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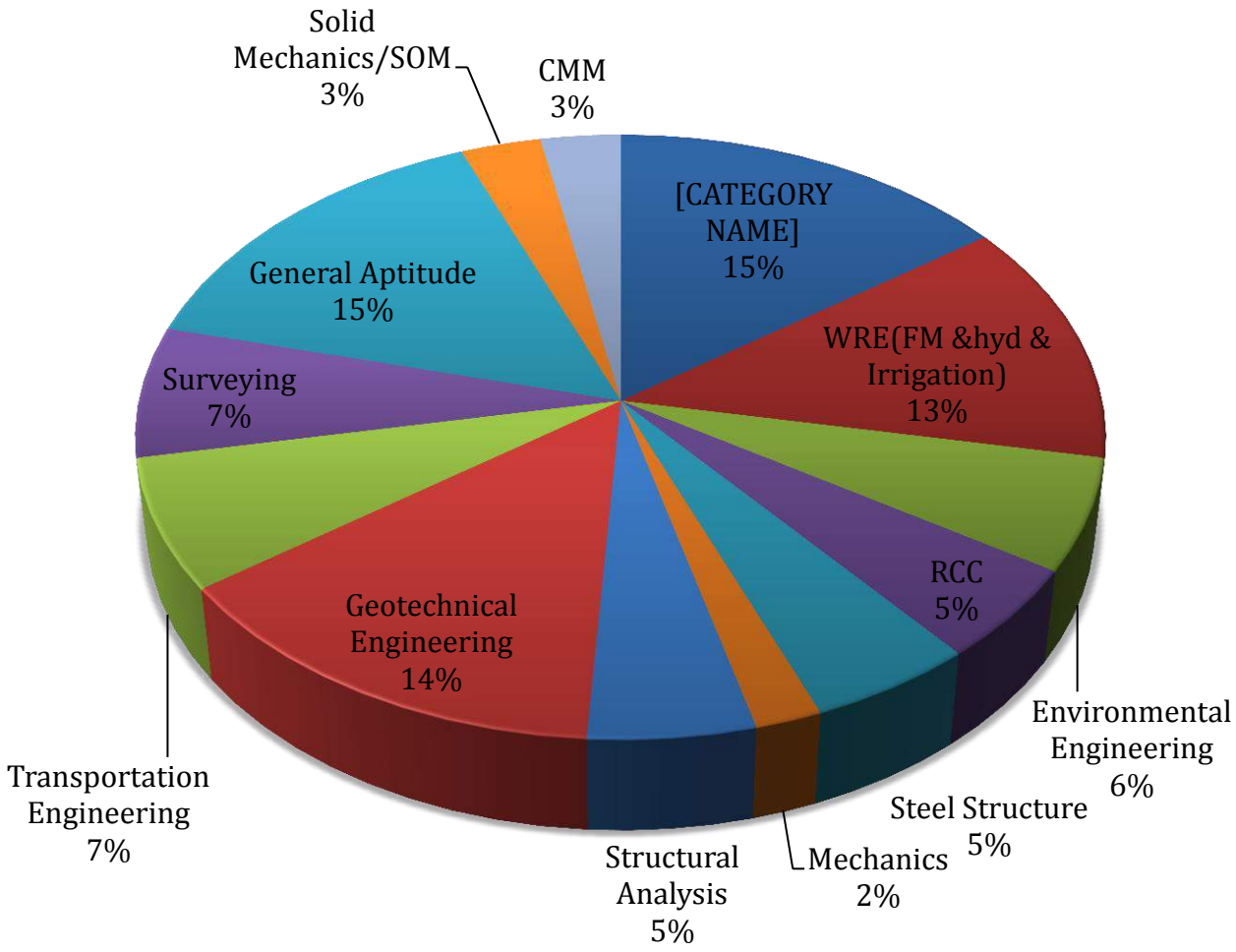
ANALYSIS OF GATE 2016
Civil Engineering



GATE-2016- CE 7-Feb 9 AM-12 PM

SUBJECT	NO OF QUESTION	Topics Asked in Paper	Level of Toughness	Total Marks
Enviormental Engineering	1 M: 2 2 M: 2	BOD,Air Pollution; Sound Pollution, Hardness, Ion Exchange Method, Sedimentation tank	Moderate	6
Structural	1 M: 1	Force in Truss, Kinematic indeterminacy in	Moderate	5

Analysis	2 M: 2	truss.		
Water Resources Engineering	1 M: 3 2 M: 5	Unit hydrographs; Khosla Theory, Well hydraulics; Jet impact, Open channel fow;Hydraulic machines, fluid properties.	Easy	13
SOM/Solid Mechanics	1 M: 1 2 M: 1	Principal stress, Vol strain; SF & BM	Easy	3
R.C.C.	1 M: 1 2 M: 2	Building materials; shear strength of RCC; modulus of rupture; Non prismatic RCC beam	Easy	5
Geomatics/Surve -ying Engineering	1 M:3 2 M:2	Photogrammetery;departure	Moderate	7
Geotechnical Engineering	1 M: 4 2 M: 5	Earth Pressure; permeability& seepage;compaction; Bearing capacity	Moderate	14
Transportation Engineering	1 M: 3 2 M: 2	Geomatric design; Signal design, pavements	Easy	7
* Construction Materials and Management	1 M: 1 2 M: 1	*Construction Management	Tough	3
Engg. Mechanics	1 M: 0 2 M: 1	*Trusses and Frames.	Tough	2
Steel Structure	1 M: 1 2 M: 2	Plastic Analysis ; Design of Tension Member	Moderate	5
Engineering Mathematics	1 M: 5 2 M: 5	Numerical Method ;Matrices;Complex Variable; Probability ; Limit & Continuty.	Moderate	15
GA	1 M: 5 2 M: 5	Time & Work ;Paragraph; English fill in Blank, ;Number theory; Venn Diagram ; Mensuration& Area	Easy	15
Total	**65**		Moderate	**100**

* Indicates Questions from New Syllabus.

Faculty Feedback:

- Few questions came from New Syllabus (2 questions from CPM, 1 question from mechanics)
- General Ability was pretty easy;
- Weightage of Environment, Geotechnical and Highway was more as usual.
- Construction management Structural analysis was scoring
- Paper was logical. Qualifying is easy but scoring is tough. More focus was on concepts.
- Prectice Online test Series & Previous year question Series Will be beneficial .

GATE-2016

Question Paper

&

Answer Keys

GATE 2016 Examination
Civil Engineering

Test Date: 07/02/2016
Test Time: 9:00 AM to 12:00 PM
Subject Name: CIVIL ENGINEERING

Section: General Aptitude

Q NO. 1.

If I were you, I _____ that laptop. It's much too expensive.

(A) won't buy
(B) shan't buy
(C) wouldn't buy
(D) would buy

[Ans. C]

Q NO. 2.

He turned a deaf ear to my request.

What does the underlined phrasal verb mean?

(A) ignored
(B) appreciated
(C) twisted
(D) returned

[Ans. A]

Q NO. 3.

Choose the most appropriate set of words from the options given below to complete the following sentence.

_____ _____ is a will, _____ is a way.

(A) Wear, there, their
(B) Were, their, there
(C) Where, there, there
(D) Where, their, their

[Ans. C

Q NO. 4.

(x % of y) + (y % of x) is equivalent to _____.

(A) 2 % of xy (B) 2 % of (xy/100) (C) xy % of 100 (D) 100 % of xy

[Ans. A]

Q NO. 5.

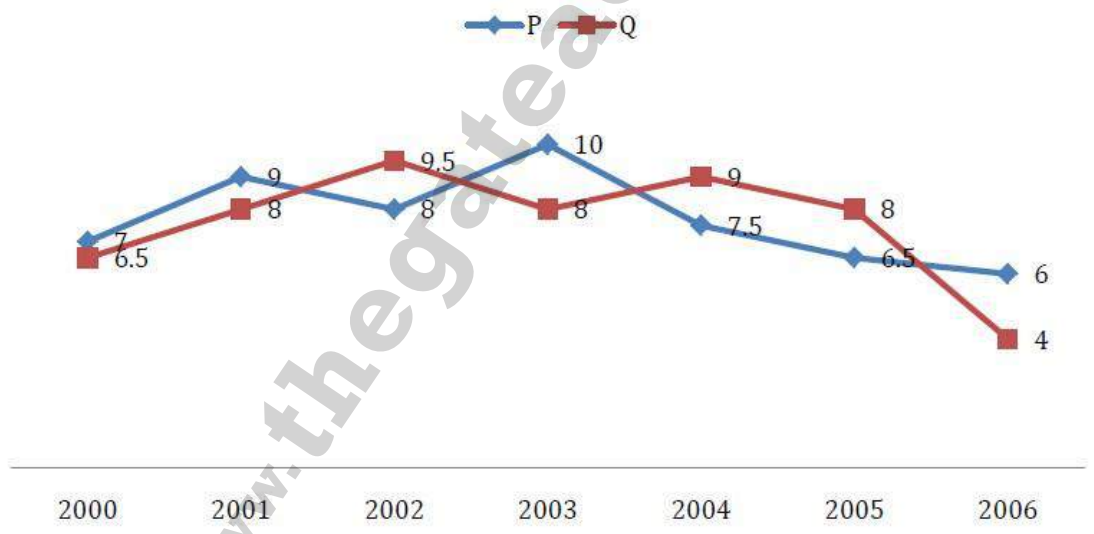
The sum of the digits of a two digit number is 12. If the new number formed by reversing the digits is greater than the original number by 54, find the original number.

(A) 39 (B) 57 (C) 66 (D) 93

[Ans. A]

Q NO. 6.

Two finance companies, P and Q, declared fixed annual rates of interest on the amounts invested with them. The rates of interest offered by these companies may differ from year to year. Year-wise annual rates of interest offered by these companies are shown by the line graph provided below.



If the amounts invested in the companies, P and Q, in 2006 are in the ratio 8:9, then the amounts received after one year as interests from companies P and Q would be in the ratio:

(A) 2:3
(B) 3:4
(C) 6:7
(D) 4:3

[Ans. D]

Q NO. 7.

Today, we consider Ashoka as a great ruler because of the copious evidence he left behind in the form of stone carved edicts. Historians tend to correlate greatness of a king at his time with the availability of evidence today.

Which of the following can be logically inferred from the above sentences?

(A) Emperors who do not leave significant sculpted evidence are completely forgotten.

(B) Ashoka produced stone carved edicts to ensure that later historians will respect him.

(C) Statues of kings are a reminder of their greatness.

(D) A king's greatness, as we know him today, is interpreted by historians.

[Ans. D]

Q NO. 8.

Fact 1: Humans are mammals.
Fact 2: Some humans are engineers.
Fact 3: Engineers build houses.

If the above statements are facts, which of the following can be logically inferred?

I. All mammals build houses.
II. Engineers are mammals.
III. Some humans are not engineers.

(A) II only.
(B) III only.
(C) I, II and III.
(D) I only.

[Ans. B]

Q NO. 9.

A square pyramid has a base perimeter x, and the slant height is half of the perimeter. What is the lateral surface area of the pyramid?

(A) x^2
(B) $0.75\,x^2$
(C) $0.50\,x^2$
(D) $0.25\,x^2$

[Ans. D]

Q NO. 10.

Ananth takes 6 hours and Bharath takes 4 hours to read a book. Both started reading copies of the book at the same time. After how many hours is the number of pages **to be** read by Ananth, twice that **to be** read by Bharath? Assume Ananth and Bharath read all the pages with constant pace.

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

[Ans. C]

Section: Technical

Q NO. 1.

The spot speeds (expressed in km/hr) observed at a road section are 66, 62, 45, 79, 32, 51, 56, 60, 53, and 49. The median speed (expressed in km/hr) is _____
(Note: answer with one decimal accuracy)

[Ans. *] Range: 54.49 to 54.51

Q NO. 2.

The optimum value of the function $f(x) = x^2 - 4x + 2$ is

(A) 2 (maximum) (B) 2 (minimum) (C) −2 (maximum) (D) −2 (minimum)

[Ans. D]

Q NO. 3.

The Fourier series of the function,

$$f(x) = 0, \quad -\pi < x \le 0$$
$$= \pi - x, \quad 0 < x < \pi$$

in the interval $[-\pi, \pi]$ is

$$f(x) = \frac{\pi}{4} + \frac{2}{\pi}\left[\frac{\cos x}{1^2} + \frac{\cos 3x}{3^2} + \dots\dots\dots\right] + \left[\frac{\sin x}{1} + \frac{\sin 2x}{2} + \frac{\sin 3x}{3} + \dots\dots\right].$$

The convergence of the above Fourier series at $x = 0$ gives

(A) $\sum_{n=1}^{\infty} \frac{1}{n^2} = \frac{\pi^2}{6}$

(B) $\sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n^2} = \frac{\pi^2}{12}$

(C) $\sum_{n=1}^{\infty} \frac{1}{(2n-1)^2} = \frac{\pi^2}{8}$

(D) $\sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{2n-1} = \frac{\pi}{4}$

[Ans. C]

Q NO. 4.

X and Y are two random independent events. It is known that $P(X) = 0.40$ and $P(X \cup Y^C) = 0.7$. Which one of the following is the value of $P(X \cup Y)$?

(A) 0.7 (B) 0.5 (C) 0.4 (D) 0.3

[Ans. A]

Q NO. 5.

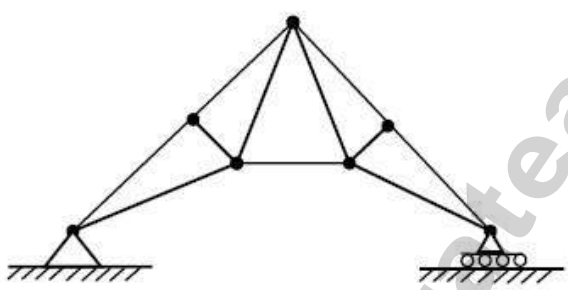
What is the value of $\lim_{\substack{x \to 0 \\ y \to 0}} \frac{xy}{x^2 + y^2}$?

(A) 1 (B) –1 (C) 0 (D) Limit does not exist

[Ans. D]

Q NO. 6.

The kinematic indeterminacy of the plane truss shown in the figure is



(A) 11 (B) 8 (C) 3 (D) 0

[Ans. A]
Kinematic inderminacy
$D_k = 2j - r_e$
$= 2 \times 7 - 2 = 11$

Q NO. 7.

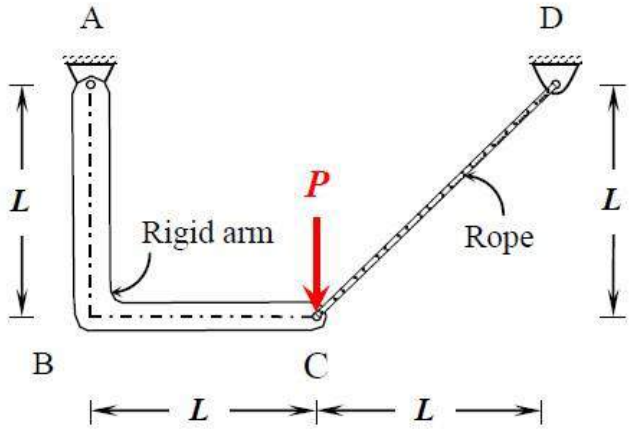
As per IS 456-2000 for the design of reinforced concrete beam, the maximum allowable shear stress $(\tau_{c\,max})$ depends on the

(A) grade of concrete and grade of steel
(B) grade of concrete only
(C) grade of steel only
(D) grade of concrete and percentage of reinforcement

[Ans. B]

Q NO. 8.

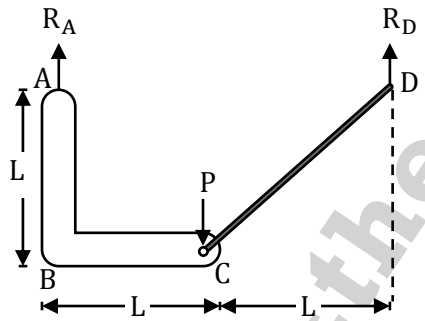
An assembly made of a rigid arm A-B-C hinged at end A and supported by an elastic rope C-D at end C is shown in the figure. The members may be assumed to be weightless and the lengths of the respective members are as shown in the figure.



Under the action of a concentrated load P at C as shown, the magnitude of tension developed in the rope is

(A) $\frac{3P}{\sqrt{2}}$ (B) $\frac{P}{\sqrt{2}}$ (C) $\frac{3P}{8}$ (D) $\sqrt{2}P$

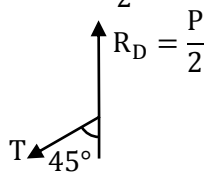
[Ans. B]



$\sum M_A = 0$

$\Rightarrow R_D \times 2L - P \times L = 0$

$\Rightarrow R_D = \frac{P}{2}$



At joint D:

$\sum F_Y = 0$

$\Rightarrow T\cos 45° = \frac{P}{2}$

$\therefore T = P/\sqrt{2}$

Q NO. 9.

As per Indian standards for bricks, minimum acceptable compressive strength of any class of burnt clay bricks in dry state is

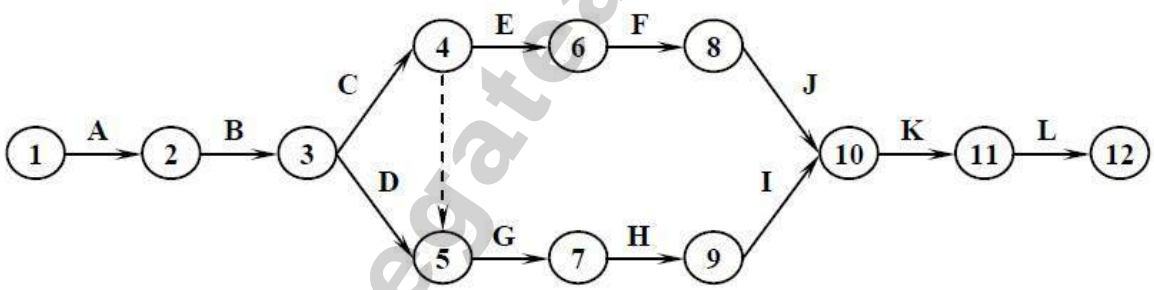
(A) 10.0 MPa (B) 7.5 MPa (C) 5.0 MPa (D) 3.5 MPa

[Ans. D]

Q NO. 10.

A construction project consists of twelve activities. The estimated duration (in days) required to complete each of the activities along with the corresponding network diagram is shown below.

Activity		Duration (days)	Activity		Duration (days)
A	Inauguration	1	G	Flooring	25
B	Foundation work	7	H	Electrification	7
C	Structural construction-1	30	I	Plumbing	7
D	Structural construction-2	30	J	Wood work	7
E	Brick masonry work	25	K	Coloring	3
F	Plastering	7	L	Handing over function	1



Total floats (in days) for the activities 5-7 and 11-12 for the project are, respectively,

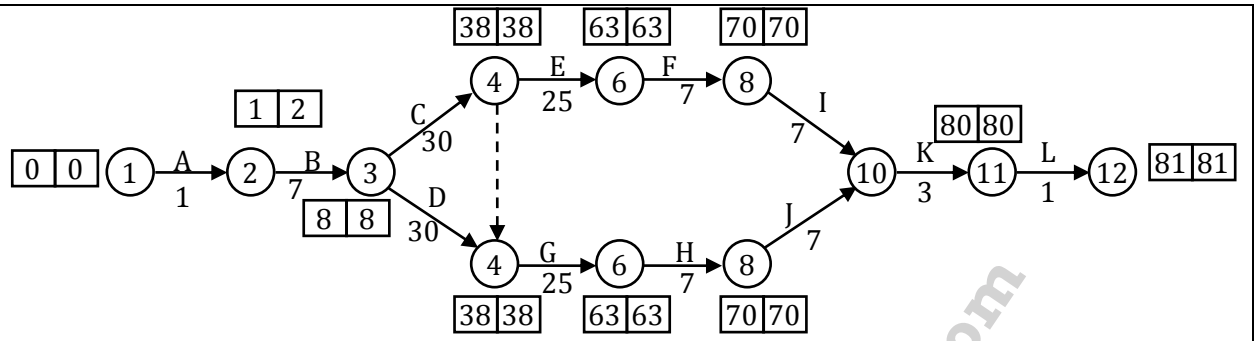
(A) 25 and 1
(B) 1 and 1
(C) 0 and 0
(D) 81 and 0

[Ans. C]

Total float can be determined once the activity time i.e., EST, EFT, LST and LFT are known

Total float, $F_R = LST - EST$

$= LFT - EFT$



For activity 5-7, EST = 38
EFT = 63
LFT = 63
LST = 38
$F_T = 0$
For activity 11-12, EST = 80
EFT = 81
LFT = 81
LST = 80
$F_T = 0$
Note: it can be seen directly that since the slack of all events are zero, there is not margin left for the occurrence of events and therefore.
Maximum available line = Time required for completion of activity
$\therefore F_T$ for all activities is zero.

Q NO. 11.

A strip footing is resting on the surface of a purely clayey soil deposit. If the width of the footing is doubled, the ultimate bearing capacity of the soil

(A) becomes double (B) becomes half (C) becomes four-times (D) remains the same

[Ans. D]
In case of clay ultimate bearing capacity is independent of width of footing

Q NO. 12.

The relationship between the specific gravity of sand (G) and the hydraulic gradient (i) to initiate quick condition in the sand layer having porosity of 30% is

(A) $G = 0.7i + 1$
(B) $G = 1.43i - 1$
(C) $G = 1.43i + 1$
(D) $G = 0.7i - 1$

[Ans. C]

$$i_c = \frac{G-1}{1+e} = (G-1)(1-n) \quad \because \frac{1}{1+e} = 1-n$$

$$i_c = (G-1)(1-0.3) = (G-1) \times 0.7$$

$$G = \frac{i_c}{0.7} + 1 = 1.43 i_c + 1$$

Q NO. 13.

The results of a consolidation test on an undisturbed soil, sampled at a depth of 10 m below the ground level are as follows:

Saturated unit weight	:	16 kN/m^3
Pre-consolidation pressure	:	90 kPa

The water table was encountered at the ground level. Assuming the unit weight of water as 10 kN/m^3, the over-consolidation ratio of the soil is

(A) 0.67 (B) 1.50 (C) 1.77 (D) 2.00

[Ans. B]

$$\text{OCR} = \frac{\text{Maximum effective stress in past}}{\text{Maximum effective stress in present}}$$

$$\text{Maximum effective stress in present} = 10\,\gamma_{sat} = 10\gamma_w$$
$$= 10 \times 16 - 10 \times 10 = 60\ \text{kN/m}^2$$

$$\therefore \text{OCR} = \frac{90}{60} = 1.5$$

Q NO. 14.

Profile of a weir on permeable foundation is shown in figure I and an elementary profile of 'upstream pile only case' according to Khosla's theory is shown in figure II. The uplift pressure heads at key points Q, R and S are 3.14 m, 2.75 m and 0 m, respectively (refer figure II).

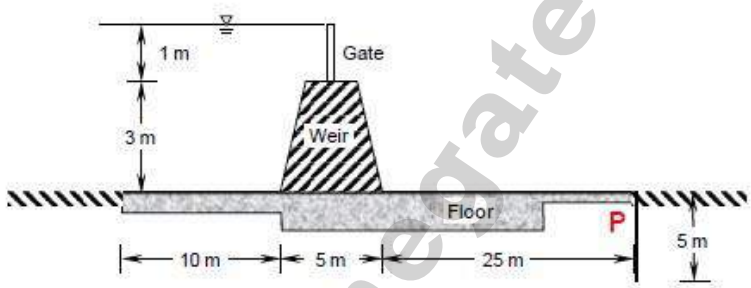


Figure I

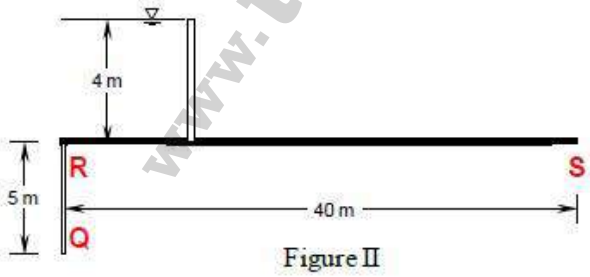


Figure II

What is the uplift pressure head at point P downstream of the weir (junction of floor and pile as shown in the figure I)?

(A) 2.75 m (B) 1.25 m (C) 0.8 m (D) Data not sufficient

[Ans. B]

$\phi_B = \frac{2.75}{4} \times 100 = 68.75\%$

$\phi_P + 100 - \phi_R = 31.25\%$

Now, $\phi_P = \frac{\text{Pressure head at point P}}{\text{Total head}} \times 100$

$31.25 = \frac{h}{4} \times 100$

$\therefore h = 1.25$ m

Q NO. 15.

Water table of an aquifer drops by 100 cm over an area of 1000 km^2. The porosity and specific retention of the aquifer material are 25% and 5%, respectively. The amount of water (expressed in km^3) drained out from the area is _____

[Ans. *] Range: 0.19 to 0.21

$S_r + S_y = n$

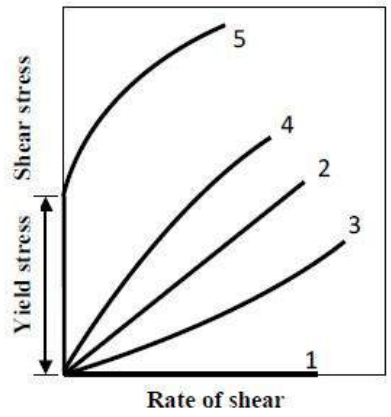
$\frac{5}{100} + \frac{V_w}{10^3 \times 10^6 \times 1} = \frac{25}{100}$

$V_w = 0.2 \times 10^9 m^3 = 0.2\ km^3$

Q NO. 16.

Group I contains the types of fluids while Group II contains the shear stress - rate of shear relationship of different types of fluids, as shown in the figure.

Group I	Group II
P. Newtonian fluid	1. Curve 1
Q. Pseudo plastic fluid	2. Curve 2
R. Plastic fluid	3. Curve 3
S. Dilatant fluid	4. Curve 4
	5. Curve 5



The correct match between Group I and Group II is

(A) P-2, Q-4, R-1, S-5
(B) P-2, Q-5, R-4, S-1
(C) P-2, Q-4, R-5, S-3
(D) P-2, Q-1, R-3, S-4

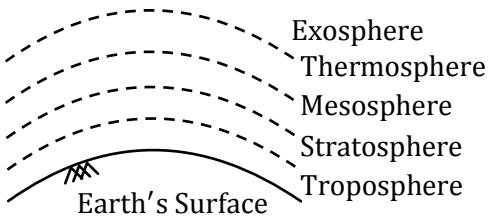
[Ans. C]

Q NO. 17.

The atmospheric layer closest to the earth surface is

(A) the mesosphere
(B) the stratosphere
(C) the thermosphere
(D) the troposphere

[Ans. D]



Q NO. 18.

A water supply board is responsible for treating 1500 m^3/day of water. A settling column analysis indicates that an overflow rate of 20 m/day will produce satisfactory removal for a depth of 3.1 m. It is decided to have two circular settling tanks in parallel. The required diameter (expressed in m) of the settling tanks is _____

[Ans. *] Range: 6.8 to 7.0

Discharge to be treated by one tank,

$$Q = \frac{1500}{2} = 750\ m^2/day$$

$$\text{Surface area, } A = \frac{Q}{OFR} = \frac{750}{20} = 37.5m^3$$

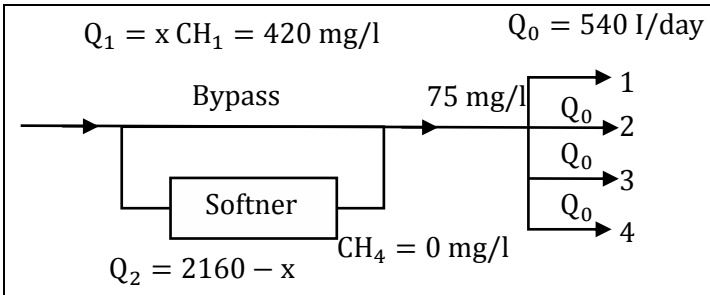
$$\Rightarrow 37.5 = \pi \times \frac{d^2}{4}$$

$$\Rightarrow d = 6.91\ m$$

Q NO. 19.

The hardness of a ground water sample was found to be 420 mg/L as $CaCO_3$. A softener containing ion exchange resins was installed to reduce the total hardness to 75 mg/L as $CaCO_3$ before supplying to 4 households. Each household gets treated water at a rate of 540 L/day. If the efficiency of the softener is 100%, the bypass flow rate (expressed in L/day) is _____

[Ans. *] Range: 380 to 390



Total water to be treated
$= 540 \times 4 = 2160$ l/day
Resultant hardness required = 75 mg/l
Let bypass rate be x l/day hardness of 420 mg/l
Resultant hardness required = 75 mg/l

$$CH_{mix} = \frac{CH_1Q_1 + CH_2Q_2}{Q}$$

$$75 = \frac{x \times 420 + (2160 - x)0}{2160}$$

$$x = \frac{2160 \times 75}{420} = 385.7 \text{ l/day}$$

Q NO. 20.

The sound pressure (expressed in μPa) of the faintest sound that a normal healthy individual can hear is

(A) 0.2 (B) 2 (C) 20 (D) 55

[Ans. C]
The sound pressure of the faintest sound that a normal healthy individual can hear is 20 μPa.
It is taken as reference sound pressure level.
A 20 μPa pressure is 0 dB on the sound pressure level scale

Q NO. 21.

In the context of the IRC 58-2011 guidelines for rigid pavement design, consider the following pair of statements.

I: Radius of relative stiffness is directly related to modulus of elasticity of concrete and inversely related to Poisson's ratio
II: Radius of relative stiffness is directly related to thickness of slab and modulus of subgrade reaction.

Which one of the following combinations is correct?

(A) I: True; II: True (B) I: False; II: False
(C) I: True; II: False (D) I: False; II: True

[Ans. C]

Q NO. 22.

If the total number of commercial vehicles per day ranges from 3000 to 6000, the minimum percentage of commercial traffic to be surveyed for axle load is

(A) 15 (B) 20 (C) 25 (D) 30

[Ans. A]

Q NO. 23.

Optimal flight planning for a photogrammetric survey should be carried out considering

(A) only side-lap
(B) only end-lap
(C) either side-lap or end-lap
(D) both side-lap as well as end-lap

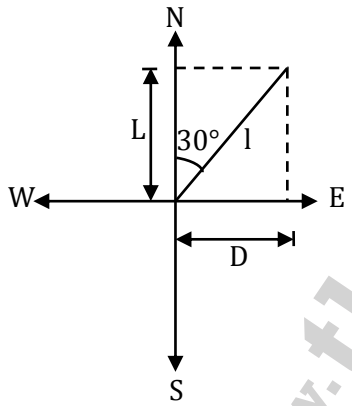
[Ans. D]

Q NO. 24.

The reduced bearing of a 10 m long line is N30°E. The departure of the line is

(A) 10.00 m (B) 8.66 m (C) 7.52 m (D) 5.00 m

[Ans. D]



The departure of the line ; $D = l \sin\theta$

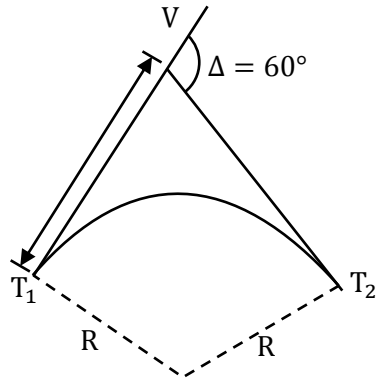
$= 10 \sin 30° = \frac{10}{2} = 5$ m

Q NO. 25.

A circular curve of radius R connects two straights with a deflection angle of 60°. The tangent length is

(A) 0.577 R (B) 1.155 R (C) 1.732 R (D) 3.464 R

[Ans. A]



Tangent length, $VT_1 = R\tan\frac{\Delta}{2}$

$= R\tan 30° = 0.577\ R$

Q NO. 26.

Consider the following linear system.

$x + 2y - 3z = a$
$2x + 3y + 3z = b$
$5x + 9y - 6z = c$

This system is consistent if a, b and c satisfy the equation

(A) $7a - b - c = 0$ (B) $3a + b - c = 0$ (C) $3a - b + c = 0$ (D) $7a - b + c = 0$

[Ans. B]

Q NO. 27.

If $f(x)$ and $g(x)$ are two probability density functions,

$$f(x) = \begin{cases} \frac{x}{a}+1 & : -a \le x < 0 \\ -\frac{x}{a}+1 & : 0 \le x \le a \\ 0 & : otherwise \end{cases}$$

$$g(x) = \begin{cases} -\frac{x}{a} & : -a \le x < 0 \\ \frac{x}{a} & : 0 \le x \le a \\ 0 & : otherwise \end{cases}$$

Which one of the following statements is true?

(A) Mean of $f(x)$ and $g(x)$ are same; Variance of $f(x)$ and $g(x)$ are same
(B) Mean of $f(x)$ and $g(x)$ are same; Variance of $f(x)$ and $g(x)$ are different
(C) Mean of $f(x)$ and $g(x)$ are different; Variance of $f(x)$ and $g(x)$ are same
(D) Mean of $f(x)$ and $g(x)$ are different; Variance of $f(x)$ and $g(x)$ are different

[Ans. B]

Q NO. 28.

The angle of intersection of the curves $x^2 = 4y$ and $y^2 = 4x$ at point (0, 0) is

(A) 0° (B) 30° (C) 45° (D) 90°

[Ans. D]

Q NO. 29.

The area between the parabola $x^2 = 8y$ and the straight line $y = 8$ is _____.

[Ans. *] Range: 85.0 to 85.5

Q NO. 30.

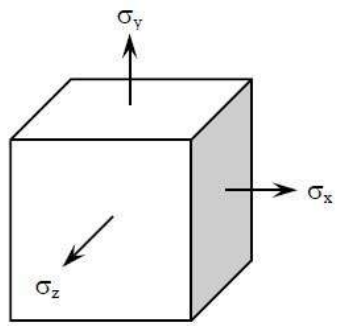
The quadratic approximation of $f(x) = x^3 - 3x^2 - 5$ at the point $x = 0$ is

(A) $3x^2 - 6x - 5$
(B) $-3x^2 - 5$
(C) $-3x^2 + 6x - 5$
(D) $3x^2 - 5$

[Ans. B]

Q NO. 31.

An elastic isotropic body is in a hydrostatic state of stress as shown in the figure. For no change in the volume to occur, what should be its Poisson's ratio?



(A) 0.00 (B) 0.25 (C) 0.50 (D) 1.00

[Ans. C]

Volumetric strain

$$\epsilon_V = \left(\frac{\sigma_x + \sigma_y + \sigma_z}{3}\right)(1 - 2\mu)$$

$$\Rightarrow \frac{\delta V}{V} = \left(\frac{\sigma_x + \sigma_y + \sigma_z}{3}\right)(1 - 2\mu)$$

As $\Delta V = 0$

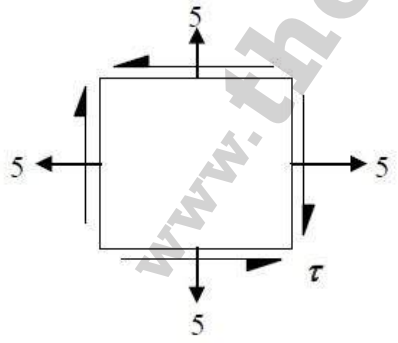
$\Rightarrow$ Either $\sigma_x + \sigma_y + \sigma_z = 0$ or $1 - 2\mu = 0$

$\Rightarrow 1 - 2\mu = 0$

$\mu = 0.5$

Q NO. 32.

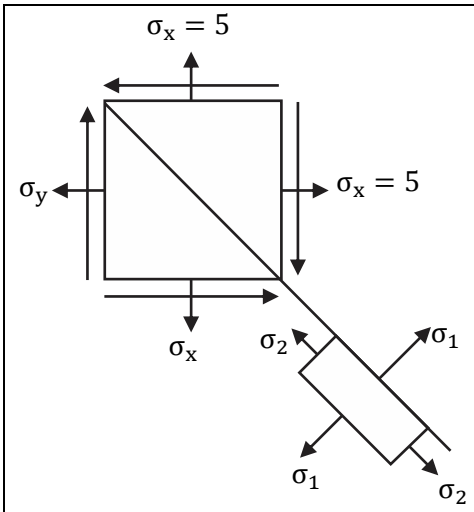
For the stress state (in MPa) shown in the figure, the major principal stress is 10 MPa.



The shear stress τ is

(A) 10.0 MPa (B) 5.0 MPa (C) 2.5 MPa (D) 0.0 MPa

[Ans. B]



$\sigma_x + \sigma_y = \sigma_1 + \sigma_2$

$\Rightarrow 5 + 5 = 10 + \sigma_2$

$\Rightarrow \sigma_2 = 0$

Now, $\sigma_{1/2} = \dfrac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\dfrac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

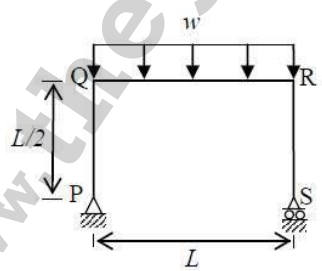
$\therefore \sigma_1 = \dfrac{5+5}{2} + \sqrt{\left(\dfrac{5-5}{2}\right)^2 + \tau_{xy}^2}$

$\Rightarrow 10 = 5 + \tau_{xy}$

$\therefore \tau_{xy} = 5$ MPa

Q NO. 33.

The portal frame shown in the figure is subjected to a uniformly distributed vertical load w (per unit length).



The bending moment in the beam at the joint 'Q' is

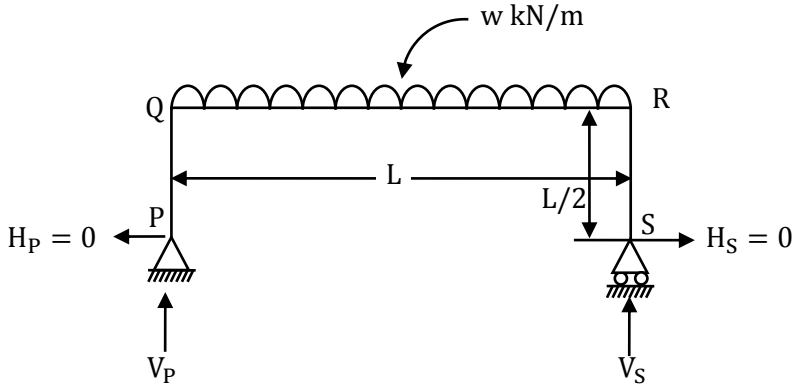
(A) zero

(B) $\dfrac{wL^2}{24}$ (hogging)

(C) $\dfrac{wL^2}{12}$ (hogging)

(D) $\dfrac{wL^2}{8}$ (sagging)

[Ans. A]



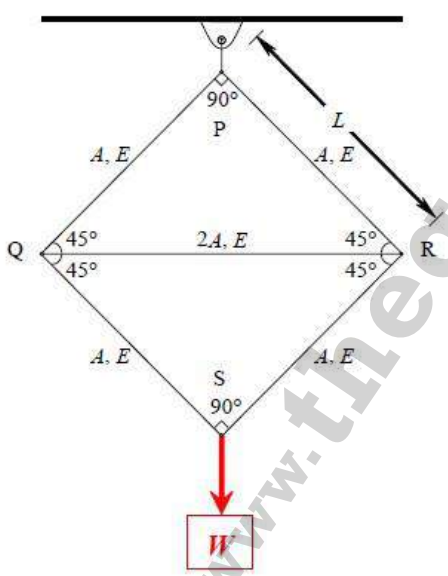
As there is no horizontal force,

Hence $H_P = H_S = 0$

$\sum M_Q = H_P \times \frac{L}{2} = 0$

Q NO. 34.

Consider the structural system shown in the figure under the action of weight W. All the joints are hinged. The properties of the members in terms of length (L), area (A) and the modulus of elasticity (E) are also given in the figure. Let L, A and E be 1 m, 0.05 m^2 and 30×10^6 N/m^2, respectively, and W be 100 kN.



Which one of the following sets gives the correct values of the force, stress and change in length of the horizontal member QR?

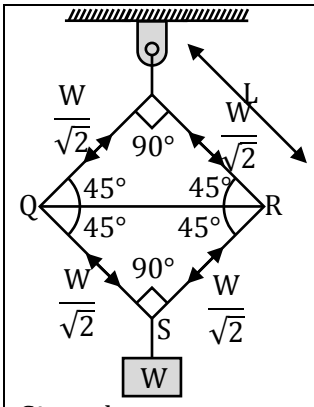
(A) Compressive force = 25 kN; Stress = 250 kN/m^2; Shortening = 0.0118 m

(B) Compressive force = 14.14 kN; Stress = 141.4 kN/m^2; Extension = 0.0118 m

(C) Compressive force = 100 kN; Stress = 1000 kN/m^2; Shortening = 0.0417 m

(D) Compressive force = 100 kN; Stress = 1000 kN/m^2; Extension = 0.0417 m

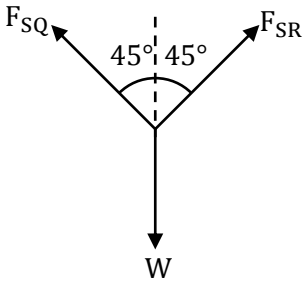
[Ans. C]



Given data

$L = 1m, A = 0.05\ m^2, E = 30 \times 10^6\ N/m^2$

Consider joint 'S'



$F_{SQ} = = F_{SR}$

$2F_{SQ} = \cos 45° = W$

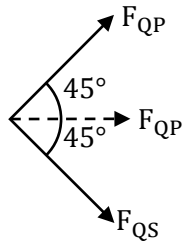
$\Rightarrow F_{SQ} = \frac{W}{2} \times \sqrt{2} = \frac{W}{\sqrt{2}}$

$\therefore F_{SQ} = \frac{W}{\sqrt{2}}$

As the truss is symmetrical

$\therefore F_{QP} = F_{PR} = \frac{W}{\sqrt{2}}$ (Tensile)

Now consider joint 'Q'



$F_{QP} = F_{QS} = \frac{W}{\sqrt{2}}$

$\sum F_x = 0$

$\Rightarrow \frac{F_{QP}}{\sqrt{2}} + \frac{F_{QS}}{\sqrt{2}} + F_{QR} = 0$

$\Rightarrow F_{QR} = W$ (Compressive)

$\therefore F_{QR} + 100$ kN (compressive)

Stress in member QR

$\sigma_{QR} = \frac{F_{QR}}{2\Delta}$

$\Rightarrow \sigma_{QR} = \frac{100}{2 \times 1.05} = \frac{100 \times 100}{2 \times 5} = 100 \text{ kN/m}^2$

$\therefore \sigma_{QR} = 1000 \text{ kN/m}^2$

As the member QR consist compressive so it will go under shortening

$\therefore \text{Shortening}, \Delta = \frac{P(\text{Length})}{2AE} = \frac{F_{QR}.L_{QR}}{2AE}$

$L_{QR} = \sqrt{L^2 + L^2} = \sqrt{2}L$

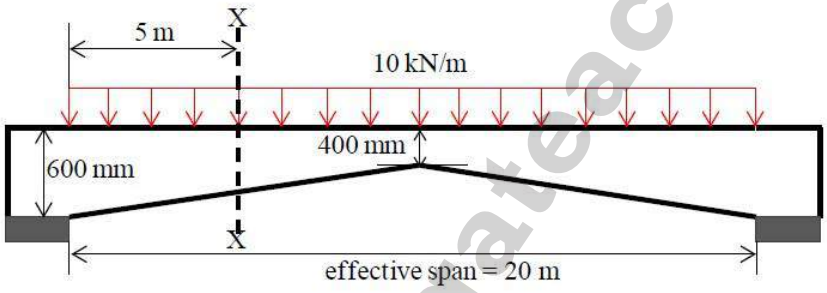
$\therefore \Delta = \frac{100 \times 10^3 \times \sqrt{2} \times 1}{2 \times 0.05 \times 30 \times 10^6}$

$= \frac{100 \times 10^3 \times \sqrt{2}}{0.1 \times 30 \times 10^6} = \frac{\sqrt{2}}{30}$

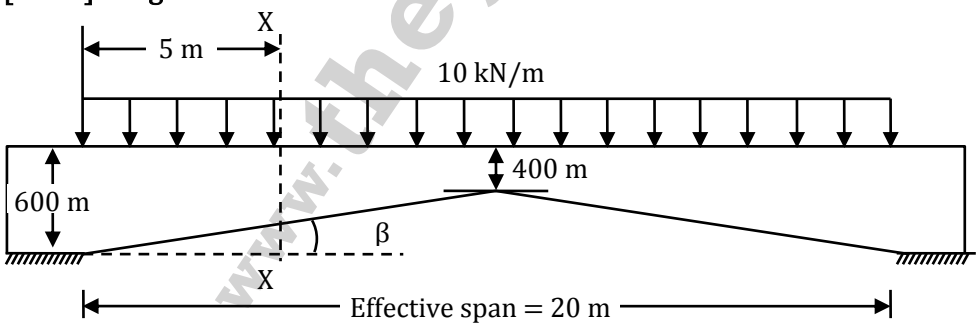
$\therefore \Delta = 0.471$

Q NO. 35.

A haunched (varying depth) reinforced concrete beam is simply supported at both ends, as shown in the figure. The beam is subjected to a uniformly distributed factored load of intensity 10 kN/m. The design shear force (expressed in kN) at the section X-X of the beam is _____



[Ans. *] Range: 64 to 66



Shear force at section X-X

$V_u = 100 - 5 \times 10 = 50 \text{ kN}$

Depth at section X-X

$d = 400 + \frac{200}{10} \times 5 = 500 \text{ mm} = 0.5 \text{ m}$

Moment at section X-X

$M_u = 100 \times 5 - 10 \times 2.5 \times 5 = 375 \text{ kNm}$

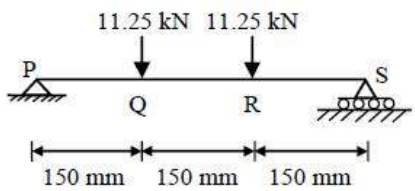
Design shear force at section X-X_,

$$V_{u,design} = V_u + \frac{M_u}{d}\tan\beta$$

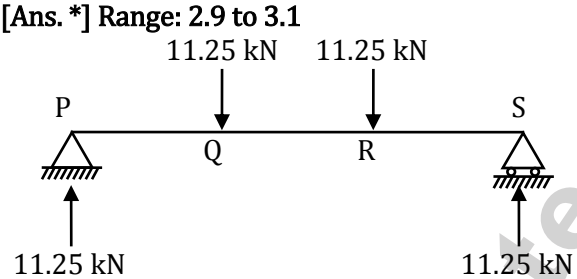
$$= 50 + \frac{375}{0.5} \times \frac{200}{10000} = 65 \text{ kN}$$

Q NO. 36.

A 450 mm long plain concrete prism is subjected to the concentrated vertical loads as shown in the figure. Cross section of the prism is given as 150 mm × 150 mm. Considering linear stress distribution across the cross-section, the modulus of rupture (expressed in MPa) is _____



[Ans. *] Range: 2.9 to 3.1



$$BM_Q = 11.25 \times 150 = 1.6875 \times 10^6 \text{N} - \text{mm}$$

$$\Rightarrow \frac{\sigma}{y} = \frac{M_Q}{I}$$

$$\text{Where, } y = \frac{150}{2} = 75 \text{ mm and } I = \frac{(150)^4}{12}$$

$$\Rightarrow \sigma = \frac{1.6875 \times 10^6 \times 75}{(150)^4/12} = 3 \text{ MPa}$$

Q NO. 37.

Two bolted plates under tension with alternative arrangement of bolt holes are shown in figures 1 and 2. The hole diameter, pitch, and gauge length are d, p and g, respectively.

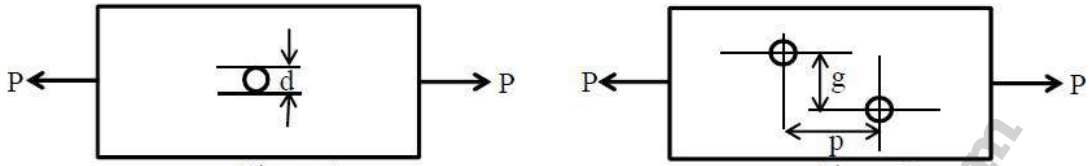


Figure 1 Figure 2

Which one of the following conditions must be ensured to have higher net tensile capacity of configuration shown in Figure 2 than that shown in Figure 1 ?

(A) $p^2 > 2gd$ (B) $p^2 < \sqrt{4gd}$ (C) $p^2 > 4gd$ (D) $p > 4gd$

[Ans. C]

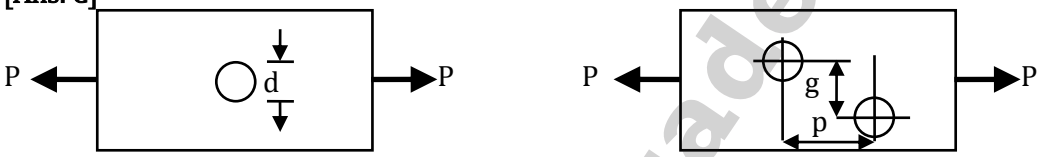


Figure 1 Figure 2

Tensile strength of plate in arrangement (2) will be greater than in arrangement (1)

$*$ As per IS code 800: 2007 close 6.3

$$\left(0.9\,A_{net}\frac{f_{up}}{\gamma_{ml}}\right)_2 > \left(0.9\,A_{net}\frac{f_{up}}{\gamma_{ml}}\right)_1$$

$$(A_{net})_2 > (A_{net})_1$$

$$\left[\left(B - 2d + \frac{p^2}{4g}\right)t\right]_2 > [(B-d)t]_1$$

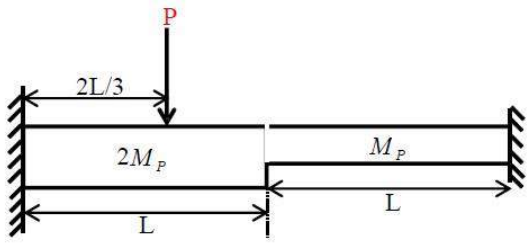
$$B - 2d + \frac{p^2}{4g} > B - d$$

$$\frac{p^2}{4g} > d$$

$$p^2 > 4gd$$

Q NO. 38.

A fixed-end beam is subjected to a concentrated load (P) as shown in the figure. The beam has two different segments having different plastic moment capacities $(M_p, 2M_p)$ as shown.



The minimum value of load (P) at which the beam would collapse (ultimate load) is

(A) $7.5M_p/L$ (B) $5.0M_p/L$ (C) $4.5M_p/L$ (D) $2.5M_p/L$

[Ans. A]

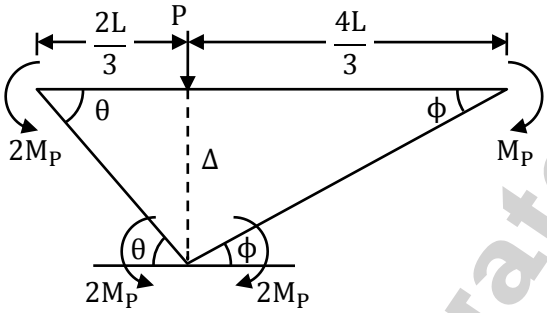
$D_S = 2$

$\therefore$ Number of plastic hinge required for complete collapse

$= D_S + 1$

$= 2 + 1 = 3$

Mechanism 1:



$$\Delta = \frac{2L}{3\theta} = \frac{4L}{3}$$

$\Rightarrow \theta = 2\theta$

For principal of virtual work done

$$-2M_P\theta - 2M_P\theta - 2M_P\phi - M_P\phi = P\left(\frac{2L}{3}\theta\right) = 0$$

$$\Rightarrow\ 4M_P\theta + 3M_P\phi = \frac{2PL}{3}\theta$$

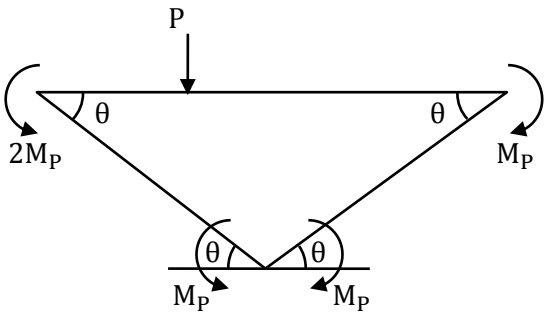
$$\Rightarrow 8M_P\phi + 3M_P\phi = \frac{2PL}{3}\phi$$

$$\Rightarrow 11M_P = \frac{4P_uL}{3}$$

$$\Rightarrow P_u = \frac{33}{4}\frac{M_P}{L}$$

$$\therefore P_u = 8.25\ \frac{M_P}{L}$$

Mechanism 2:



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

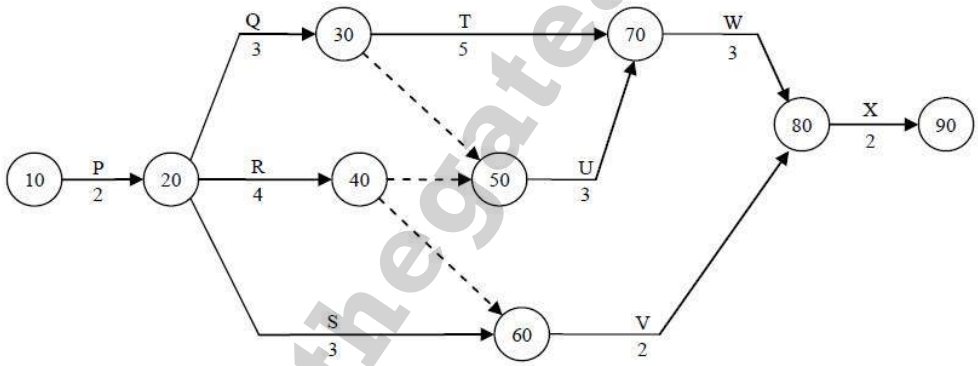
$$\Rightarrow 5M_P = \frac{2PL}{3}$$

$$\Rightarrow P_u = \frac{15M_P}{2L}$$

$$\therefore P_u = 7.5\frac{M_P}{L}$$

Q NO. 39.

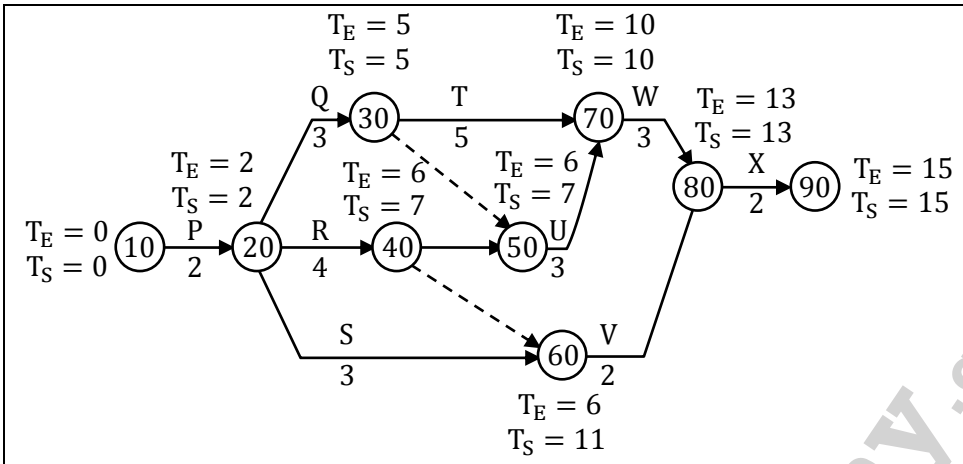
The activity-on-arrow network of activities for a construction project is shown in the figure. The durations (expressed in days) of the activities are mentioned below the arrows.



The critical duration for this construction project is

(A) 13 days (B) 14 days (C) 15 days (D) 16 days

[Ans. C]



The critical duration is 15 days which is observed along the path P-Q-T-W-X which is the critical path of the project

Note: Critical path is the one which consumes maximum amount of time

Q NO. 40.

The seepage occurring through an earthen dam is represented by a flownet comprising of 10 equipotential drops and 20 flow channels. The coefficient of permeability of the soil is 3 mm/min and the head loss is 5 m. The rate of seepage (expressed in cm^3/s per m length of the dam) through the earthen dam is _____

[Ans. *] Range: 495 to 505

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

$$K = \frac{3mm}{min} = \frac{3 \times 10^{-3} m}{60} m/s$$

$$H = 5\ m, N_f = 20, N_d = 10$$

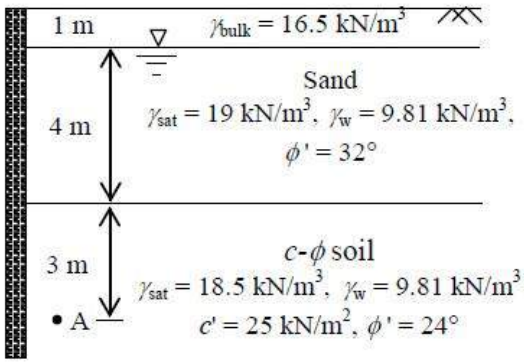
$$q = \frac{3 \times 10^{-3}}{60} \times 5 \times \frac{20}{10} m^3/sec \text{ per m length of dam}$$

$$q = \frac{3 \times 10^{-3} \times 5 \times 20}{60 \times 10} \times 10^6 cm^3/sec \text{ perm length of dam}$$

$$q = 500\ cm^3/sec \text{ per m lnegth of dam}$$

Q NO. 41.

The soil profile at a site consists of a 5 m thick sand layer underlain by a c-ϕ soil as shown in figure. The water table is found 1 m below the ground level. The entire soil mass is retained by a concrete retaining wall and is in the active state. The back of the wall is smooth and vertical. The total active earth pressure (expressed in kN/m^2) at point A as per Rankine's theory is _____



[Ans. *] Range: 69 to 70.5

In c- ϕ soil

Earth pressure $p_a = k_a\sigma_v - 2c\sqrt{k_a}$

$$k_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 24}{1+\sin 24 = 0.4217}$$

Note: Below water table, water pressure will not be multiplied by k_a at point A

$\sigma_y = 1\times\gamma_b + 4\gamma_{sat} + 3\gamma_{sat}$

$\sigma_y = 1\times\gamma_b + (4\times\gamma' + 4\times\gamma_w) + (3\gamma' + 3\gamma_w)$

$\sigma_y = (1\times\gamma_b + 4\gamma' + 3\gamma') + (4\gamma_w + 3\gamma_w)$

Earth Pressure at 'A'

$p_a = k_a\sigma_v - 2c\sqrt{k_a}$

$= k_a[\gamma_b + 4\gamma' + 3\gamma'] + 4\gamma_w + 3\gamma_w - 2\times c\sqrt{k_a}$

$= 0.4217[16.5 + 4(19-9.81) + 3(18.5-9.81)] + 7\times 9.81 - 2\times 25\times\sqrt{0.4217}$

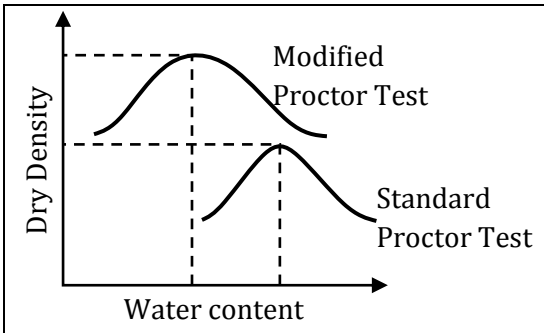
$p_a = 69.65\ \text{kN/m}^2$

Q NO. 42.

OMC-SP and MDD-SP denote the optimum moisture content and maximum dry density obtained from standard Proctor compaction test, respectively. OMC-MP and MDD-MP denote the optimum moisture content and maximum dry density obtained from the modified Proctor compaction test, respectively. Which one of the following is correct?

(A) OMC-SP < OMC-MP and MDD-SP < MDD-MP
(B) OMC-SP > OMC-MP and MDD-SP < MDD-MP
(C) OMC-SP < OMC-MP and MDD-SP > MDD-MP
(D) OMC-SP > OMC-MP and MDD-SP > MDD-MP

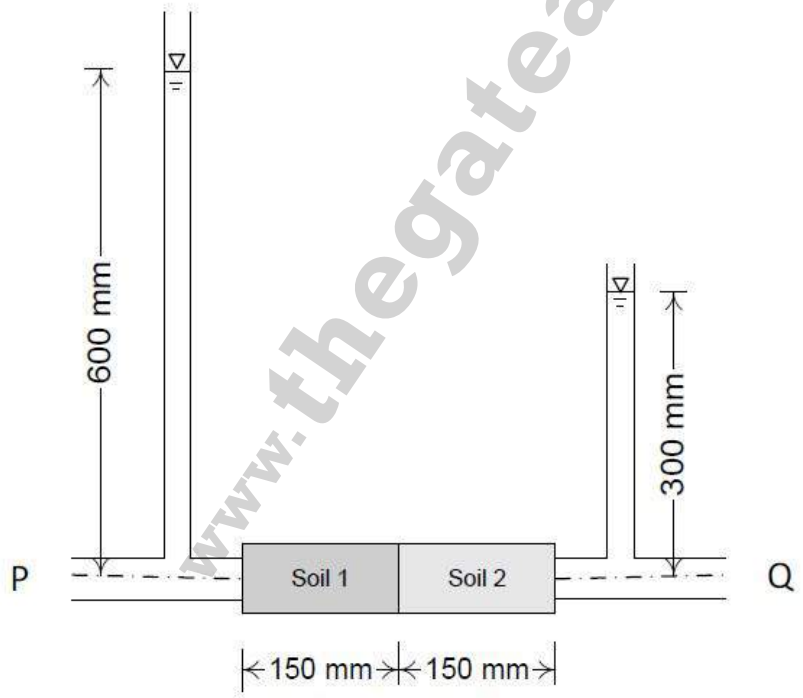
[Ans. B]



$\text{OMC} - \text{SP} > \text{OMC} - \text{MP}$
$\text{MDD} - \text{SP} < \text{MDD} - \text{MP}$

Q NO. 43.

Water flows from P to Q through two soil samples, Soil 1 and Soil 2, having cross sectional area of 80 cm^2 as shown in the figure. Over a period of 15 minutes, 200 ml of water was observed to pass through any cross section. The flow conditions can be assumed to be steady state. If the coefficient of permeability of Soil 1 is 0.02 mm/s, the coefficient of permeability of Soil 2 (expressed in mm/s) would be _____



[Ans. *] Range: 0.04 to 0.05

$$\text{Discharge} = \frac{200\text{ ml}}{15\text{ min}} = \frac{200\text{ cm}^3}{15 \times 60\text{ sec}} = \frac{200 \times 10^3}{900}\frac{\text{mm}^3}{\text{sec}}$$

As per Darcy $q = k_{avg}iA$

$$k_{avg} = \frac{\Sigma Z_i}{\Sigma \frac{Z_i}{k_i}} \quad [\because \text{ Flow is normal to bedding plane}]$$

$$k_{avg} = \frac{150 + 150}{\frac{150}{0.02} + \frac{150}{k}}$$

$$i = \frac{\text{Head difference}}{\text{length}} = \frac{600 - 300}{300} = 1$$

$$A = 80\ cm^2 = 80 \times 10^2\ mm^2$$

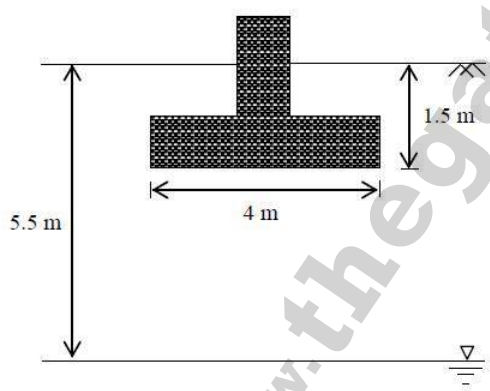
$$q = \left[\frac{150 + 150}{\frac{150}{0.02} + \frac{150}{k}}\right] \times 1 \times 80 \times 10^2 = \frac{200 \times 10^3}{900}$$

$$k = 0.045\ mm/sec$$

Q NO. 44.

A 4 m wide strip footing is founded at a depth of 1.5 m below the ground surface in a c-ϕ soil as shown in the figure. The water table is at a depth of 5.5 m below ground surface. The soil properties are: $c' = 35$ kN/m^2, $\phi' = 28.63°$, $\gamma_{sat} = 19$ kN/m^3, $\gamma_{bulk} = 17$ kN/m^3 and $\gamma_w = 9.81$ kN/m^3. The values of bearing capacity factors for different ϕ' are given below.

ϕ'	N_c	N_q	N_γ
15°	12.9	4.4	2.5
20°	17.7	7.4	5.0
25°	25.1	12.7	9.7
30°	37.2	22.5	19.7



Using Terzaghi's bearing capacity equation and a factor of safety $F_s = 2.5$, the net safe bearing capacity (expressed in kN/m^2) for local shear failure of the soil is _____

[Ans. *] Range: 298 to 299

Local shear failure is occurring hence modified c and ϕ should be used

$$c_m = \frac{2}{3}c = \frac{2}{3} \times 35 = 23.33\ kN/m^2$$

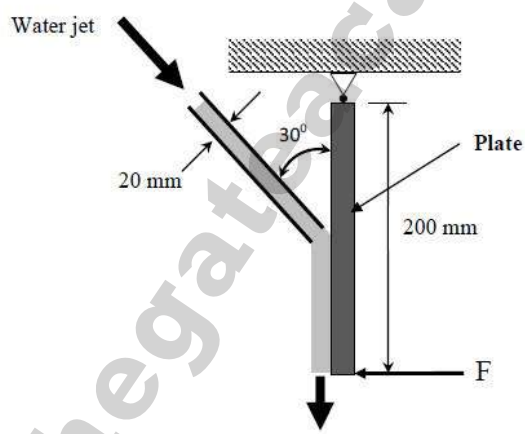
$$\tan\phi_m = \frac{2}{3}\tan\phi\frac{2}{3}\tan 28.63$$

$$\phi_m = 20°$$

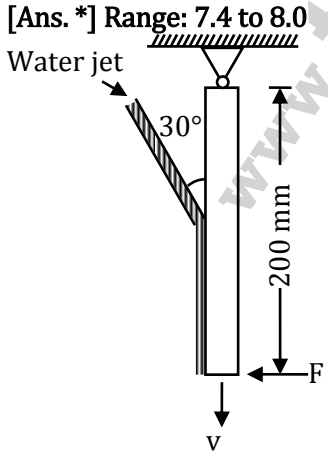
For $\phi_m = 20°, N_c = 17.7, N_q = 7.4, N_\gamma = 50$
$\Rightarrow$ Water table is at
$D_f + B = 1.5 + 4 = 5.5$ m hence no effect on bearing capacity
$\Rightarrow$ As per Terzaghi for strip footing
$q_u = cN_c + 8D_fN_q + 0.5\,B\gamma\,N_\gamma$
$q_u = \frac{2}{3} \times 35 \times 17.7 + 17 + 1.5 \times 7.4 + 0.5 \times 4 \times 17 \times 5$
$q_u = 771.7\,kN/m^2$
$q_{nu} = q_u - \gamma D_f = 771.7 - 17 \times 1.5$
$q_{nu} = 746.2\ kN/m^2$
Net safe bearing capacity
$q_{ns} = \frac{q_{nu}}{F} = \frac{746.2}{2.5} = 298.48\ kN/m^2$

Q NO. 45.

A square plate is suspended vertically from one of its edges using a hinge support as shown in figure. A water jet of 20 mm diameter having a velocity of 10 m/s strikes the plate at its mid-point, at an angle of 30° with the vertical. Consider g as 9.81 m/s^2 and neglect the self-weight of the plate. The force F (expressed in N) required to keep the plate in its vertical position is _____



[Ans. *] Range: 7.4 to 8.0



Force exerted by jet in x-direction

$F_x = \dot{m}[v\sin\theta - 0]$
$= \rho \times q \times v\sin\theta$
$= (10^3)\left|\frac{\pi}{4}(0.02)^2 \times 10\right| 10\sin 30°$
$= 15.7079$ N
Taking moment about hinge
$F_x \times \frac{0.2}{2} = F \times 0.2$
$F = 7.85$ N

Q NO. 46.

The ordinates of a one-hour unit hydrograph at sixty minute interval are 0, 3, 12, 8, 6, 3 and 0 m^3/s. A two-hour storm of 4 cm excess rainfall occurred in the basin from 10 AM. Considering constant base flow of 20 m^3/s, the flow of the river (expressed in m^3/s) at 1 PM is _____

[Ans. *] Range: 59 to 61

Time (1)	Ordinate of 1 hr UH (m^3/s) (2)	Offset ordinate (m^3/s) (3)	Ordinate of 2 hr DRH (m^3/s) (4) = (2) +(3)	Ordinate of DRH of 4 cm rainfall excess (m^3/s) (5) $= (4) \times 4/2$	Ordinate of flood hydrograph (m^3/s) $(6) = (5) + 20$
10:00 am	0	-	0	0	20
11:00 am	3	0	3	6	26
12:00 pm	12	3	15	30	50
01:00 pm	8	12	20	40	60
2:00 pm	6	8	14	28	48
3:00 pm	3	6	9	18	38
5:00 pm	0	3	3	6	26
			0	0	20

Ordinate of 01:00 pm = 60 m^3/s

Q NO. 47.

A 3 m wide rectangular channel carries a flow of 6 m^3/s. The depth of flow at a section P is 0.5 m. A flat-topped hump is to be placed at the downstream of the section P. Assume negligible energy loss between section P and hump, and consider g as 9.81 m/s^2. The maximum height of the hump (expressed in m) which will not change the depth of flow at section P is _____

[Ans. *] Range: 0.19 to 0.21

The maximum jump (ΔZ) that can be provided is given by

$$y + \frac{Q^2}{2gA^2} = \Delta Z_{jump} + \frac{3}{2}y_c$$

Here, $A = 3 \times 0.5 = 1.5\ m^2$

$$y_c = \left(\frac{Q^2}{gB^2}\right)^{1/3} = \left(\frac{6^2}{9.81 \times 3^2}\right)^{1/3} = 0.7415\ m$$

$$\Rightarrow 0.5 + \frac{6^2}{2 \times 9.81 \times 1.5^2} = \Delta Z_{jump} + \frac{3}{2} \times 0.7415$$
$$\Rightarrow \Delta Z_{jump} = 0.20 \text{ m}$$

Q NO. 48.

A penstock of 1 m diameter and 5 km length is used to supply water from a reservoir to an impulse turbine. A nozzle of 15 cm diameter is fixed at the end of the penstock. The elevation difference between the turbine and water level in the reservoir is 500 m. Consider the head loss due to friction as 5% of the velocity head available at the jet. Assume unit weight of water = 10 kN/m^3 and acceleration due to gravity (g) = 10 m/s^2. If the overall efficiency is 80%, power generated (expressed in kW and rounded to nearest integer) is _____

[Ans. *] Range: 6565 to 6580

Apply energy equation at the free surface of reservoir and exit of nozzle

$$500 = \text{Head loss} + \frac{v_1^2}{2g}$$
$$500 = 0.05\frac{v_1^2}{2g} + \frac{v_1^2}{2g}$$
$$\sqrt{\frac{2 \times 10 \times 500}{1.05}} = v_1$$
$$V_1 = 97.59 \text{ m/sec}$$
$$\text{Water Power (W.P)} = \frac{1}{2}\dot{m}v_1^2$$
$$= \frac{1}{2}(10^3) \times \frac{\pi}{4}(0.15)^2(97.59) = 8212.178 \text{ kW}$$
$$\text{Now, } \eta_0 = \frac{\text{Shaft Power(S.P)}}{\text{W.P}}$$
$$0.8 = \frac{\text{Shaft Power(S.P)}}{8212.178}$$
$$\text{S.P} = 6569.74 \text{ kW}$$
$$\cong 6570 \text{ kW}$$

Q NO. 49.

A tracer takes 100 days to travel from Well-1 to Well-2 which are 100 m apart. The elevation of water surface in Well-2 is 3 m below that in Well-1. Assuming porosity equal to 15%, the coefficient of permeability (expressed in m/day) is

(A) 0.30 (B) 0.45 (C) 1.00 (D) 5.00

[Ans. D]

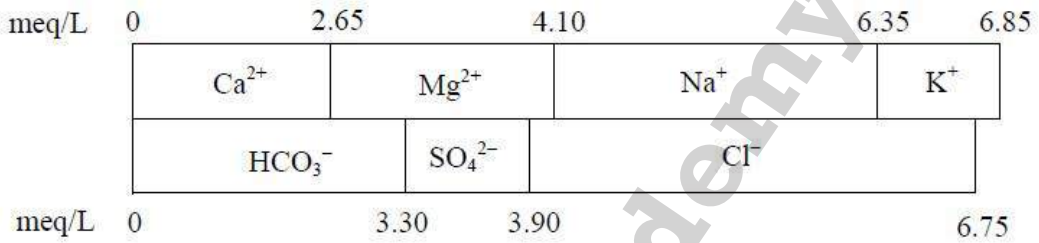
Seepage velocity

$$V_s = \frac{v}{n} = \frac{\text{distance}}{\text{time}}$$
As per Darcy, $v = ki$
$$\frac{ki}{n} = \frac{100 \text{ m}}{100 \text{ days}}$$

$$i = \frac{\text{head difference}}{\text{length}} = \frac{3}{100}$$
$$\frac{k \times 3}{0.15 \times 100} = \frac{100}{100} \text{m/day}$$
$$k = 5 \text{ m/day}$$

Q NO. 50.

A sample of water has been analyzed for common ions and results are presented in the form of a bar diagram as shown.



The non-carbonate hardness (expressed in mg/L as $CaCO_3$) of the sample is

(A) 40 (B) 165 (C) 195 (D) 205

[Ans. A]

$Ca^{2+} = 2.65 \text{ meq/l}, Mg^{2+} = 1.45 \text{ meq/l}$
$Na^{+} = 2.25 \text{ meq/l}, K^{+} = 0.5 \text{ meq/l}$
$HCO_3^{-} = 3.3 \text{ meq/l}, SO_4^{2-} = 0.6 \text{ meq/l}$
$Cl^{-} = 2.85 \text{ meq/l}$
Hardness is due to multivalent metallic cations, i.e. Ca^{2+} and M_g^{2+}

$$\text{Total hardness } \left(\frac{\text{mg}}{\text{l}} \text{ as } CaCO_3\right) = (\text{Total meq/l}) \times (\text{eq. weight of } CaCO_3 \text{ in mg})$$
$$= (2.65 + 1.45) \times 50 \text{ mg/l as } CaCO_3$$
$$= 205 \text{ mg/l as } CaCO_3$$

Alkalinity is due to the presence of HCO_3^{-} in this case

$$\text{Alkalinity (mg/l as } CaCO_3) = 3.3 \times 50 \text{ mg/l as } CaCO_3$$
$$= 165 \text{ mg/l as } CaCO_3$$

Now, Carbonate Hardness = Min {Total Hardness, Alkalinity}
= 165 mg/l

Non- carbonate hardness = Total hardness – carbonate hardness
$= 205 - 165 = 40 \text{ mg/l as } CaCO_3$

Q NO. 51.

A noise meter located at a distance of 30 m from a point source recorded 74 dB. The reading at a distance of 60 m from the point source would be _____

[Ans. *] Range: 67 to 69

$L_2 = L_1 - \left|20\log\left(\frac{R_2}{R_1}\right)\right|$
$= 74 - 20\log 0.5$
$= 67.98\ \text{dB}$

Q NO. 52.

For a wastewater sample, the three-day biochemical oxygen demand at incubation temperature of 20°C ($BOD_{3day,\ 20°C}$) is estimated as 200 mg/L. Taking the value of the first order BOD reaction rate constant as 0.22 day^{-1}, the five-day BOD (expressed in mg/L) of the wastewater at incubation temperature of 20°C ($BOD_{5day,\ 20°c}$) would be _____

[Ans. *] Range: 275 to 277

$BOD_5 = L_0(1 - e^{-0.22\times5})$
$BOD_3 = L_0(1 - e^{-0.22\times3})$
From equation ① and ②, we get
$\frac{BOD_5}{BOD_3} = \frac{(1 - e^{-0.22\times5})}{(1 - e^{-0.22\times3})}$
$BOD_5 = 200 \times \frac{0.667}{0.483}$
$= 200 \times 1.38 = 276.19\ \text{mg/l}$

Q NO. 53.

The critical flow ratios for a three-phase signal are found to be 0.30, 0.25, and 0.25. The total time lost in the cycle is 10 s. Pedestrian crossings at this junction are not significant. The respective Green times (expressed in seconds and rounded off to the nearest integer) for the three phases are

(A) 34, 28, and 28 (B) 40, 25, and 25 (C) 40, 30, and 30 (D) 50, 25, and 25

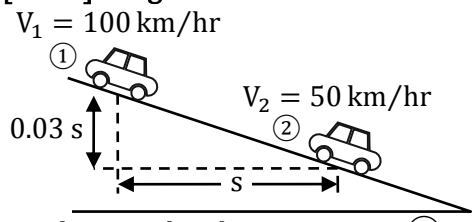
[Ans. A]

$Y = y_1 + y_2 + y_3 = 0.30 + 0.25 + 0.25 = 0.80$
New total lost time, $L = 10$ sec (given)
∴Optimum cycle time,
$C_0 = \frac{1.5\,L + 5}{1 - Y}$
$\Rightarrow C_0 = \frac{(1.5 \times 10) + 5}{1 - 0.80} = \frac{15 + 5}{0.20} = \frac{20}{20} = 100\ \text{sec}$
Now green times are calculated by,
$G_1 = \frac{y_1}{y_2}(C_0 - L) = \frac{0.30}{0.80}(100 - 10) = 33.75 \cong 34\ \text{sec}$
$G_2 = \frac{y_2}{y}(C_0 - L) = \frac{0.25}{0.80}(100 - 10) = 28.11 \cong 28\ \text{sec}$
$G_3 = \frac{y_3}{y}(C_0 - L) = \frac{0.25}{0.80}(100 - 10) = 28.11 \cong 28\ \text{sec}$

Q NO. 54.

A motorist traveling at 100 km/h on a highway needs to take the next exit, which has a speed limit of 50 km/h. The section of the roadway before the ramp entry has a downgrade of 3% and coefficient of friction (f) is 0.35. In order to enter the ramp at the maximum allowable speed limit, the braking distance (expressed in m) from the exit ramp is _____

[Ans. *] Range: 92 to 93



Total energy lost between point ① and ② = Work done by frictional force

$$\frac{1}{2}mv_1^2 - \frac{1}{2}mv_2^2 + mg \times 0.03s = f \times (mg) \times s$$

$$\frac{(0.278 \times 100)^2}{2} - \frac{(0.278 \times 50)^2}{2} + 9.81 \times 0.03 \times s = 0.35 \times 9.81 \times s$$

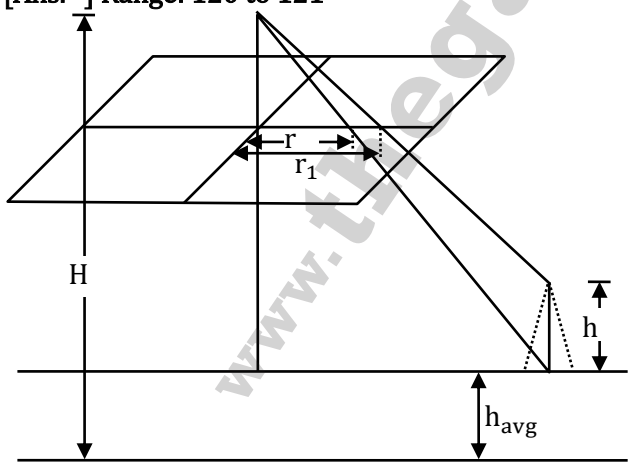
$$289.815 = 3.1392\ s$$

$$\Rightarrow s = 92.32\ m$$

Q NO. 55.

A tall tower was photographed from an elevation of 700 m above the datum. The radial distances of the top and bottom of the tower from the principal points are 112.50 mm and 82.40 mm, respectively. If the bottom of the tower is at an elevation 250 m above the datum, then the height (expressed in m) of the tower is _____

[Ans. *] Range: 120 to 121



Given, $H = 700$ m, $h_{avg} = 250$

Relief distance, $d = r_1 - r = 112.5 - 82.40 = 30.1$ mm

$$\therefore d = \frac{hr_1}{H - h_{avg}} \qquad \text{[Where h is height of tower]}$$

$$\Rightarrow 30.1 = \frac{h \times 112.5}{700 - 250}$$

$\therefore h = 120.4$ mm