100 |
| Q | –0.95 | – | –1.5 | – | 102.205 | 103.155 |
| R | – | – | 0.75 | – | – | 101.455 |

∴ RL of R = **101.455 m**

End of Solution

**Q.32** A given cohensionless soil has $e_{max}$ = 0.85, $e_{min}$ = 0.5. In the field, the soil is compacted to a mass density of 1800 kg/m$^3$ at water content of 8%. Take the mass density of water as 1000 kg/m$^3$ and $G_S$ = 2.7.

(a) 56.43
(b) 60.25
(c) 62.87
(d) 65.41

**Ans. (d)**

$$e_{max} = 0.85$$
$$e_{min} = 0.5$$
$$\rho_{field} = 1800 \text{ kg/m}^3 \text{ at water content} = 8\%$$
$$\rho_w = 1000 \text{ kg/m}^3$$
$$G_S = 2.7$$

Relative density, $I_D$ = ?

$$\rho = \frac{G\rho_w(1+w)}{1+e} = \frac{2.7 \times 1000(1.08)}{1+e}$$

$$\Rightarrow \quad 1 + e = \frac{2.7 \times 1000 \times 1.08}{1800}$$

$$\Rightarrow \quad e = 0.62$$

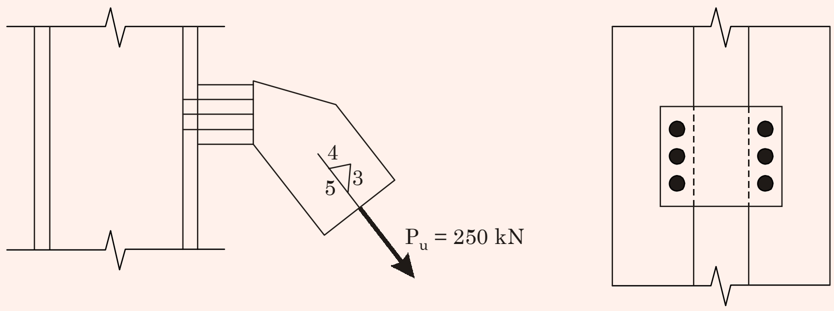
$$\Rightarrow \quad I_D = \frac{e_{max} - e}{e_{max} - e_{min}} \times 100$$

$$= \frac{0.85 - 0.62}{0.85 - 0.5} \times 100$$

$$= \mathbf{65.714\%}$$

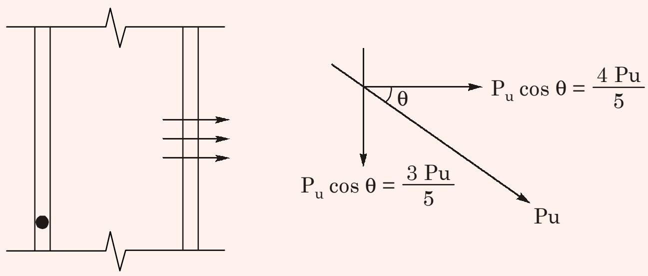
End of Solution

**Q.33** Then tension and shear force (both in kN) at both joints as shown below are respectively




(a) 30.3 and 20
(b) 30.33 and 25
(c) 33.33 and 20
(d) 33.33 and 25

**Ans. (d)**




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

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

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

$$\text{Tension in each bolt} = \frac{4P_u}{5 \times 6}$$

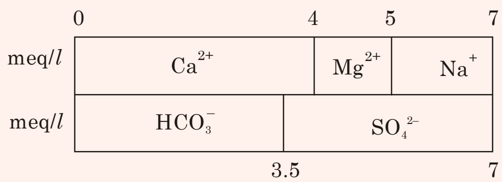
$$\frac{4 \times 250}{5 \times 6} = 33.33 \text{ kN}$$

$$\text{Shear in each bolt} = \frac{3P_u}{5 \times 6} = \frac{3 \times 250}{5 \times 6}$$

$$= \mathbf{25 \text{ kN}}$$

End of Solution

**Q.34** For a sample of water with the ionic composition shown below, the Carbonate and Non-carbonate hardness concentration (in mg/*l* as $CaCO_3$) respectively are.




(a) 200 and 500
(b) 175 and 75
(c) 75 and 175
(d) 50 and 200

**Ans. (c)**

Carbonate hardness = $3.5 \times 10^{-3}$ g-eq [if NCH is present sodium alkalinity will be absent i.e. $NaHCO_3$ absent]

$$= 3.5 \times 10^{-3} \times \frac{50g}{l} \text{ as } CaCO_3$$

$$= 175 \text{ mg}/l \text{ as } CaCO_3$$

Non carbonate hardness = total hardness-carbonate hardness

Total hardness = $5 \times 50$ mg/*l* as $CaCO_3$ [total hardness is due to $Ca^{2+}$ and $Mg^{2+}$]

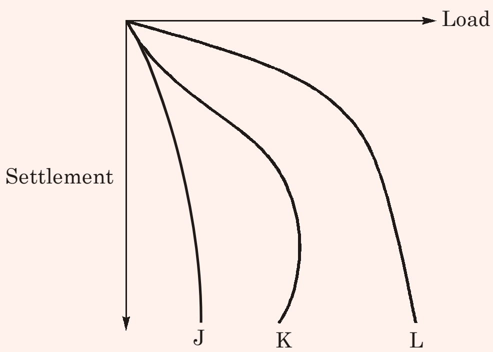
$$= 250 \text{ mg/l as CaCO3}$$

$\Rightarrow$ NCH = 250 – 175 = 75 mg/*l* as $CaCO_3$

End of Solution

**Q.35**

| Group-I | Group-II |
|---|---|
| **P.** Curve J | **1.** No apparent heaving of soil around the footing. |
| **Q.** Curve K | **2.** Rankine 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

**Ans. (d)**

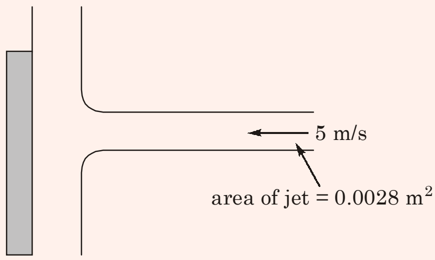
L → General shear failure
K → Local shear failure
J → Punching shear failure

End of Solution

**Q.36** A horizontal jet of water with its cross section area 0.0028 $m^2$ hits a fixed vertical plate with a velocity of 5 m/s. After impact the jet split 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

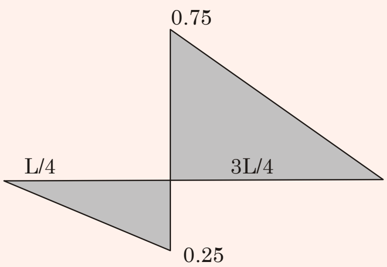
**Ans. (c)**

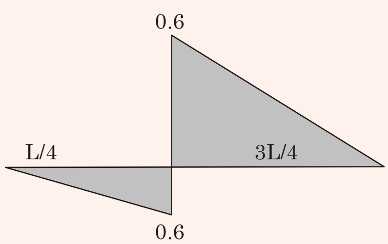


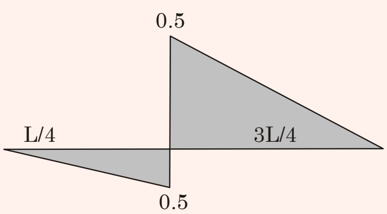

$$\text{Force on plate} = (\rho_w a V)V$$
$$= \rho_w a V^2 = 1000 \times 0.0028 \times (5)^2$$
$$= \mathbf{70\ N}$$

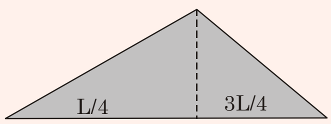
End of Solution

**Q.37** In a simply supported beam of length L four influence line diagram for shear at a section located at a distance of L/4 from the left support marked (P, Q, R, S) are shown below the correct, ILD is

P.


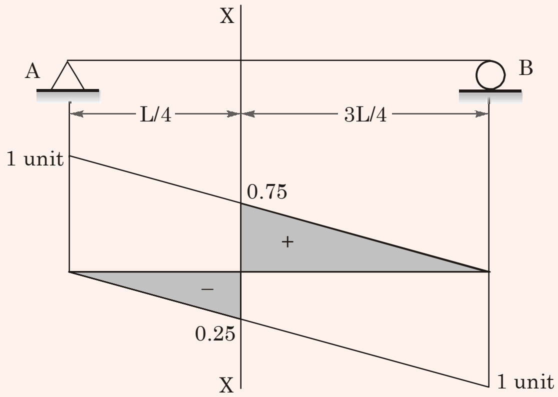

Q.



R.



S.


(a) P (b) Q
(c) R (d) S

**Ans. (a)**



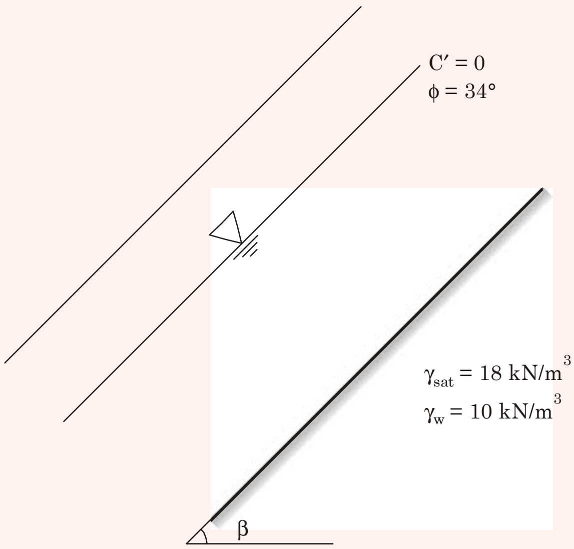

ILD for SF at X-X
i.e., **option (a)**

*End of Solution*

**Q.38** A long slope is formed in a soil with shear strength parameter $C' = 0$, $\phi' = 34°$. Firm strate lies below the slope and it is assumed that water table may occasionally rise to the surface, with seepage taking place parallel to the slope. Use $\gamma_{sat}$ = 18 kN/m$^3$ and $\gamma_w$ = 10 kN/m$^3$. maximum slope angle (in degree) to ensure the factor of safety 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

**Ans. (d)**



$$\text{FOS} = \frac{\gamma_{sub}}{\gamma_{sat}} \cdot \frac{\tan\phi}{\tan\beta}$$

$$\Rightarrow \quad \tan\beta = \left(\frac{\gamma_{sub}}{\gamma_{sat}} \cdot \frac{\tan\phi}{\text{FOS}}\right)$$

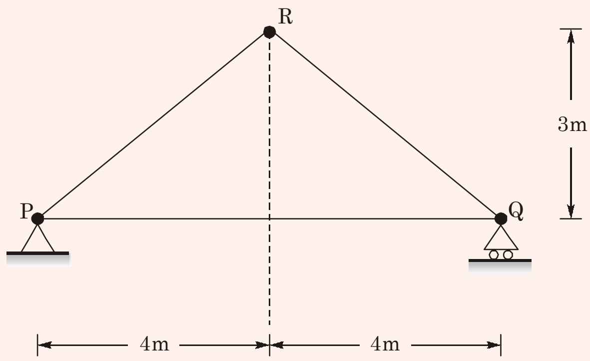
$$\Rightarrow \quad \tan\beta = \frac{\gamma_{sub}}{\gamma_{sat}} \cdot \frac{\tan\phi}{1.5}$$

$$\tan\beta = \frac{(18-10)}{18\times1.5} \times \tan 34°$$

$$\Rightarrow \quad \beta = \mathbf{11.30°}$$

*End of Solution*

**Q.39** For the truss shown below, the member PQ is short by 3 mm. The magnitude of the vertical displacement of joint R in mm is ________.



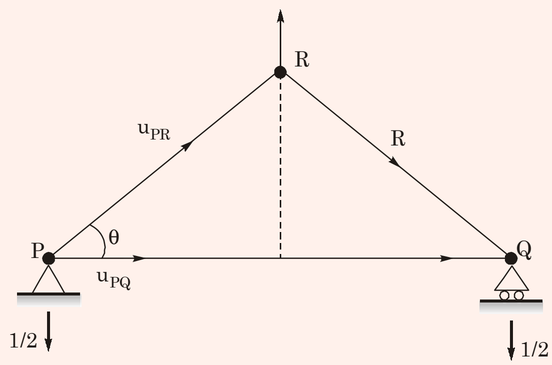

**Sol.**

PQ is short by 3 mm

We have to find out vertical displacement of joint R in mm

$$\Delta_R = \Sigma u(\lambda)$$

Let in apply unit load at R as shown below



$$u_{PR} \sin\theta = \frac{1}{2}$$

$$u_{PQ} + u_{PR} \cos\theta = 0$$

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

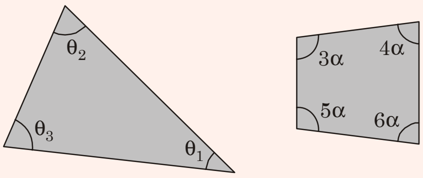
$$u_{PQ} = -\frac{1}{2}\cot\theta = \frac{-1\times 4/3}{2} = \frac{-2}{3}$$

$$\Delta_R = u_{PQ}\times\lambda_{PQ} = \frac{-2}{3}(-3) = 2\,\text{mm upwards}$$

End of Solution

**Q.40** The smallest angle of a triangle is equal to two third of the smallest angle of a quadrilateral. The ratio between the angle 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.**




$18\alpha = 360$
$\alpha = 20°$

Largest angle of quadrilateral = 120°

Smallest angle of quadrilateral = 60°

$\Rightarrow$ Smallest angle of triangle $= \frac{2}{3}\times(2\times 20) = 40°$

Largest angle of triangle = 2 × 40 = 80°

$\Rightarrow$ Third angle of triangle = 60°

$\Rightarrow$ Sum of largest angle of quadrilateral and second largest angle of triangle

= 120° + 60° = **180°**

End of Solution

**Q.41** A straight 100 m long raw water gravity main is to carry water from intake to the jackwell of a water treatment plant. The required flow of water is 0.25 $m^3/s$. Allowable velocity through main is 0.75 m/s. Assume f = 0.01, g = 9.81. The minimum gradient (in cm/100 length) required to be given to this main so that water flow without any difficulty should be ________ .

**Sol.**

$$Q = 0.25 \ m^3/s$$
$$\text{Allowable velocity} = 0.75 \ m/s$$
$$f = 0.01$$
$$g = 9.81$$

$$\frac{\pi d^2}{4} = \frac{Q}{V} = \frac{0.25}{0.75} = \frac{1}{3} m^2$$

$$\Rightarrow \quad d = 0.6515 \ m$$

$$\Rightarrow \quad \frac{flv^2}{2gd} = h_f = \frac{0.01 \times 100 \times (0.75)^2}{2 \times 9.81 \times 0.6515} m$$

$$= 0.044 \ m = 4.4 \ cm$$

$$\Rightarrow \text{Minimum gradient} = \frac{h_f}{l} = \frac{4.4 \, cm}{100 \, m}$$

Hence answer is **4.4.**

End of Solution

**Q.42** For a beam cross section W = 230 mm, effective depth = 500 mm, the number of reinforcement bars of 12 mm diameter required to satisfy minimum tension reinforcement requirement specified by IS-456-2000 (assume grade of steel is Fe500) is ________.

**Sol.**

$$\frac{A_{st\,min}}{bd} = \frac{0.85}{f_y}$$

$$A_{st} = \frac{0.85}{500} \times 230 \times 500 \, mm^2$$

$$n = \frac{A_{st}}{\frac{\pi d^2}{4}} = \frac{0.85 \times 230}{\frac{\pi}{4}(12)^2}$$

$$= 1.729 = \mathbf{2 \ bars}$$

End of Solution

**Q.43** 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/s²) is _______ seconds.

**Sol.**

$$SSD = 0.278\,vt_r + \frac{(0.278\,v)^2}{2gf}$$

$$\Rightarrow \quad 170 = 0.278 \times 90 \times t_r + \frac{(0.278 \times 90)^2}{2 \times 9.81 \times 0.35}$$

$$\Rightarrow \quad t_r = \mathbf{3.1510\ sec.}$$

End of Solution

**Q.44** A traffic office impose on an average 5 number of penalties daily on traffic violators. Assume that the number of penalties on different day is independent and follows a Poisson distribution. The probability that there will be less than 4 penalties in a day is ________.

**Sol.**

Mean $\lambda = 5$

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

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

$$= e^{-5}\left[1 + 5 + \frac{25}{2} + \frac{125}{6}\right] = e^{-5}\left(\frac{118}{3}\right) = \mathbf{0.265}$$

End of Solution

**Q.45** The speed-density (v-k) relationship on a single lane road with unidirectional flow is v = 70 – 0.7 K, where v is in km/hr and k is in veh/km. The capacity of the road (veh/hr) is

**Ans.** **(a)**

$$\text{Capacity} = \text{Velocity} \times \text{Density}$$

$$\Rightarrow \quad C = V \times K$$

$$= 70\,K - 0.7\,K^2$$

$$\text{Now,} \quad \frac{dC}{dK} = 70 - 1.4\,K = 0$$

$$\Rightarrow \quad K = 50$$

$$\Rightarrow \text{Capacity,} \quad C = 70 \times 50 - 0.7(50)^2$$

$$= \mathbf{1750\ veh/hr}$$

End of Solution

**Q.46** A particle moves along a curve whose parametric equation are $x = t^3 + 2t$, $y = -3e^{-2t}$ and $z = 2 \sin(5t)$, where x, y and z show variation of the distance covered by the particles in (cm) with time (t) (in second). The magnitude of the acceleration of the particle (in cm/s²) at t = 0 is ________.

**Sol.**

$$x = t^3 + 2t$$

$$y = -3e^{-2t}$$

$$z = 2 \sin(5t)$$

$$\frac{dx}{dt} = 3t^2 + 2$$

$$\Rightarrow \quad a_x = \frac{d^2x}{dt^2} = 6t$$

$$\frac{dy}{dt} = -3e^{-2t} \times (-2) = 6e^{-2t}$$

$$\Rightarrow \quad a_y = \frac{d^2y}{dt^2} = -12e^{-2t}$$

$$\Rightarrow \quad \frac{dz}{dt} = -10 \times 5 \sin(5t) = -50 \sin 5t$$

$$\Rightarrow \quad a_z = \frac{d^2z}{dt^2} = -50 \sin 5t$$

$$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$$

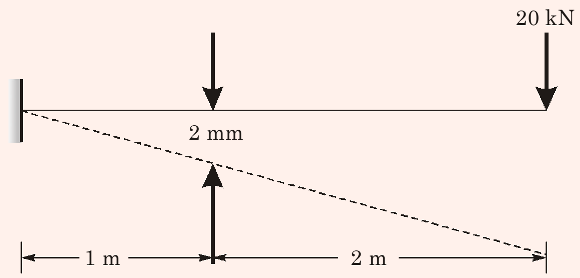
$$\vec{a} \text{ at } t = 0 = 0\hat{i} - 12\hat{j} + 0\hat{k}$$

$$\vec{a} = -12\hat{j}$$

$\Rightarrow$ Magnitude of acceleration at
$t = 0 =$ **12 cm/s²**

End of Solution

**Q.47** For a cantilever beam of a span 3m as shown a concentrated load of 20 kN applied to the free end causes a vertical displacement of 2mm at a section located at a distance of 1m from the fixed end (with no other load on the beam) the maximum vertical displacement in the same (in mm) is ________.



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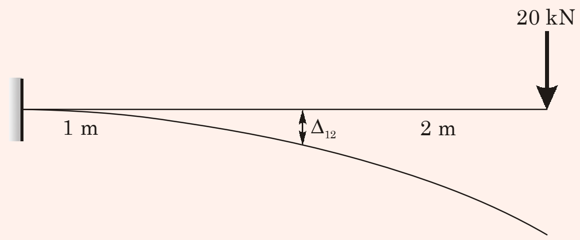
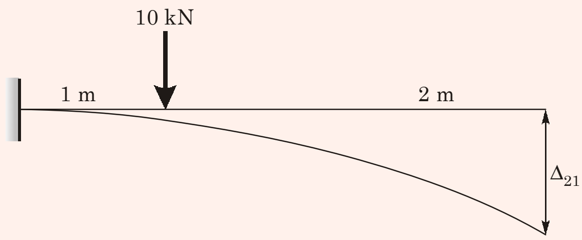
**Sol.**




From Betti's law $\quad P_1 \times \Delta_{12} = P_2 \times \Delta_{21}$

$\Rightarrow \quad 10 \times 2 = 20 \times \Delta_{21}$

$\Rightarrow \quad \Delta_{21} = \mathbf{1\ mm}$

End of Solution

**Q.48** An isolated three-phase traffic signal is designed by webster's method. The critical flow ratio for three phase are 0.2, 0.3 and 0.25 respectively and lost time per phase is 4 second. The optimum cycle length (in sec.) is ________.

**Sol.**

Sum of the flow, $\quad y = y_1 + y_2 + y_3$

$= 0.2 + 0.3 + 0.25 = 0.75$

Total lost time in a cycle L = 4 × 3 = 12 sec.

Optimum cycle length, $\quad C_0 = \frac{1.5L + 5}{1 - y}$

$$\frac{1.5 \times 12 + 5}{1 - 0.75} = \mathbf{92\ sec.}$$

End of Solution

**Q.49** Mathematical idealization of a crane has three bar with their vertices arranged as shown with load of 80 kN hanging vertically. The coordinate of the vertices are given in parenthesis. The force in member QR is ______.



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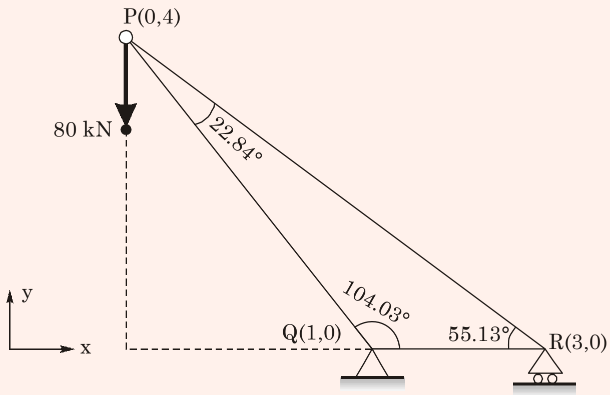
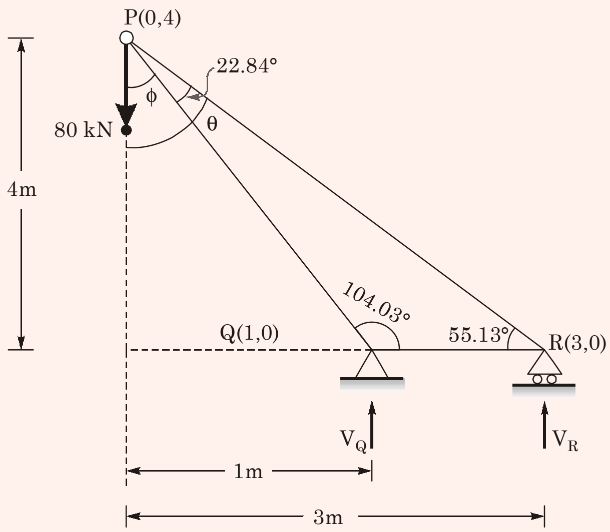



**Sol.**




$$V_Q + V_R = 80 \quad \text{...(i)}$$

$$\Sigma M_R = 0$$

$$\Rightarrow \quad 80 \times 3 = V_Q \times 2$$

$$V_Q = 120 \text{ kN}$$

$$\Rightarrow \quad V_R = -40 \text{ kN} \quad \text{From eq. (i)}$$

$$\tan\phi = \frac{1}{4}$$

$$\Rightarrow \quad \sin\phi = \frac{1}{\sqrt{17}}, \cos\phi = \frac{4}{\sqrt{17}}$$

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

$$\Rightarrow \quad \cos\theta = \frac{4}{5}$$



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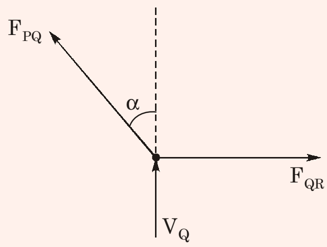
Consider joint Q




$$\alpha = 104.03° - 90° = 14.03°$$

$$\Sigma F_y = 0$$

$$\Rightarrow \quad F_{PQ}\cos\alpha = +V_Q = 0$$

$$\Rightarrow \quad F_{PQ}\cos 14.03° + 120 = 0$$

$$\Rightarrow \quad F_{PQ} = -123.6897 \text{ kN}$$

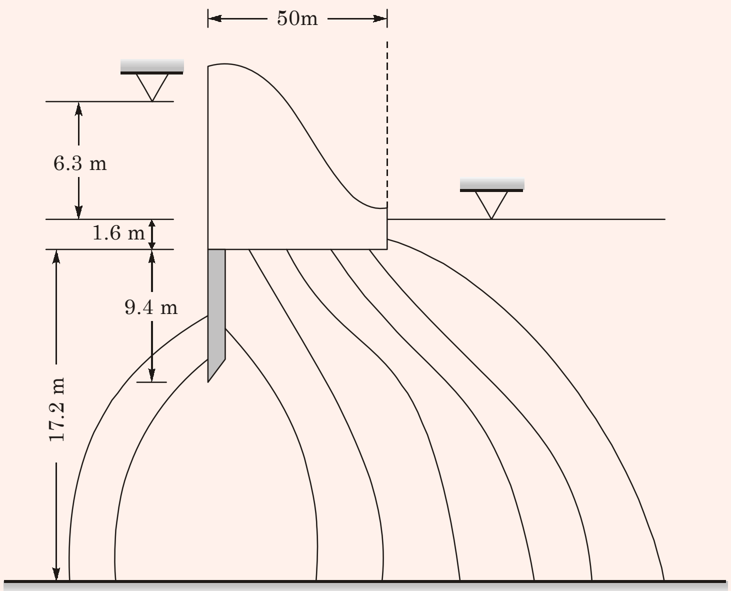
$$\Sigma F_x = 0$$

$$\Rightarrow \quad F_{PQ}\sin\alpha = F_{QR}$$

$$F_{QR} = -29.986 \text{ kN} \approx \mathbf{30 \text{ kNm}}$$

End of Solution

**Q.50** The flow net constructed for a dam is shown in the figure below. Taking coefficient of permeability as $3.8 \times 10^{-6}$ m/s, the quantity of flow (in $cm^3$/sec) under the dam per m is ________.




**Sol.**

Quantity of flow, $$Q = KH\frac{N_f}{N_d}$$

Here, $N_f$ = No. of flow channels = 3

$N_d$ = No. of equipotential drops = 10

Given, K = 3.8 × $10^{-6}$ m/s

and H = 6.3 m

$$\therefore \quad Q = 3.8\times10^{-6}\times6.3\times\frac{3}{10}$$

$$= 7.182 \times 10^{-6}\ m^3/s/m$$

$$= 7.182 \times 10^{-6} \times 10^{6}\ cm^3/s/m$$

$$Q = \mathbf{7.182\ cm^3/s/m}$$

End of Solution

**Q.51** The full data are given for laboratory sample $\sigma'_0$ = 175 kPa, $e_0$ = 1.1 $\sigma'_0$ + $\Delta\sigma'_0$ = 300 kPa, e = 0.9. If thickness of the clay specimen is 25 mm, the value of coefficient of volume compressibility is ________ × $10^{-4}$ $m^2/kN$.

**Sol.**

$$m_v = \frac{a_v}{1+e_0} = \frac{\frac{\Delta e}{\Delta\bar{\sigma}}}{1+e_0}$$

$$= \frac{(1.1-0.9)}{125\times2.1}$$

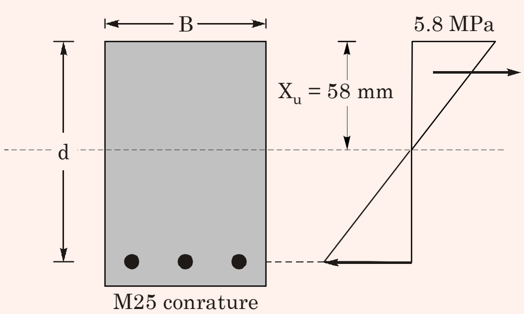
$$= \mathbf{7.619 \times 10^{-4}\ m^2/kN}$$

End of Solution

**Q.52** The reinforced concrete section, the stress at extreme fibre in compression is 5.8 MPa. The depth of Neutral Axis in the section is 58 mm and grade of concrete is M25. Assuming Linear elastic behavior of the concrete, the effective curvature of the section (in per mm) is

(a) 2 × $10^{-6}$
(b) 3 × $10^{-6}$
(c) 4 × $10^{-6}$
(d) 5 × $10^{-6}$

**Ans. (c)**



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Modulus of elasticity of concrete

$$E = 5000\sqrt{25} = 25000 \text{ N/mm}^2$$

$$\therefore \quad \frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

$$\Rightarrow \quad \frac{1}{R} = \frac{\sigma}{Ey} = \frac{5.8}{EX_u} = \frac{5.8}{58 \times 25000}$$

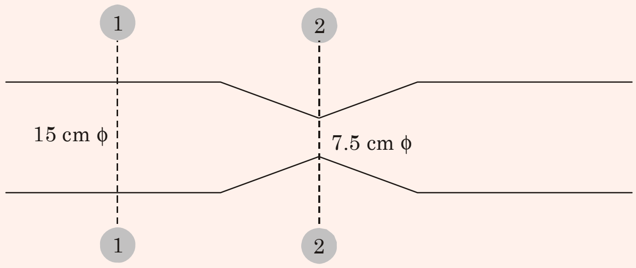
$$= 4 \times 10^{-6} \text{ Per mm}$$

$\Rightarrow$ Curvature = **$4 \times 10^{-6}$ per mm**

End of Solution

**Q.53** A venturimeter having 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 incompressible fluid at steady rate of 30 *l*/s. The difference of pressure head measured in terms of the moving fluid in between the enlarged and the throat of the vent is observed to be 2.45 m. Taking the g = 9.8 m/s$^2$, the coefficient of discharge of venturimeter (correct upto 2 decimal) is _________.

**Sol.**




$$Q = 30 \ l/s$$

$$\left(\frac{P_1}{w} + Z_1\right) - \left(\frac{P_2}{w} + Z_2\right) = 2.45 \text{ m} = h$$

$$g = 9.81$$

$$Q = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh}$$

$$C_d = \frac{Q}{\dfrac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh}}$$

$$= \frac{30 \times 30^{-3}\ m^3/s}{\dfrac{\dfrac{\pi}{4}(0.15)^2 \times (0.075)^2}{\sqrt{(0.15)^2 - (0.075)^2}} \times \sqrt{2 \times 9.81 \times 2.45}}$$

$$C_d = \mathbf{0.95}$$

End of Solution

**Q.54** A traffic surveying conducted on a road yield an average daily traffic count of 5000 vehicle. The axle load distribution on the same road is given in the following table.

| Axle load (tones) | Frequency of traffic (f) |
|---|---|
| 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% 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.**

Calculation of vehicle damage factor

$$\text{VDF} = \frac{V_1\left(\frac{W_1}{W_s}\right)^4 + V_2\left(\frac{W_2}{W_3}\right)^y + V_3\left(\frac{W_3}{W_s}\right)^4 + V_4\left(\frac{W_4}{W_s}\right)^4 + V_5\left(\frac{W_5}{W_s}\right)^4}{V_1 + V_2 + V_3 + V_4 + V_5}$$

where $W_s$ = standard axle load = 80 kN = 8.2 tonn

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

$$= 4.989$$

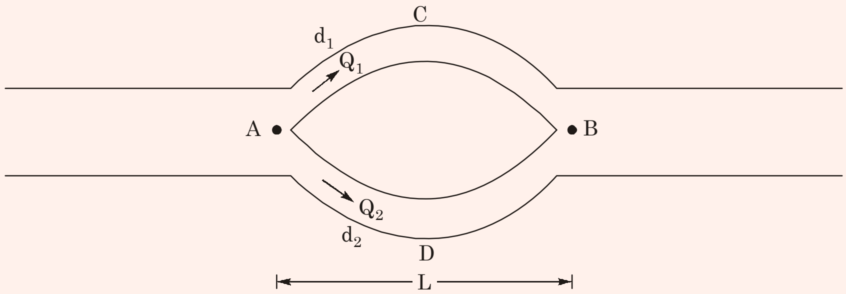
$$\Rightarrow \quad N = \frac{365 \times 5000\left[(1.075)^{15} - 1\right]}{0.075} \times 4.989$$

$$= \mathbf{237.806\ MSA}$$

End of Solution

**Q.55** An incompressible fluid is flown at steady rate in horizontal pipe. From a section the pipe divides into two horizontal parallel pipes of diameter ($d_1$ and $d_2$) that run, for a distance of L each and then again join back to a pipe of the original size. For both the pipes, assume the head loss due to friction only and the Darcy-weisbach friction factor to be same. The velocity ratio between bigger and smaller branched pipe is ________.

**Sol.**




$$d_1 = 4d_2$$

$$\frac{flv_1^2}{2gd_1} = \frac{flv_2^2}{2gd_2}$$

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

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

$$\frac{v_1}{v_2} = \mathbf{2}$$

End of Solution

## Section - II (General Aptitude)

### One Mark Questions

**Q.56** 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 statement below is logically valid and can be inferred from the above sentences?

(a) Rajan has decided to work only in group.
(b) Rajan and Sajan were formed into a group against their wishes.
(c) Sajan decided to give into Rajan's request to work with him.
(d) Rajan had believed that Sajan and he would be working together.

**Ans.** **(d)**

End of Solution

**Q.57** A boundary has a fixed daily cost of Rs 50,000 whenever it operates and variable cost of Rs. 8000 Q, 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.

**Sol.**

Total cost for 100 tonne

$$= 8000 \times 100 + 50000 = 850000$$

$$\text{Cost per tonne} = \frac{850000}{100} = \text{Rs. } \mathbf{8500/tonne.}$$

End of Solution

**Q.58** Choose the most appropriate word from the option given below to complete the following sentences, one of his biggest _______ was his ability to forgive.

(a) Vice
(b) Virtues
(c) Choices
(d) Strength

**Ans.** **(b)**

End of Solution

**Q.59** A student is required to demonstrate a high level of comprehension for the subject, especially in the social sciences.

The word closes in meaning to comprehension is

(a) Understanding
(b) Meaning
(c) Concentration
(d) Stability

**Ans.** **(a)**

End of Solution

**Q.60** Find the odd one in the following group ALRVX, EPVZB, ITZDF, OYEIX

(a) ALRVX
(b) EPVZB
(c) ITZDF
(d) OYEIX

**Ans.** **(d)**

End of Solution

## Two Marks Questions

**Q.61** One percent of the people of country X are taller than 6 ft, 2 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 % of people are taller than 6 ft?

(a) 3
(b) 2.5
(c) 1.5
(d) 1.25

**Ans. (d)**

Let the population of county Y is P

$\therefore$ Population of country X is 3P

$$\% \text{ of people taken than } 6\,\text{ft} = \frac{\frac{3P \times 1}{100} + \frac{P \times 2}{100}}{3P + P}$$

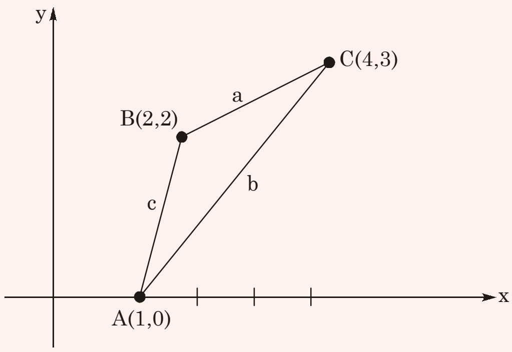
$$= \mathbf{1.25}$$

End of Solution

**Q.62** With reference to the conventional certesion (X, Y) the vertices of a triangle have $x_1, y_1 = 1, 0$, $x_2, y_2 = 2, 2$, and $x_3, y_3 = 4, 3$, the area of triangle is

(a) $\frac{3}{2}$
(b) $\frac{3}{4}$
(c) $\frac{4}{5}$
(d) $\frac{5}{2}$

**Ans. (a)**




Area of triangle is

$$A = \sqrt{p(p-a)(p-b)(p-c)}$$

$$\text{when } P = \frac{a+b+c}{2}$$

$$a = \sqrt{(4-2)^2 + (2-1)^2} = \sqrt{5}$$

$$b = \sqrt{(4-1)^2 + (3)^2} = 3\sqrt{2}$$

$$c = \sqrt{(2-1)^2 + (2)^2} = \sqrt{5}$$

$$p = \frac{\sqrt{5} + \sqrt{5} + 3\sqrt{2}}{2} = \sqrt{5} + \frac{3}{\sqrt{2}}$$

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

$$= \mathbf{\frac{3}{2}}$$

End of Solution

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