GATE WALLAH

CIVIL ENGINEERING

EXAM HELD ON

4th FEBRUARY 2024

MORNING SESSION

DETAILED SOLUTION BY TEAM

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Civil Engineering

[MCQ]

Q.1. In the 4 × 4 array shown below, each cell of the first three columns has either a cross (X) or a number, as per the given rule.

1	1	2	
2	X	3	
2	X	4	
1	2	X	

Rule: The number in a cell represents the count of crosses around its immediate neighbouring

As per this rule, the **maximum** number of crosses possible in the empty column is

(a) 1 (b) 0

(c) 3 (d) 2

Sol. **(d)**

[MCQ]

Q.2. On a given day, how many times will the second-hand and the minute-hand of a clock cross each other during the clock time 12.05:00 hours to 12.55.00 hours?

(a) 51 (b) 49

(c) 50 (d) 55

Sol. **(c)**

[MCQ]

Q.3. For positive integers p and q, with $\frac{p}{q} \neq 1$, $\left(\frac{p}{q}\right)^{\frac{p}{q}} = p^{\left(\frac{p}{q}-1\right)}$. Then,

(a) $q^p = p^{2q}$ (b) $q^p = p^q$

(c) $\sqrt[p]{q} = \sqrt[q]{p}$ (d) $\sqrt{q} = \sqrt{p}$

Sol. **(b)**

$$\frac{(p)^{p/q}}{(q)^{p/q}} = p^{(p/q)}P^{-1}$$

$$p = (q)^{p/q}$$

$$p^q = q^p$$

[MCQ]

Q.4. In a locality, the houses are numbered in the following way:

The house-numbers on one side of a road are consecutive odd integers starting from 301. while the house-numbers on the other side of the road are consecutive even numbers starting from 302. The total number of houses is the same on both sides of the road.

If the difference of the sum of the house-numbers between the two sides of the road is 27. then the number of houses on each side of the road is

(a) 27 (b) 54

(c) 26 (d) 52

Civil Engineering

Sol. **(a)**

$S_1 = 302 + 304 + 306 \ldots\ldots + n$

$$Sn_1 = \frac{n}{2}\left[2a + (n-1)d\right]$$

$$= \frac{n}{2}\left[2\times 302 + (n-1)\times 2\right]$$

$S_2 = 301 + 303 + 305 \ldots\ldots + n$

$$Sn_2 = \frac{n}{2}\left[2a + (n-1)d\right]$$

$$= \frac{n}{2}\left[2\times 301 + (n-1)\times 2\right]$$

$Sn_1 = Sn_2 = 27$

$$\frac{n}{2}\left[2\times 302 + (n-1)\times 2\right] - \frac{n}{2}\left[2\times 301 + (n-1)\times 2\right] = 27$$

$$n = 27$$

[NAT]

Q.5. If '→' denotes increasing order of intensity, then the meaning of the words [simmer → seethe → smolder] is analogous to [break → raze → _____]. Which one of the given options is appropriate to fill the blank?

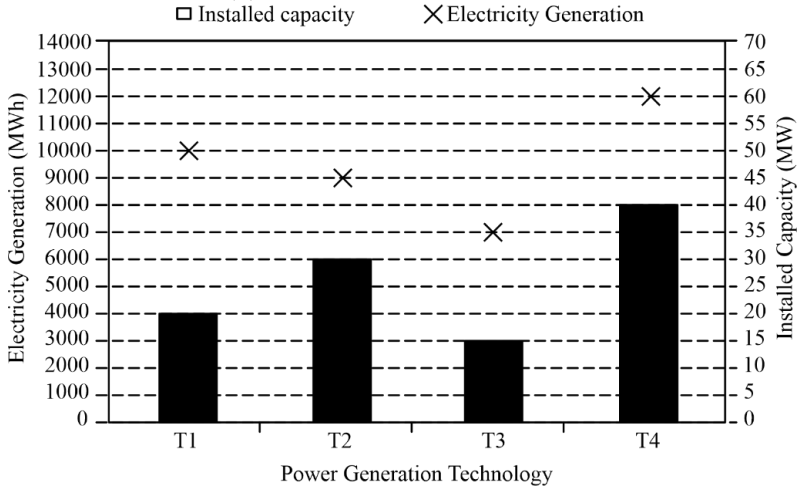
(a) obfuscate (b) fracture

(c) fissure (d) obliterate

Sol. **(d)**

[MCQ]

Q.6. The chart given below compares, the Installed Capacity' (MW) of four power generation technologies. T1. T2. T3. and T4. and their Electricity Generation (MWh) in a time of 1000 hours (h).



The Capacity Factor of a power generation technology is:

$$\text{Capacity Factor} = \frac{\text{Electricity Generation (MWh)}}{\text{Installed Capacity (MW)} \times 100(\text{h})}$$

(a) T3 (b) T4

(c) T2 (d) T1

Sol. **(d)**

For T_1, Capacity Factor $= \dfrac{10,000}{20 \times 100} = 5$

For T_2, Capacity Factor $= \dfrac{9,000}{30 \times 100} = 3$

For T_3, Capacity Factor $= \dfrac{7,000}{15 \times 100} = 4.67$

For T_4, Capacity Factor $= \dfrac{12,000}{40 \times 100} = 3$

$\therefore$ Technology T_1 has highest capacity factor

[MCQ]

Q.7. During a half-moon phase, tire Earth-Moon-Sun form a right triangle. If the Moon-Earth-Sun angle at this half-moon phase is measured to be S9.S50. the ratio of the Earth-Sun and Earth-Moon distances is closest to

(a) 283 (b) 238
(c) 382 (d) 328

Sol. **(c)**

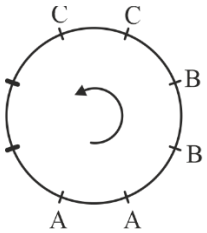
[MCQ]

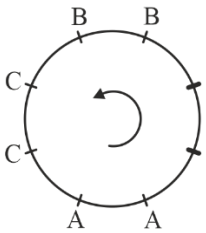
Q.8. Three distinct sets of indistinguishable twins are to be seared at a circular table that has S identical chairs. Unique seating arrangements are defined by the relative positions of the people.
How many unique seating arrangements are possible such that each person is sitting next to then twin?

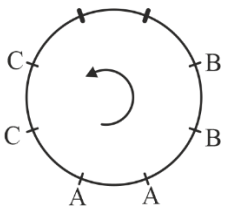
(a) 10 (b) 14
(c) 12 (d) 28

Sol. **(c)**

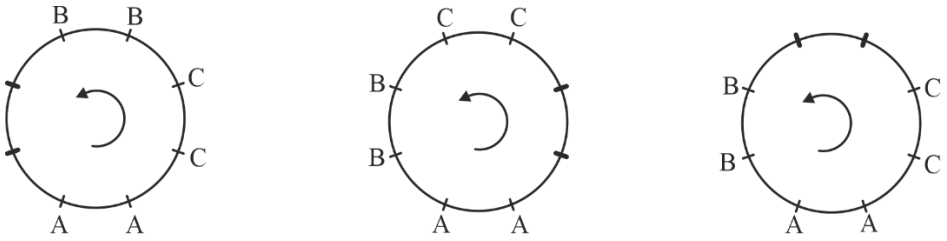
Case 1 (ABC in order) $\rightarrow$ 3 possibilities



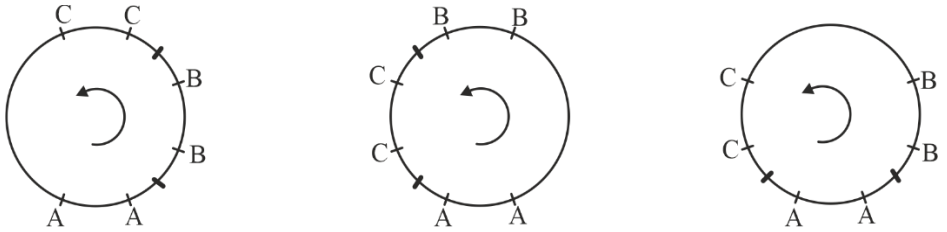




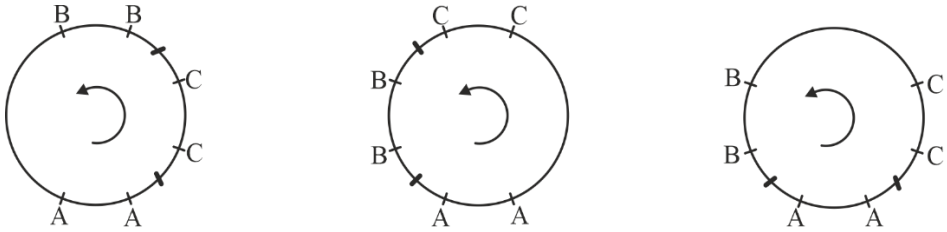
Case 2 (ACB in order) $\rightarrow$ 3 possibilities



Case 3 (ABC in order) → 3 possibilities



Case 4 (ACB in order) → 3 possibilities

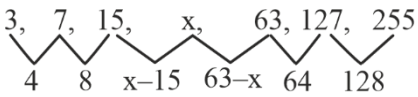


[MCQ]

Q.9. Which one of the given options is a possible value of x in the following sequence?
3, 7, 15, x, 63, 127, 255

(a) 35 (b) 31
(c) 40 (d) 45

Sol. **(b)**



$x - 15 = 16$
$x = 31$

[MCQ]

Q.10. In the given text, the blanks are numbered (i) – (iv). Select the best match for all the blanks.
From the ancient Athenian arena to the modem Olympic stadiums, athletics (i) the potential for a spectacle. The crowd (ii) with bated breath as the Olympian artist twists Ins body, stretching the javelin behind him. Twelve strides in. he begins to cross-step. Six cross-steps (iii) in an abrupt stop on his left foot. As his body (iv) like a door turning on a hinge, the javelin is launched skyward at a precise angle.

(a) (i) holds (ii) wait (iii) culminates (iv) pivot

(b) (i) holds (ii) waits (iii) culminate (iv) pivots
(c) (i) hold (ii) waits (iii) culminates (iv) pivot
(d) (i) hold (ii) wait (iii) culminates (iv) pivot

Sol. **(b)**

[MCQ]

Q.1. The three-dimensional state of stress at a point is given by

$$\sigma\begin{pmatrix}10 & 0 & 0\\ 0 & 40 & 0\\ 0 & 0 & 0\end{pmatrix}\text{MPa.}$$

The maximum shear stress at the point is

(a) 15 MPa
(b) 5 MPa
(c) 25 MPa
(d) 20 MPa

Sol. **(d)**

Stress matrix, $\sigma = \begin{bmatrix}\sigma_x & \tau_{xy} & \tau_{xz}\\ \tau_{yx} & \sigma_y & \tau_{yz}\\ \tau_{zx} & \tau_{zy} & \sigma_z\end{bmatrix}$

Given,

$$\sigma = \begin{bmatrix}10 & 0 & 0\\ 0 & 40 & 0\\ 0 & 0 & 0\end{bmatrix}\text{MPa}$$

Comparing it with standard stress matrix, we have $\sigma_x = 10$ MPa; $\sigma_y = 40$ MPa, $\sigma_z = 0$ MPa

Therefore τ_{max} = maximum of $\left[\left|\frac{\sigma_x-\sigma_y}{2}\right|,\left|\frac{\sigma_y-\sigma_z}{2}\right|,\left|\frac{\sigma_z-\sigma_x}{2}\right|\right]$

= maximum of $\left[\left|\frac{10-40}{2}\right|,\left|\frac{40}{2}\right|,\left|\frac{0-10}{2}\right|\right] = 20$ MPa

Civil Engineering

[MSQ]

Q.2. Consider a balanced doubly-reinforced concrete section. If the material and other sectional properties remain unchanged, for which of the following cases will the section becomes under-reinforced?

(a) Area of compression reinforcement is decreased.
(b) Area of compression reinforcement is increased.
(c) Area of tension reinforcement is increased.
(d) Area of tension reinforcement is decreased.

Sol. **(b, d)**

From the relation:

$0.36\, f_{ck}\, x_u\, b + (f_{sc} - 0.45\, f_{ck})\, A_{sc} = 0.87\, f_y\, A_{st}$

$$x_u = \frac{0.87\, f_y A_{st} - (f_{sc} - 0.45\, f_{ck})\, A_{sc}}{0.36\, f_{ck} b}$$

[MCQ]

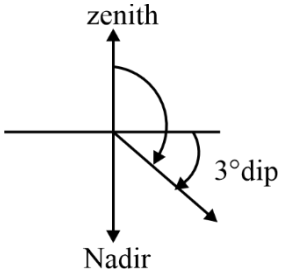
Q.3. A surveyor observes a zenith angle of 93° 00' 00° during a theodolite survey. The corresponding vertical angle is

(a) - 87° 00' 00"
(b) – 03° 00' 00"
(c) + 87° 00' 00"
(d) + 03° 00' 00"

Sol. **(b)**

Zenith ∠ = 93°0'0"

Vertical ∠ = _____



[MCQ]

Q.4. The probability that a student passes only in Mathematics is 1/3. The probability that the student passes only in English is 4/9. The probability that the student passes in both of these subjects is 1/6. The probability that the student will pass in at least one of these two subjects.

(a) $\frac{1}{18}$
(b) $\frac{11}{18}$
(c) $\frac{17}{18}$
(d) $\frac{14}{18}$

Sol. **(c)**

$P(M) = \frac{1}{3}, P(E) = \frac{4}{9}$

$= P(M \cap E)\frac{1}{6}$

Probability of not passing in any subject

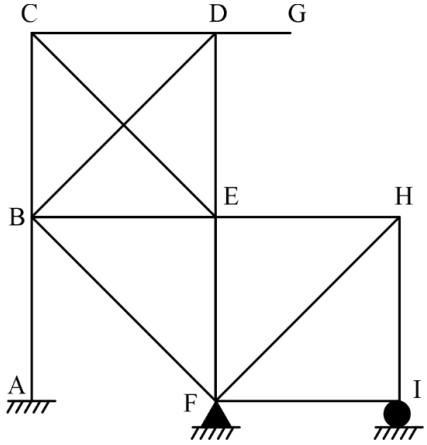
$$= 1P(M)+P(E)+P(M\cap E)$$

$$=\left(\frac{1}{3}+\frac{4}{9}+\frac{1}{6}\right)$$

$$=\frac{17}{18}$$

[NAT]

Q.5. The plane frame shown in the figure has fixed support at joint A. hinge support at joint F. and roller support at joint I. hi the figure, A to I indicate joints of the frame.



If the axial deformations are neglected, the degree of kinematic indeterminacy is (in integer').

Sol. **(9)**

A is fixed joint. So Dk = 0

A(fixed) = 0

B = θ_B

C = θ_C

D = θ_D

E = θ_E

F = θ_F

G = θ_G, Δ_{yG}

H = θ_H

J = θ_J

Total = 9

[MSQ]

Q.6. For the following partial differential equation.

$$x\frac{\partial^2 f}{\partial x^2} + y\frac{\partial^2 f}{\partial y^2} = \frac{x^2 + y^2}{2}$$

which of the following option(s) is/are CORRECT?

(a) parabolic for x > 0 and v > 0

(b) elliptic for x = 0 and v > 0

(c) elliptic for x > 0 and v > 0

(d) hyperbolic for x < 0 and y > 0

Sol. **(c, d)**

S = 0, R = x, T = y

$S^2 - 4RT$

$0^2 - 4xy = -4xy$

Option (A):

If x > 0, y > 0

– 4xy < 0, elliptic (wrong)

B. – 4xy = 0 parabolic

C. – 4xy < 0, for x > 0, y > 0 elliptic

D. – 4xy > 0, for x < 0, y > 0 hyperbolic

[NAT]

Q.7. An embankment is constructed with soil by maintaining the degree of saturation as 75% during compaction. The specific gravity of soil is 2.68 and the moisture content is 17% during compaction. Consider the unit weight of water as 10 kN/m^3. The dry unit weight (in kN/m^3) of the compacted soil is (rounded off to 2 decimal places).

Sol. **(16.67)**

S.e = w.G

$$\text{or } e = \frac{w.G}{S} = \frac{0.17 \times 2.68}{0.75} = 0.6075$$

$$\gamma_d = \frac{G.\,r_w}{1+e} = \frac{2.68 \times 10}{1 + 0.6075}$$

= 16.67 kN/m^3

[MCQ]

Q.8. Among the following statements relating the fundamental lines of a transit theodolite, which one is CORRECT?

(a) The axis of altitude level must be perpendicular to the line of collimation.
(b) The line of collimation must be perpendicular to the horizontal axis at its intersection with the vertical axis.
(c) The Vernier of vertical circle must read zero when the line of collimation is vertical.
(d) The axis of plate level must lie in a plane parallel to the vertical axis.

Sol. **(b)**

Altitude level: it is a straight line tangential to longitudinal curve of level tube at its center.

Plate level axis: its is perpendicular to vertical axis when the bubble is at center.

Asis of plate level must be perpendicular to vertical axis.

The vertical circle vernier must read zero when the line of collimation is horizontal.

[MCQ]

Q.9. Consider the statements P and Q.

P: Client's Preliminary Estimate is used for budgeting costs toward the end of planning and design phase.
Q: Client's Detailed Estimate is used for controlling costs during the execution of the project.

Which one of the following options is CORRECT?

(a) P is FALSE and Q is TRUE
(b) Both P and Q are FALSE
(c) P is TRUE and Q is FALSE
(d) Both P and Q are TRUE

Sol. **(d)**

Estimate type	**Used for**
Project proposal indicative cost estimate	Feasibility stage
Preliminary estimate	Budgeting cost towards the end of planning and design phase
Detailed estimate	Controlling costs during the execution of project
Definitive estimate	To assess cost of completion
Final closure cost estimate	Final cost determination

[MCQ]

Q.10. Which one of the following statements related to bitumen is FALSE'

(a) Softer grade bitumen possesses higher softening point than hard grade bitumen.

(b) Flash point of bitumen is the lowest temperature at which application of a test flame causes vapours of the bitumen to catch an instant fire in the form of flash under specified test conditions.

(c) Ductility test is earned out on bitumen to test its adhesive property and ability' to stretch.

(d) Kinematic viscosity is a measure of resistance to the flow of molten bitumen under gravity.

Sol. **(a)**

Softer grade means higher penetration and as penetration is higher, softening point is less.

So correct statement is softer grade bitumen possess LOWER softening point than hard grade bitumen.

Other statements are correct

Viscosity is resistance to flow

Ductility is adhesive property test and ability to deform (stretch)

[MCQ]

Q.11. As per the International Civil Aviation Organization (ICAO), the basic runway length is increased by x (%) for every v (m) raise in elevation from the Mean Sea Level (MSL). The values of x and v. respectively, are

(a) 10% and 1000 m (b) 5% and 200 m

(c) 4% and 500 m (d) 7% and 300 m

Sol. **(d)**

As per the International Civil Aviation Organization (ICAO), the basic runway length is increased by 7 (%) for every 300 (m) raise in elevation from the Mean Sea Level (MSL).

[MSQ]

Q.12. The primary air pollutant(s) is/are

(a) Lead (b) Sulphuric acid

(c) Ozone (d) Sulphur dioxide

Sol. **(a, d)**

Primary pollutants

(i) Carbon oxides

(ii) Nitrogen oxides

(iii) Sulphur oxides

(iv) particulates

(v) Lead

(vi) VOC

[MCQ]

Q.13. A 2 m wide strip footing is founded at a depth of 1.5 m below the ground level in a homogeneous pure clay bed. The clay bed has unit cohesion of 40 kPa. Due to seasonal fluctuations of water table from peak summer to peak monsoon period, the net ultimate bearing capacity of the footing, as per Terzaghi's theory, will

(a) Decrease
(b) Remain the same
(c) Become zero
(d) Increase

Sol. **(b)**

$$q_u = CN_c + \gamma D_f N_q + 0.5B\gamma N_\gamma$$

$q_u = 5.7C + \gamma D_f$

$q_{nu} = 5.7C$

Due to water table fluctuation, $q_{nu} = 5.7C'$

$C = C'$

Thus, in pure clay case, the net ultimate bearing capacity of the footing as per Terzaghi's theory will remain the same.

[MSQ]

Q.14. The elements that DO NOT increase the strength of structural steel are

(a) Sulphur
(b) Carbon
(c) Chlorine
(d) Manganese

Sol. **(a, c)**

Manganese and Carbon increases the strength of structural steel.

[MCQ]

Q.15. Consider the statements P and Q.

P : Soil particles formed by mechanical weathering, and close to their origin are generally subrounded.

Q : Activity of the clay physically signifies its swell potential.

Which one of the following options is CORRECT?

(a) P is FALSE and Q is TRUE
(b) Both P and Q are FALSE
(c) Both P and Q are TRUE
(d) P is TRUE and Q is FALSE

Sol. **(a)**

P is false because it is residual soil which is more angular
Q is true activity of the clay physically signifies its swell potential.

[MCQ]

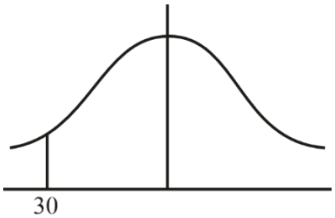
Q.16. Concrete of characteristic strength 30 MPa is required. If 40 specimens of concrete cubes are to be tested, the minimum number of specimens having at least 30 MPa strength should be

(a) 37
(b) 39
(c) 38
(d) 35

Sol. **(c)**

$f_{ck} = 30$ MPa
$n = 40$ specimens

→ How many specimens are the at least having strength of 30 MPa?



$f \geq f_{ck} \Rightarrow$
95%
$\Rightarrow$ 95% of 40
= 38 Specimens

[MCQ]

Q.17. The smallest positive root of the equation
$x^5 - 5x^4 - 10x^3 + 50x^2 + 9x - 45 = 0$
lies in the range

(a) $10 \leq x \leq 100$ (b) $6 < x \leq 8$
(c) $2 < x \leq 4$ (d) $0 < x \leq 2$

Sol. **(d)**

Smallest positive root of

$x^5 - 5x^4 - 10x^3 + 50x^2 + 9x - 45 = 0 \quad \rightarrow \quad a < x < b$

$f(a) \cdot f(b) < 0$

$f(0) < 0$

$f(2) = 32 - 80 - 80 + 200 + 18$

$= 45 > 0$

$\therefore$ Smallest root in $0 < x \leq 2$

[MCQ]

Q.18. If the number of sides resulting in a closed traverse is increased from three to four, the sum of the interior angles increases by

(a) 90° (b) 360°
(c) 180° (d) 270°

Sol. **(c)**

Sum of interior angles = $(2n - 4) \times 90$

For 3 sides → Sum of interior angle = $(2 \times 3 - 4) \times 90 = 180°$

For 4 sides → Sum of interior angle = $(2 \times 4 - 4) \times 90 = 360°$

$\therefore$ Change in interior angle = $360° - 180°$

$= 180°$

[NAT]

Q.19. Consider the data of f(x) given in the table.

i	0	1	2
xi	1	2	3
f(xi)	0	0.3010	0.4771

The value of (1.5) estimated using second-order Newton's interpolation formula is {rounded off to 2 decimal places).

Sol. **(0.17)**

i	0	1	2
x_i	1	2	3
$f(x_i)$	0	0.3010	0.4771

Newton's 2nd order Interpolation f (1.5) = ?

$$f(x)=f(x_1)+\frac{f(x_2)-f(x_1)}{x_2-x_1}(x-x_1)$$

$$\frac{f(x_3)-f(x_2)}{x_3-x_2}-\frac{f(x_2)-f(x_1)}{x_3-x_1}\times(x-x_1)(x-x_2)$$

$$f(1.5)=0.3010(0.5)+\frac{0.4771-2(0.3010)}{2}\times(0.5)(-0.5)$$

$$\Rightarrow f(1.5)=0.166\approx 0.17$$

[MCQ]

Q.20. The second-order differential equation in an unknown function u:u (x, y) is defined as

$$\frac{\partial^2 u}{\partial x^2}=2$$

Assuming g:g(x), f:f(y), and h:h(y), the general solution of the above differential equation is

(a) $u = x^2 + f(y) + y\,g(x)$ (b) $u = x^2 + x\,f(y) = g(x)$

(c) $u = x^2 + f(y) + g(x)$ (d) $u = x^2 + x\,f(y) + h(y)$

Sol. **(d)**

$$\int\frac{\partial^2 u}{\partial x^2}=2$$

$$\frac{\partial u}{\partial x}=2\int 1dx+f(y)$$

$$\frac{\partial u}{\partial x}=2x+f(y)$$

$$u = x^2 + xf(y) + h(y)$$

[MCQ]

Q.21. The number of degrees of freedom for a natural open channel flow with a mobile bed is

(a) 2 (b) 4
(c) 3 (d) 5

Sol. **(b)**

For Rigid Boundary Channel, D.O.F = 1
For Mobile Boundary Channel, D.O.F = 4
(Bed width, Bed Slope, Depth and Layout can be independently changed)

[MCQ]

Q.22. The following (able gives various components of Municipal Solid Waste (MSW) and a list of treatment, separation techniques.

Component of MSW	Treatment/separation technique
P - Ferrous metals	i - Incineration
Q - Aluminum and copper	ii - Rapid composting
R - Food waste	iii - Eddy current separator
S – Cardboard]	iv - Magnetic separator

The CORRECT match is

(a) P-iv. Q-iii. R-i. S-ii (b) P-iv. Q-iii. R-ii. S-i
(c) P-iii. Q-iv. R-ii. S-i (d) P-iii. Q-iv. R-i. S-ii

Sol. **(b)**

Ferrous metal: Magnetic separator

Aluminium powdes: Eddy current separator

Food waste: Rapid compositing

Cardboard: Incineration

[NAT]

Q.23. A 30 cm diameter well fully penetrates an unconfined aquifer of saturated thickness 20 m with hydraulic conductivity of 10 m/day. Under the steady pumping rare for a long time, the drawdowns in two observation wells located at 10 m and 100 m from the pumping well are 5 m and 1 m. respectively. The corresponding pumping rate (in m^3/day) from the well is _____ (rounded off to 2 decimal places).

Sol. **(1855.217)**

$$Q = \frac{\pi K\left(h_2^2 - h_1^2\right)}{2.303\log_{10}\left(\frac{r_2}{r_1}\right)} = \frac{\pi \times 10\left(19^2 - 15^2\right)}{2.303\log_{10}\left(\frac{100}{10}\right)}$$

$\therefore$ Q = 1855.217 m^3/day

[MCQ]

Q.24. A car is Travelling at a speed of 60 km/hr on a section of a National Highway having a downward gradient of 2%. The driver of the cat suddenly observes a stopped vehicle on the car path at a distance 130 m ahead, and applies brake. If the brake efficiency is 60%. coefficient of friction is 0.7. driver's reaction time is 2.5 s. and acceleration due to gravity is 9.81 m/s^2. the distance (in meters) required by the driver to bring the car to a safe stop lies in the range

(a) 33 to 37 (b) 41 to 45
(c) 126 to 130 (d) 75 to 79

Sol. **(d)**

$f = 0.6 \times 0.7 = 0.42$

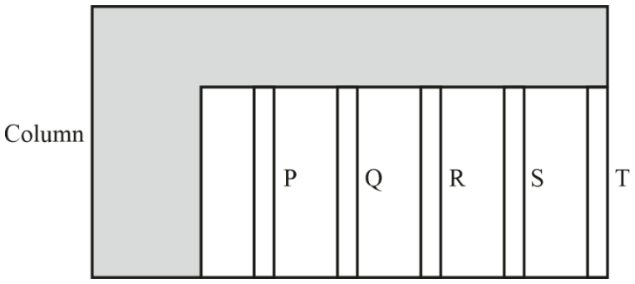
$$\text{SSD} = 0.278\ V.\ t_R + \frac{V^2}{254(f - s\%)}$$

$$= 0.278 \times 60 \times 2.5 + \frac{(60)^2}{254(0.42 - 0.02)}$$

$= 77.133$ m

[MCQ]

Q.25. The following figure shows the arrangement of formwork for casting a cantilever RC beam.



The correct sequence of removing the Shores/Props is

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

Sol. **(a)**

In cantilever beam, tension is on top, thus tension reinforcement is provided on top, to avoid tension at bottom, order of removing props T → S → R → Q → P

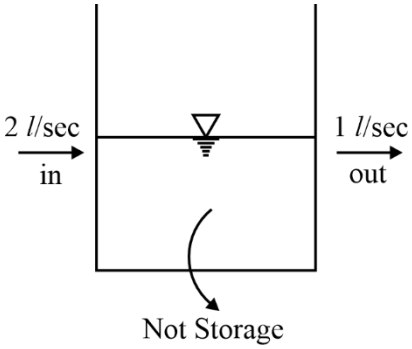
[NAT]

Q.26. A 2 m × 2 m tank of 3 in height has inflow, outflow and stirring mechanisms. Initially, the tank was half-filled with fresh water. At t = 0. an inflow of a salt solution of concentration 5 g/m^3 at the rate of 2 litre/s and an outflow of the well stirred mixture at the rate of 1 liter/s are initiated. This process can be modelled using the following differential equation:

$$\frac{dm}{dx} + \frac{m}{6000 + \tau} = 0.01$$

where m is the mass (grams) of the salt at time t (seconds). The mass of the salt (in grams) in the tank at 75% of its capacity is _____
(rounded off to 2 decimal places).

Sol. **(25.51)**



Total capacity = 2 × 2 × 3

= 12 m^3

Half capacity = 0.5 × 12 m^3

= 6 m^3 = $\forall_o$

7.5% capacity = 0.75 × 12 m^3

= 9 m^3 = $\forall_f$

$$\frac{DV}{l} = \forall_f - \forall_o$$

Require increase = 9 – 6

= 3 m^3 = 3 × 1000 = 3000 litre.

Total time required = 3000 s

$$\frac{dm}{dt} + \frac{m}{6000+t} = 0.01$$

$$\Rightarrow \frac{dm}{dt} = 0.01 - \frac{m}{900}$$

$$\Rightarrow \int_{m_0}^{m=?} \frac{dm}{\left(0.01 - \frac{m}{9000}\right)} = \int_{t_0=0}^{t} dt$$

= Fresh Water

$$\Rightarrow \frac{\left[\ln\left\{0.01 - \frac{m}{900}\right\}\right]_0^m}{0 - \frac{1}{9000}}$$

$$\Rightarrow \{3000-0\} = \frac{\ln\left\{0.01-\frac{m}{9000}\right\} - \ln\ 0.01}{-\frac{1}{9000}}$$

$$\Rightarrow -\frac{1}{3} = \ln\left\{0.01-\frac{m}{9000}\right\} - \ln\ 0.01$$

$$\Rightarrow 0.01-\frac{m}{9000} = 0.007163$$

$\Rightarrow$ m = 25 gm

= 25.512 gm

[NAT]

Q.27. The following data is obtained from an axle load survey at a site:
Average rear axle load = 12000 kg
Number of commercial vehicles = 800 per day
The pavement at this site would be reconstructed over a period of 5 years from the date of survey. The design life of the reconstructed pavement is 15 years. Use the standard axle load as 8160 kg and the annual average vehicle growth rate as 4.0%. Assume that Equivalent Wheel Load Factor (EWLF) and Vehicle Damage Factor (VDF) are equal. The cumulative standard axle (in msa) for the pavement design is_____
(rounded off to 2 decimal places).

Sol. **(33.27)**

Axel load = 12000 kg

P = 800 CVPD

X = 5 years

n = 15 years

Standard Axel (L_S) = 8160 kg

r = 4%

EALF = VDF

N(MSA)

As per IRC : 37

$$N = \frac{365 \times A\left[\left(1+\frac{r}{100}\right)^n - 1\right] \times VDF \times LDF \times FOS}{100}$$

$$A = P\left[1+\frac{r}{100}\right]^x$$

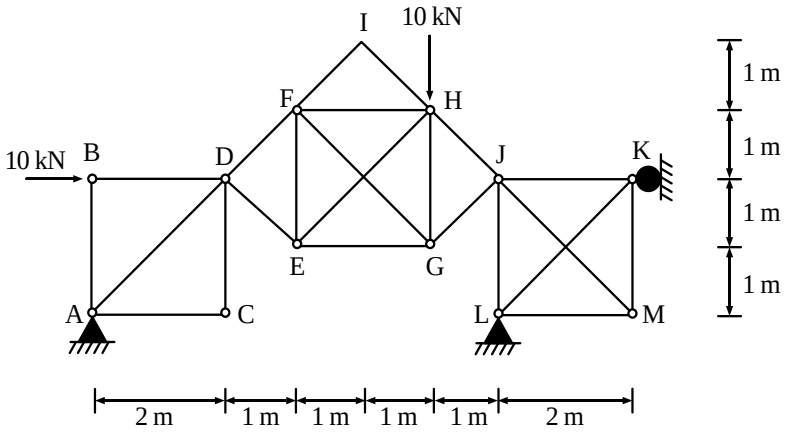
$$A = 800\left[1+\frac{4}{100}\right]^5 = 973.32 \text{ CPVD}$$

$$N = \frac{365\times 973.32\left[\left(1+\frac{4}{100}\right)^{15}-1\right]\times 1}{0.04\times 10^6}\times\left(\frac{12000}{8160}\right)^4$$

$N = 33.27$

[NAT]

Q.28. The plane trass shown in the figure has 13 joints and 22 members. The truss is made of a homogeneous, prismatic, linearly elastic material. All members have identical axial rigidity. A to M indicate the joints of the truss. The truss has pin supports at joints A and L and roller support at joint K. The truss is subjected to a 10 kN vertically downward force at joint H and a 10 kN horizontal force in the rightward direction at joint B as shown.

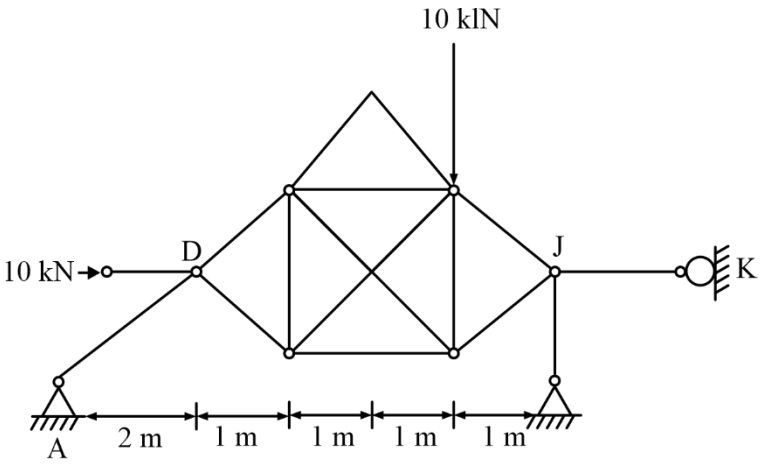


The magnitude of the reaction (in kN) at the pin support L is _____ (rounded off to 1 decimal place).

Sol. **(7.5)**

From the given truss,

Member AB, AC, CD, LM, JM, MK are carrying zero forces.



Taking moment about D

$V_L \times 4 - 10 \times 3$

$$V_L = \frac{10 \times 3}{4} = 7.5kN$$

[NAT]

Q.29. The return period of a large earthquake for a given region is 200 years. Assuming that earthquake occurrence follows Poisson's distribution, the probability that it will be exceeded at least once in 50 years is_____%
(rounded off to the nearest integer).

Sol. **(22)**

T = 200 years

$$P = \frac{1}{T} = \frac{1}{200}$$

$$\text{Mean } (\lambda) = np = 50 \times \frac{1}{200} = 0.25$$

$P(x \geq 1) = 1 - P(x = 0)$

$$= 1 - \frac{\lambda^r e^{-\lambda}}{0!}$$

$$= 1 - \frac{0.25^0 \times e^{-\lambda}}{0!}$$

$= 1 - e^{-0.25} = 0.22$

$= 100 \times 0.22 = 22$

[NAT]

Q.30. An infinite slope is made up of cohesionless soil with seepage parallel to and up to the sloping surface. The angle of slope is 30° with respect to horizontal ground surface. The unit weights of the saturated soil and water are 20 kN/m^{3}and 10 kN/m^3. respectively.
The minimum angle of shearing resistance of the soil (in degrees) for the critically stable condition of the slope is _____ (rounded off to the nearest integer).

Sol. **(49)**

$$\text{F.O.S} = \frac{\gamma'}{\gamma_{sat}} \times \frac{\tan\phi}{\tan\beta} \geq 1$$

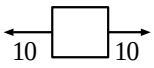
$\therefore \gamma' = \gamma_{sat} - \gamma_w = 20 - 10 = 10$ kN/m^3

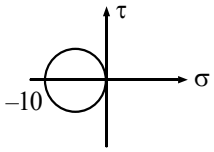
$$= \frac{10}{20} \times \frac{\tan\phi}{\tan 30} \geq 1$$

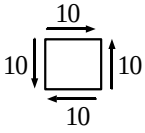
Solving, we get:
$\phi \geq 49.10°$

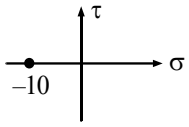
[MCQ]

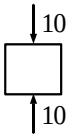
Q.31. Find the correct match between the plane stress states and the Mohr's circles.

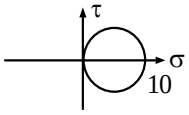
(P) 

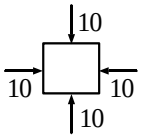
(I) 

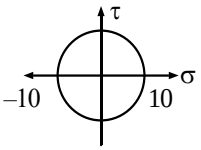
(Q) 

(II) 

(R) 

(III) 

(S) 

(IV) 

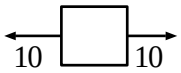
(a) (P)-(III); (Q)-(IV); (R)-(I); (S)-(II)
(b) (P)-(I); (Q)-(IV); (R)-(III); (S)-(II)
(c) (P)-(I); (Q)-(II); (R)-(III); (S)-(IV)
(d) (P)-(III); (Q)-(II); (R)-(I); (S)-(IV)

Sol. **(a)**

(P) – III

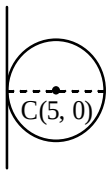
$\sigma_1 = 10$

$\sigma_2 = 0$



$C\left(\frac{\sigma_1+\sigma_2}{2}, 0\right)$

C(5, 0)

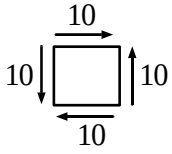


$r = \frac{\sigma_1-\sigma_2}{2} = \frac{10-0}{2} = 5$

r = 5

(Q)

Pure hear case



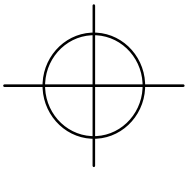
$\sigma_1 = 10$

$\sigma_2 = -10$

$$C = \left(\frac{\sigma_1 + \sigma_2}{2}, 0\right)$$

(0, 0)

$$\text{radius} = \left(\frac{\sigma_1 - \sigma_2}{2}\right)$$



$$= \frac{10+10}{2} = 10$$

(iv)

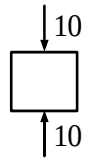
R – I

$\sigma_1 = 0$

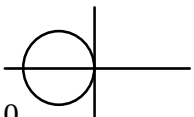
$\sigma_2 = -10$

C = – 5

r = 5

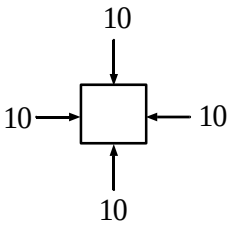


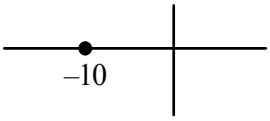
S–II



$$C = \frac{\sigma_1 + \sigma_2}{2} = \frac{-10-10}{2} = -10$$

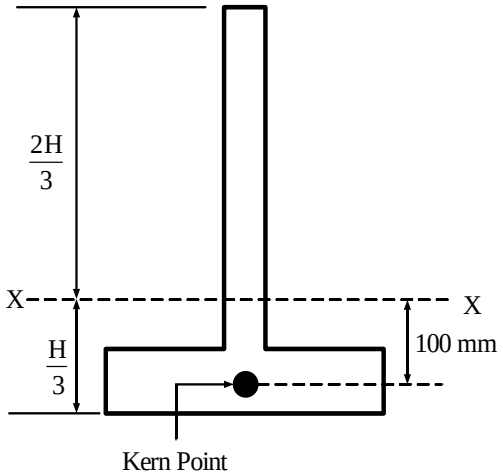
$$r = \frac{\sigma_1 + \sigma_2}{2} = \frac{-10+10}{2} = 0$$





[NAT]

Q.32. An inverted T-shaped concrete beam (B1) in the figure, with centroidal axis X–X. is subjected to an effective prestressing force of 1000 kN acting at the bottom kern point of the beam cross-section. Also consider an identical concrete beam (B2) with the same grade of concrete but without any prestressing force.



The additional cracking moment (in kN.m) that can be carried by beam Bl in comparison to beam B2 is (rounded off to the nearest integer).

Sol. **(300)**

- For pre-stress at kern, there will be no tensile stress at top,

$$\frac{P}{A}-\frac{Pe}{Z_t}=0$$

$$\Rightarrow \boxed{e=\frac{Z_t}{A}}=\frac{Z_b}{2A}\Rightarrow\frac{Z_b}{A}=2e\left(Z_t=\frac{Z_b}{2}\right)$$

- Now, for prestressed beam

$$\frac{P}{A}+\frac{Pe}{Z_b}-\frac{M_2}{Z_b}=-f_{cr} \qquad \ldots(i)$$

Also, for identical beam,

$$\frac{M_1}{Z_b}=f_{cr} \qquad \ldots(ii)$$

Addition equation (i) and (ii),

$$\frac{P}{A}+\frac{Pe}{Z_b}-\frac{M_2}{Z_b}+\frac{M_1}{Z_b}=0$$

$$\frac{P.Z_b}{A}+P.e-M_2+M_1=0$$

$(M_2 - M_1) = 3$ Pe
$= 3 \times 1000 \times 0.1$
$= 300$ kNm

[MCQ]

Q.33. A vector field $\vec{p}$ and a scalar field r are given by

$$\vec{p}=\left(2x^2-3xy+z^2\right)\hat{i}+\left(2y^2-3yz+x^2\right)\hat{j}+\left(2z^2-3xz+x^2\right)\hat{k}$$

$$r=6x^2+4y^2-z^2-9xyz-2xy+3xz-yz$$

Consider the statements P and Q

P: Curl of the gradient of the scalar field r is a null vector.

Q: Divergence of curl of the vector field $\vec{p}$ is zero.

Which one of the following options is CORRECT?

(a) P is TRUE and Q is FALSE
(b) Both P and Q are TRUE
(c) P is FALSE and Q is TRUE
(d) Both P and 0 are FALSE

Sol. **(b)**

By vector identies;

$\nabla\times\nabla r=0$

$\nabla.\nabla\times\vec{p}=0$

Both P and Q are true

[NAT]

Q.34. Activated carbon is used to remove a pollutant from wastewater in a mixed batch reactor, which follows first-order reaction kinetics.

At a reaction rate of 0.38 /day. the time (in days) required to remove the pollutant by 95% is _____ (rounded off to 1 decimal place).

Sol. **(7.9) (Range : 7.8 to 8.0)**

For CMFR

$$C_0 = \frac{C}{1+kt}$$

$$\frac{1}{1+kt} = \frac{C_0}{C}$$

$$\eta = \frac{C_0 - C}{C_0} \times 100$$

$$\eta = \frac{1-C}{C_0} \times 100$$

$$0.95 = 1 - \frac{C}{C_0}$$

$$\frac{C}{C_0} = 1 - 0.95 = 0.05$$

$$\frac{1}{1+kt} = 0.05$$

$$\frac{1}{1+0.38 \times t} = 0.05$$

t = 50 days

OR

For Plug flow reactor

$n = (1 - e^{-kt}) \times 100$

$$\Rightarrow \frac{95}{100} = \left(1 - e^{-0.38 \times t}\right)$$

$\Rightarrow 0.95 = 1 - e^{-0.38 \times t}$

$e^{-0.38t} = 1 - 0.95$

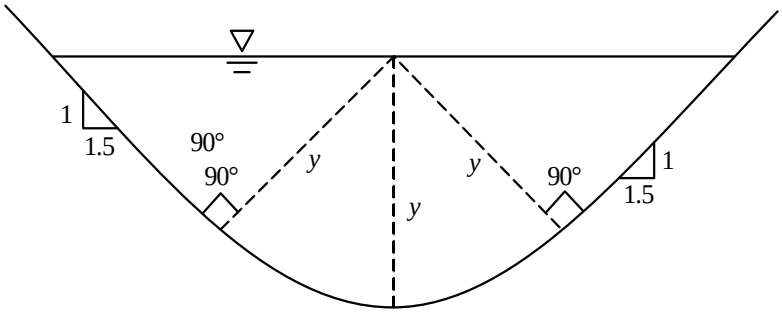
$-0.38t = \ln(0.05)$

$$t = \frac{\ln(0.05)}{-0.38}$$

t = 7.88 days

[NAT]

Q.35. A standard round bottom triangular canal section as shown in the figure has a bed slope of 1 in 200. Consider the Chezy's coefficient as 150 $m^{1/2}/s$.



The normal depth of flow, y (in meters) for carrying a discharge of 20 m^3/s is _____ (rounded off to 2 decimal places).

Sol. **(1.10)**

$$S = \frac{1}{200}$$

$C = 150\ m^{1/2}.sec$

$Cot(\theta) = 1.5,\ \theta = 0.587$

$\theta = 20\ m^3/sec$

$$A = y^2[\theta + \cot\theta]$$

$= y^2[0.587 + 1.5]$

$= 2.087\ y^2$

$$R = \frac{A}{P} = \frac{y^2(\theta + \cot 10)}{2y(\theta + \cot 10)} = 2y$$

$$\theta = CA\sqrt{RS}$$

$$20 = 150 \times 2.087 y^2 \times \left(\sqrt{\frac{y}{2} \times \frac{1}{200}}\right)$$

$$\frac{20 \times \sqrt{2} \times \sqrt{200}}{150 \times 2..087} = y^2 \times y^{1/2}$$

$y^{5/2} = 1.2778$

$y = 1.10$

[MSQ]

Q.36. Which of the following statement(s) is/are CORRECT?

(a) Among the several corrections to be applied to the SPT-N value, the dilatancy correction applied before all other corrections.

(b) In electrical resistivity tomography. the depth of current penetration is half of the spacing between the electrodes.

(c) Both loose and dense sands with different initial void ratios can attain similar void ratio at large strain during shearing.

(d) Swell potential of soil decreases with an increase in the shrinkage limit.

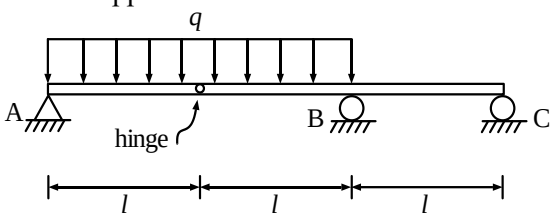
Sol. **(c, d)**

Both loose and dense sands with different initial void ratios can attain similar void ratio at large strain during shearing

Swell potential of soil decreases with an increase in the shrinkage limit.

[MCQ]

Q.37. The beam shown in the figure is subjected to a uniformly distributed downward load of intensity q between supports A and B



Considering the upward reactions as positive, the support reactions are

(a) $R_A = \frac{ql}{2}; R_B = ql; R_C = \frac{ql}{2}$

(b) $R_A = \frac{ql}{2}; R_B = \frac{5ql}{2}; R_C = -ql$

(c) $R_A = \frac{ql}{2}; R_B = \frac{5ql}{2}; R_C = 0$

(d) $R_A = -ql; R_B = \frac{5ql}{2}; R_C = \frac{ql}{2}$

Sol. **(b)**

$$T_P + T_R = T$$

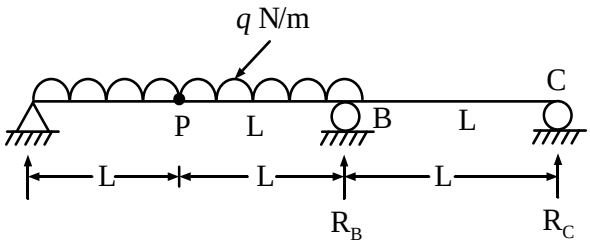
$$5T_R = T$$

$$Q_{PQ} + Q_{QR} = 0$$

$$\frac{T_{PQ}L_1}{GT_1} + \frac{T_{QR}L_2}{GT_2} = 0$$

$$\frac{T_P L_1}{2T_2} + \frac{(T_P - T)}{T_2} = 0$$

$$\frac{L_1}{L_2}=\frac{1}{2}$$



$BM_P = 0$

$$(R_A \times L) = WL\frac{L}{2} \ldots..(1)$$

$$(-R_C \times 2L) + (-R_B \times L) + \left(WL\frac{L}{2}\right) = 0 \ldots..(2)$$

$$R_A + R_B + R_C = W2L \ldots..(3)$$

$$R_A = \frac{WL}{2}$$

$R_C = -$ WL

$R_B = 2.5$ WL

[NAT]

Q.38. A water treatment plant treats 25 MLD water with a natural alkalinity of 4.0 mg/L (as $CaCO_3$). It is estimated that, during coagulation of this water. 450 kg day of calcium bicarbonate ($Ca(HCO_3)_2$) is required based on the alum dosage.
Consider the atomic weights as; Ca-40. H-l. C-12. O-16.
The quantity of pure quick lime. CaO (in kg) required for this process per day is_____ (rounded off to 2 decimal places).

Sol. **(99.56)**

Q = 25 MLD

$(AIK)_{present}$ = 4 mg/l as $CaCo_3$

$(AIK)_{required}$ = 450 kg/d of $Ca(HCo_3)_2$

$$(AIK)_{required} \text{ as } CaCo_3 \frac{450}{Eq \text{ unit of } Ca(HCo_3)_2} \times Eq \text{ unit of } CaCo_3$$

$$= \frac{450}{81} \times 50$$

$(AIK)_{required}$ = 277.78 kg/d as $CaCo_3$

Amount of Q will line required

$$= \frac{56}{100} \times \left(\text{AIK}_{\text{deficiency}}\right)$$

$$= \frac{56}{100}\left((\text{AIK})_{\text{reqd}} - (\text{AIK})_{\text{present}}\right)$$

$$= \frac{56}{100}(277.78 - 100)$$

= 99.5568 kg/d

[NAT]

Q.39. A soil sample was consolidated at a cell pressure of 20 kPa and a back pressure of 10 kPa for 24 hours during a consolidated undrained (CU) triaxial test. The cell pressure was increased to 30 kPa on the next day and it resulted in the development of pore water pressure of 1 kPa. The soil sample failed when the axial stress was gradually increased to 50 kPa. The pore water pressure at failure was recorded as 21 kPa. The value of Skempton's pore pressure parameter B for the soil sample is_____ (rounded off to 2 decimal places).

Sol. **(0.10)**

Initial cell pressure $\sigma_3^i = 20$ kPa

Backpressure = 10 kPa

Final cell pressure $\sigma_3^f = 30$ kPa

$\Delta U_c = 1$ kPa

Skempton's pore pressure parameter $B = \frac{\Delta U_c}{\Delta \sigma_3} = \frac{1}{10} = 0.10$

[NAT]

Q.40. The number of trains and their corresponding speeds for a curved Broad Gauge section with 437 m radius, are

- 20 trains travel at a speed of 40 km/hr
- 15 trains travel at a speed of 50 km/hr
- 12 trains travel at a speed of 60 km/hr
- 8 trains travel at a speed of 70 km/hr
- 3 trams travel at a speed of 80 km/hr

If the gauge (center-to-center distance between the rail heads) is taken as 1750 mm. the required equilibrium cant (in mm) will be _____ (rounded off to the nearest integer).

Sol. **(88.34)**

437 m Radius

$$V_{\text{Average}} = \frac{20(40)+15(50)+12(60)+8(70)+3(80)}{20+15+12+8+3}$$

= 52.93 lamph

$$e_{eq} = \frac{GV^2}{127R} = \frac{1750 \times 52.93^2}{127 \times 437} = 8.834\text{mm}$$

< 165 mm

< 140 mm

[NAT]

Q.41. The total primary consolidation settlement (S_c) of a building constructed on a 10 m thick saturated clay layer is estimated to be 50 mm. After 300 days of the construction of the building, primary consolidation settlement was reported as 10 mm. The additional time (in days) required to achieve 50% of S_c will be_____ *(rounded off to the nearest integer).*

Sol. **(1575)**

H = 10 m

Δh_1 = 10 mm, t_1 = 300 day

ΔH = 50 mm

Additional time required for 50% settlement

$$U_1 = \frac{\Delta h_1}{\Delta H} \times 100 = 20\%$$

$U_1, U_2 < 60\%$

$$T_v = \frac{C_v t}{H^2} = \pi/4 U^2$$

$$\frac{t_2}{t_1} = \frac{U_2^2}{U_1^2}$$

$$\Rightarrow t_2 = \left(\frac{0.5}{0.2}\right)^2 \times 300$$

= 1875 days

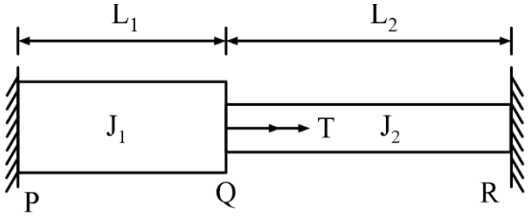
Additional time (t) = $t_2 - t_1$ = 1875 – 300

= 1575 days

[MCQ]

Q.42. A homogeneous shaft PQR with fixed supports at both ends is subjected to a torsional moment T at point Q. as shown in the figure The polar moments of inertia of the

portions PQ and QR of the shaft with circular cross-sections are J_1 and J_2. respectively. The torsional moment reactions at the supports P and R are T_P and T_R. respectively.



(figure NOT to scale)

If $T_P/T_R = 4$ and $J_1/J_2 = 2$. the ratio of the lengths L_1/L_2 is

(a) 0.25 (b) 0.50

(c) 4.00 (d) 2.00

Sol. **(b)**

$$T_P + T_R = T$$

$$5T_R = T$$

$$Q_{PQ} + Q_{QR} = 0$$

$$\frac{T_{PQ}L_1}{GT_1} + \frac{T_{QR}L_2}{GT_2} = 0$$

$$\frac{T_P L_1}{2T_2} + \frac{(T_P - T)}{T_2} = 0$$

$$\frac{L_1}{L_2} = \frac{1}{2}$$

[MCQ]

Q.43. A map is prepared with a scale of 1:1000 and a contour interval of 1 m. If the distance between two adjacent contours on the map is 10 mm. the slope of the ground between the adjacent contours is

(a) 40% (b) 10%

(c) 35% (d) 30%

Sol. **(b)**

1: 1000
C.I = 1 m
H2 = 10 mm
1 : 1000
↓ ↓
1 mm 1 m
Plan G
10 m Horizontal distance
1 Vertical distance
G = 1/100 × 1000 = 10%

[NAT]

Q.44. The initial cost of an equipment is Rs. 1.00.000. Its salvage value at the end of accounting life of 5 years is Rs. 10,000. The difference in depreciation (in Rs.) computed using 'double-declining balance method' and 'straight line method' of depreciation in Year-2 is_____ *(in positive integer').*

Sol. **(6000)**

Double declining rate $= \frac{2}{n} = \frac{2}{5} = 0.4$ (40%)

$D_1 = 100000 \times 0.4 = 40000$

$B_1 = 100000 - 40000 = 60000$

$D_2 = 60000 \times 0.4 = 24000$

For Straight line method, $D = \frac{C_i - C_s}{n} = \frac{100000 - 10000}{5}$ = ₹18000/year

Difference = 24000 – 18000 = ₹6000

[MCQ]

Q.45. The free mean speed is 60 km/hr on a given road The average space headway at jam density on this road is 8m. For a linear speed-density relationship, the maximum flow (in veh/hr/lane) expected on the road is

(a) 938 (b) 1038
(c) 2075 (d) 1875

Sol. **(d)**

Space headway at jam density = 8m

V_f = 60 kmph

Q_{max} = ?

$K_j = \frac{1000}{5} = \frac{100}{8} = 125$

Greenshield's

$q_{max} = \frac{V_f \cdot K_j}{4}$

$= \frac{60 \times 125}{4}$

$q_{max} = 1875 \frac{veh}{hr}$

Civil Engineering

[MCQ]

Q.46. What are the eigenvalues of the matrix $\begin{bmatrix} 2 & 1 & 1 \\ 1 & 4 & 1 \\ 1 & 1 & 2 \end{bmatrix}$?

(a) 1, 3, 4
(b) –5, –1, 2
(c) –5, 1, 2
(d) 1, 2, 5

Sol. **(d)**

$|A - \lambda I| = 0$

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

$$= \begin{vmatrix} 2-\lambda & 1 & 1 \\ 1 & 4-\lambda & 1 \\ 1 & 1 & 2-\lambda \end{vmatrix} = 0$$

$\lambda = 1, 2, 5$

[MCQ]

Q.47. A flow velocity field $\vec{V} : \vec{V}$ (x, y) for a fluid is represented by

$\vec{V} = 3\hat{i} + (5x)\hat{j}$

In the context of the fluid and the flow, which one of the following statements is CORRECT?

(a) The fluid is compressible and the flow is irrotational.
(b) The fluid is incompressible and the flow is rotational.
(c) The fluid is incompressible and the flow is irrotational.
(d) The fluid is compressible and the flow is rotational.

Sol. **(b)**

$$\vec{V} = \underset{u}{3}\hat{i} + \underset{v}{(5x)}\hat{j}$$

$$\nabla \cdot \vec{V} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

Therefore flow is incompressible

Given, $u = 3$, $v = 5x$

$$\nabla \times \vec{V} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 3 & 5x & 0 \end{vmatrix}$$

$$= \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)\hat{k} = 5\hat{k} \neq \vec{0}$$

Therefore flow is rotational.

[NAT]

Q.47. The ordinates of a 1-hour unit hydrograph (UH) are given below.

Time (hours)	0	1	2	3	4	5
Ordinates of 1-hour UH (m^3/s)	0	13	50	80	95	85

Time (hours)	6	7	8	9	10	11
Ordinates of 1-hour UH (m^3/s)	55	35	15	10	3	0

These ordinates are used to derive a 3-hour UH. The peak discharge (in m^3/s) for the derived 3-hour UH is (rounded off to the nearest integer).

Sol. **(87)**

t (hr)	**1-hr UH**	**1-hr UH (Lagged by 1 hr)**	**1-hr UH (Lagged by 2 hr)**	**DRH**	**Peak 3-hr UH**
0	0				
1	13	0			
2	50	13	0		
3	80	50	13		
4	95	80	50		
5	85	95	80	260	260/3 = 86.66 ≈ 87
6	55	85	95		
7	35	55	85		
8	15	35	55		
9	10	15	35		
10	3	10	15		
11	0	3	10		
		0	3		
			0		

Thus, peak discharge for derived 3 hr UH = 87 m^3/s

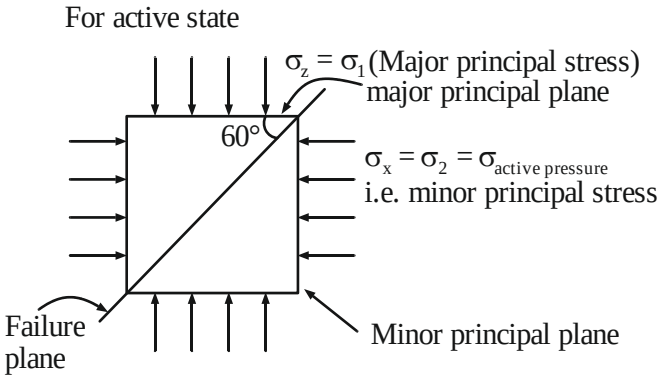
[MCQ]

Q.49. A vertical smooth rigid retaining wall is supporting horizontal ground with dry cohesionless backfill having a friction angle of 30°. The inclinations of failure planes with respect to the major principal plane for Rankine's active and passive earth pressure conditions, respectively, are

(a) 60° and 30°
(b) 30° and 30°
(c) 60° and 60°
(d) 30° and 60°

Sol. **(c)**

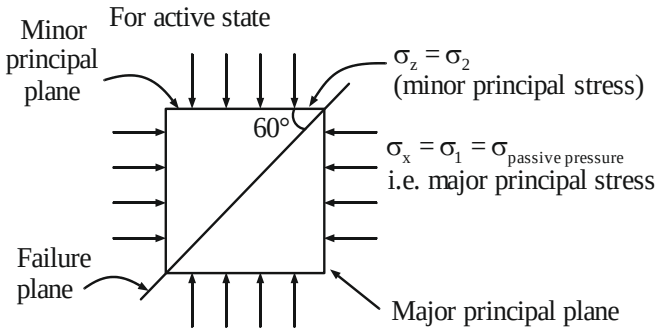
Given, (ϕ) friction angle = 30°
For active state



Failure plane inclination with major principal plane (horizontal)

$$\Rightarrow \theta_c = 45° + \frac{\phi}{4} = 45° + \frac{30°}{2}$$

$\theta_c = 60°$



Failure plane inclination with major principal plane

$$(\theta_c) = 45° + \frac{\phi}{2}$$

$$\theta_c = 45° + \frac{30°}{2} = 60°$$

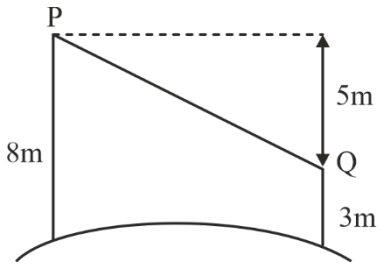
Hence inclination of failure planes with major principal plane for both active & passive conditions is 60°

[NAT]

Q.50. A bird is resting on a point P at a height of 8 in above the Mean Sea Level (MSL). Upon hearing a loud noise, the bird flies parallel to the ground surface and reaches a point Q which is located at a height of 3 in above MSL. The ground surface has a falling gradient of 1 in 2. Ignoring the effects of curvature and refraction, the horizontal

distance (in meters) between points P and Q is _____ *(in integer).*

Sol. **(10)**



Given,
1 in 2
5 vertical = 10 m horizontal

[NAT]

Q.51. A slab panel with an effective depth of 250 mm is reinforced with 0.2% main reinforcement using 8 mm diameter steel bars. The uniform center-to-center spacing (in mm) at which the 8 mm diameter bars are placed in the slab panel is_____ *(rounded off to the nearest integer).*

Sol. **(100)**

Slab $\rightarrow$ d = 250 mm $\simeq$ D

ϕ = 8 mm

$$A_{st} = 0.2\% = \frac{0.2 \times 250 \times 1000}{100} = 500 \text{ mm}^2$$

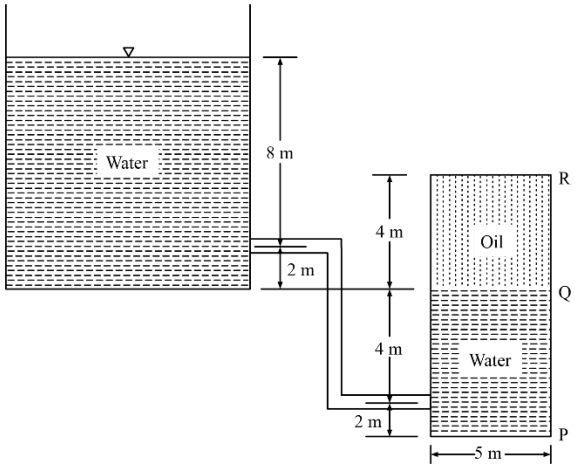
$$S \leq \text{leser of} \begin{cases} \frac{1000}{Ast} \times \frac{\pi}{4}\phi^2 \\ 3d \\ 300 \text{ mm} \end{cases}$$

= 100.53 mm

Round off to nearest integer so answer is 100 mm.

[NAT]

Q.52. A 5 in × 5 m closed tank of 10 m height contains water and oil. and is connected to an overhead water reservoir as shown in the figure. Use γ_w = **10** kN/m^3 and Specific gravity of oil = 0.8.



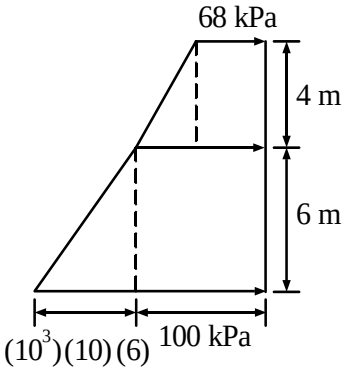
The total force (in kN) due to pressure on the side PQR of the tank is_____ *(rounded off to the nearest integer').*

Sol. **(5580)**

$P_P + (800)(10)(4) = (10^3)(10)(10)$

$P_P = 68 \times 10^3$ Pa

$= 68$ kPa



$= 60$ kPa

$$\text{Force} = \left[\frac{1}{2}(68+100)^4 + \frac{1}{2}(100+160)^6\right]^5$$

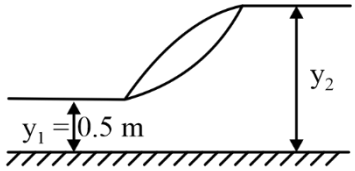
$= 5580$ kN

[NAT]

Q.53. A spillway has unit discharge of 7.5 $m^3/s/m$. The flow depth at the downstream horizontal apron is 0.5 in. The tail water depth (in meters) required to form a hydraulic jump is_____*(rounded off to 2 decimal places).*

Sol. **(4.55)**

$$F_{r1} = \frac{V_1}{\sqrt{gy_1}} \Rightarrow V_1 = g / y_1$$



$q = 7.5\ m^2/s/m$

$$\frac{y_2}{y_1} = \frac{1}{2}\left[-1+\sqrt{8F_{r1}^2+1}\right]$$

$= 7.5/05 = 15$

$$F_{r1} = \frac{V_1}{\sqrt{gy_1}}$$

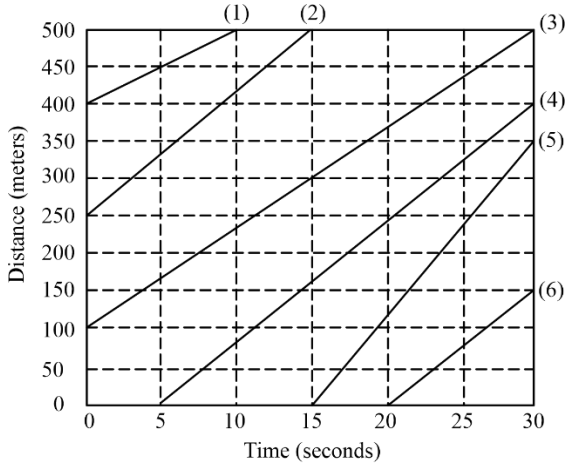
$$= \frac{15}{\sqrt{9.81\times 0.5}}$$

$= 6.77$

$$\frac{y_2}{0.5} = \frac{1}{2}\left[-1+\sqrt{8\times 6.77+1}\right] \Rightarrow y_2 = 4.55\text{m}$$

[NAT]

Q.54. The figure presents the trajectories of six. vehicles within a time-space domain. The number in the parentheses represents unique identification of each vehicle.



The mean speed (in km/hr) of the vehicles in the entire time-space domain is_____*(rounded off to the nearest integer).*

Sol. **(57)**

For,

$$V_1 = \frac{(500-400)}{10} = 10\ \text{m/sec}$$

$$V_2 = \frac{(500-250)}{15} = 16.67 \text{ m/sec}$$

$$V_3 = \frac{(500-100)}{30} = 13.33 \text{ m/sec}$$

$$V_4 = \frac{(400-0)}{(30-5)} = 16 \text{ m/sec}$$

$$V_5 = \frac{(350-0)}{30-15} = 23.33$$

$$V_6 = \frac{(150-0)}{30-25} = 15 \text{ m/sec}$$

$$\text{Mean speed} = \frac{10+16.67+13.33+16}{6} = 15.72 \text{ m/sec}$$

= 56.598 km/hr

[MCQ]

Q.55. For assessing the compliance with the emissions standards of incineration plants, a correction needs to be applied to the measured concentrations of air pollutants. The emission standard (based on 11% Oxygen) for HC1 is 50 Mg/Nm^3 and the measured concentrations of HC1 and Oxygen in flue gas are 42 mg/Nm^3 and 13%. respectively. Assuming 21% Oxygen in air. the CORRECT statement is:

(a) Compliance is there, as there is no need to apply the correction since Oxygen is greater than 11% and HCl emission is lesser than the emission standard.

(b) Compliance is there, as the corrected HCl emission is lesser than (lie emission standard

(c) No compliance, as the corrected HCl emission is greater than the emission standard.

(d) No compliance, as the Oxygen is greater than 11% in the flue gas.

Sol. **(a)**

Compliance is there, as there is no need to apply the correction since Oxygen is greater than 11% and HCl emission is lesser than the emission standard.

❐❐❐

GATE WALLAH

SOLDIERS

THANK YOU