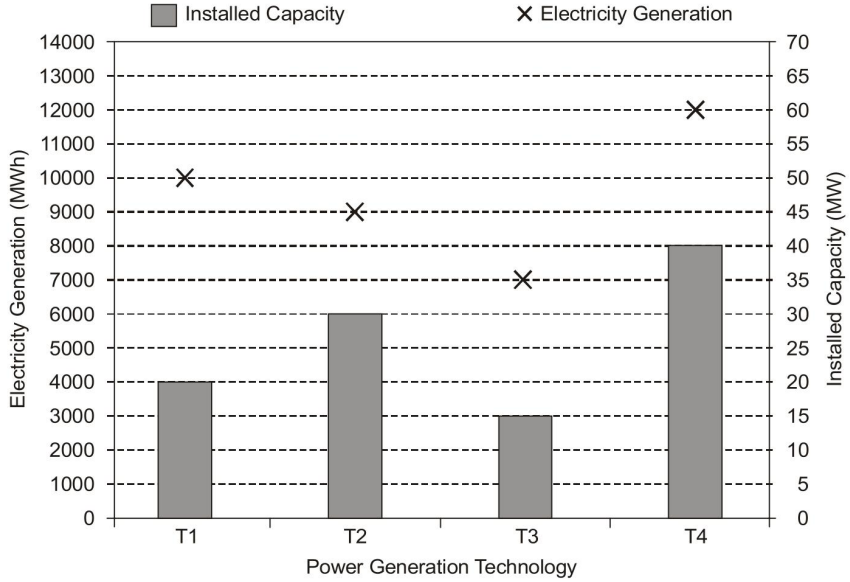
Civil Engineering
(Forenoon Session)
Exam Date- 04-02-2024

SECTION - A GENERAL APTITUDE

Q.1 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:

$$\text{Capacity Factor} = \frac{\text{Electrivity Generation (MWh)}}{\text{Installed Capacity (MW)} \times 1000(\text{h})}$$

Which one of the given technologies has the highest Capacity Factor?

(a) T2 (b) T1

(c) T3 (d) T4

Ans. (b)

End of Solution

Q.2 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 neighboring cells (left, right, top, bottom, diagonals).

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

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

Ans. **(d)**

End of Solution

Q.3 Three distinct sets of indistinguishable twins are to be seated at a circular table that has 8 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 their twin?

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

Ans. **(a)**

End of Solution

Q.4 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) $\sqrt[p]{q} = \sqrt[q]{p}$ (b) $\sqrt{q} = \sqrt{p}$
(c) $q^p = p^{2q}$ (d) $q^p = p^q$

Ans. **(d)**

Given, $p > 0$, $q > 0$ and $\frac{p}{q} \neq 1$

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

$\because$ $$\left(\frac{p}{q}\right)^{p/q} = p^{\left(\frac{p-q}{q}\right)}$$

$\because$ $$\left(\frac{p}{q}\right)^{p} = p^{q-q}$$

$\because$ $$\left(\frac{p}{q}\right)^{p} = \frac{p^p}{p^q}$$

$\therefore$ $$q^p = p^q$$

End of Solution

Q.5 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

Ans. **(c)**

Between 12:05:00 to 12:55:00
There are 50 interval of 1 minute in which a second hand and minute hand crosses one another time. So during 12:05:00 to 12:55:00 minute and second hand crosses 50 times.

End of Solution

Q.6 In the given text, the blanks are numbered (1)-(iv). Select the best match for all the blanks.

From the ancient Athenian arena to the modern Olympic stadiums, athletics $\underline{\quad(i)\quad}$ the potential for a spectacle. The crowd $\underline{\quad(ii)\quad}$ with bated breath as the Olympian artist twists his body, stretching the javelin behind him. Twelve strides in, he begins to cross-step. Six cross-steps $\underline{\quad(iii)\quad}$ in an abrupt stop on his left foot. As his body $\underline{\quad(iv)\quad}$ 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) hold (ii) wait (iii) culminate (iv) pivots
(c) (i) holds (ii) waits (iii) culminate (iv) pivots
(d) (i) hold (ii) Waits (iii) culminates (iv) pivot

Ans. **(c)**

End of Solution

Q.7 If ' $\rightarrow$ ' denotes increasing order of intensity, then the meaning of the words [simmer $\rightarrow$ seethe $\rightarrow$ smolder] is analogous to [break $\rightarrow$ raze $\rightarrow$ _____]. Which one of the given options is appropriate to fill the blank?

(a) obliterate (b) fissure
(c) fracture (d) obfuscate

Ans. **(a)**

End of Solution

Q.8 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) 45 (d) 40

Ans. **(b)**

$3 \times 2 + 1 = 7$

$7 \times 2 + 1 = 15$

$15 \times 2 + 1 = \boxed{31}$

$31 \times 2 + 1 = 63$

$63 \times 2 + 1 = 127$

$127 \times 2 + 1 = 255$

End of Solution

Q.9 During a half-moon phase, the Earth-Moon-Sun form a right triangle. If the Moon-Earth-Sun angle at this half-moon phase is measured to be 89.85", the ratio of the Earth-Sun and Earth-Moon distances is closest to

(a) 283 (b) 382

(c) 328 (d) 238

Ans. **(b)**

End of Solution

Q.10 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 rood is

(a) 52 (b) 54

(c) 26 (d) 27

Ans. **(d)**

301 303 305 ------

302 304 306 ------

Let sum of $301 + 303 + 305 + \ldots\ldots = A$

and $302 + 304 + 306 + \ldots\ldots = B$

Given, $A - B = 27$

and $302 - 301 = 1$

$304 - 303 = 1$

As difference of one pair is 1 and total difference is 27.

$\therefore$ Number of house in one side is 27.

End of Solution

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SECTION - B TECHNICAL

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) 20 MPa

(c) 25 MPa (d) 5 MPa

Ans. **(b)**

In the given matrix, shear stresses are zero. So, the elements on diagonal of this matrix are principal stress.

So,
$$\tau_{max} = \left| \left(\frac{\sigma_{p1} - \sigma_{p2}}{2} \right), \left(\frac{\sigma_{p2} - \sigma_{p3}}{2} \right), \left(\frac{\sigma_{p3} - \sigma_{p1}}{2} \right) \right|_{max}$$

$$= \left| \left(\frac{10 - 40}{2} \right), \left(\frac{40 - 0}{2} \right), \left(\frac{0 - 10}{2} \right) \right|_{max}$$

$$= |(-15), 20, (-5)|$$

$$= 20 \text{ MPa}$$

End of Solution

Q.2 Among the following statements relating the fundamental lines of a transit theodolite, which one is CORRECT

(a) The axis of plate level must lie in a plane parallel to the vertical axis.

(b) The axis of altitude level must be perpendicular to the line of collimation

(c) The Vernier of vertical circle must read zero when the line of collimation is vertical.

(d) The line of collimation must be perpendicular to the horizontal axis at its intersection with the vertical axis.

Ans. **(d)**

End of Solution

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

(a) $\frac{17}{18}$ (b) $\frac{1}{18}$

(c) $\frac{11}{18}$ (d) $\frac{14}{18}$

Ans. **(c)**

$$P(M \cup E) = P(M) + P(E) - P(M \cap E)$$

$$= \frac{1}{3} + \frac{4}{9} - \frac{1}{6}$$

$$= \frac{6+8-3}{18} = \frac{11}{18}$$

NOTE: As per GATE answer key, anwer is given as (a).

End of Solution

Q.4 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

Ans. **(b)**

Degree of freedom in a mobile boundary channel are bed width, depth, slope and planiform.

End of Solution

Q.5 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), h : h(y), the general solution of the above differential equation

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

(c) $u = x^2 + xf(y) + h(y)$ (d) $u = x^2 + f(y) + yg(x)$

Ans. **(c)**

Integrating with respect to 'x'

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

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

Again integrating,

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

End of Solution

Q.6 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) 360° (b) 270°

(c) 90° (d) 180°

Ans. **(d)**

Sum of interior angles = $(n - 2) \times 180°$

So, sum of interior angles for 3 sides = $(3 - 2) \times 180° = 180°$

Now, sum of interior angles for 4 sides = $(4 - 2) \times 180° = 360°$

$\therefore$ Increase in sum of interior angles = $360° - 180° = 180°$

End of Solution

Q.7 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 rate 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).

Ans. **(1855)(1852 - 1858)**

Thickness of aquifer, $H = 20$ m

$r_1 = 10$ m

$r_2 = 100$ m

$h_2 = H - S_{w1} = 20 - 5 = 15$ m

$h_1 = H - S_{w2} = 20 - 1 = 19$ m

Now discharge for unconfined aquifer is given as

$$Q = \frac{\pi \cdot K\left[h_1^2 - h_2^2\right]}{\ln\left[\frac{r_2}{r_1}\right]} = \frac{\pi \times 10 \times \left[19^2 - 15^2\right]}{\ln\left[\frac{100}{10}\right]}$$

$Q = 1855.55$ m^3/day

End of Solution

Q.8 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) Both P and Q are FALSE
(b) Both P and Q are TRUE
(c) P is TRUE and Q is FALSE
(d) P is FALSE and Q is TRUE

Ans. **(d)**

End of Solution

Q.9 The primary air pollutant(s) is/are

(a) Sulphur dioxide
(b) Sulphuric acid
(c) Lead
(d) Ozone

Ans. **(a, c)**

Whether glucose gets aerobically or anaerobically decomposed, the product which cannot be obtained is H2S because Sulphur is not present in the reaction.

End of Solution

Q.10 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)

Ans. **(16.75)(16.60 - 16.80)**

Dry density, $\gamma_d = \dfrac{G\gamma_w}{1+e}$

$$e = \frac{wG}{S} = \frac{0.17 \times 2.68}{0.75} = 0.6$$

$\therefore$ $\gamma_d = \dfrac{2.68 \times 10}{1+0.6}$

$= 16.75$ kN/m^3

End of Solution

Q.11 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) Both P and Q are TRUE
(b) P is FALSE and Q is TRUE
(c) Both P and Q are FALSE
(d) P is TRUE and Q is FALSE

Ans. **(a)**

- During the planning and design phase of a construction project, the client's preliminary estimate is often used as a basis for budgeting costs. Hence statement P is true.
- During the execution phase of a construction project, the clients detailed estimate which is a refined and updated version of the preliminary estimate is used for controlling costs. Hence statement Q is true.

End of Solution

Q.12 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) 35 (b) 37
(c) 38 (d) 39

Ans. **(c)**

As per IS456:2000, atleast 95% of the specimen should have strength equal to more than the characteristics strength.

$\therefore$Minimum number of specimens = $0.95 \times 40 = 38$

End of Solution

Q.13 As per the International Civil Aviation Organization (ICAO), the basic runway length is increased b x (%) for every y (m) raise in elevation from the Mean Sea Level (MSL) The values of x and y respectively, are

(a) 10% and 1000 m (b) 4% and 500 m
(c) 5% and 200 m (d) 7% and 300 m

Ans. **(d)**

End of Solution

Q.14 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) hyperbolic for $x < 0$ and $y > 0$ (b) parabolic for $x > 0$ and $y > 0$

(c) elliptic for $x = 0$ and $y > 0$ (d) elliptic for $x > 0$ and $y > 0$

Ans. **(a, d)**

For elliptical

$$B^2 - 4AC < 0$$

$$0 - 4xy < 0$$

i.e. for $x > 0$ and $y > 0$

Hence option (d) is correct.

For hyperbolic

$$B^2 - 4AC > 0$$

$$0 - 4xy > 0$$

i.e. for $x < 0$ and $y > 0$

Hence option (a) is correct.

End of Solution

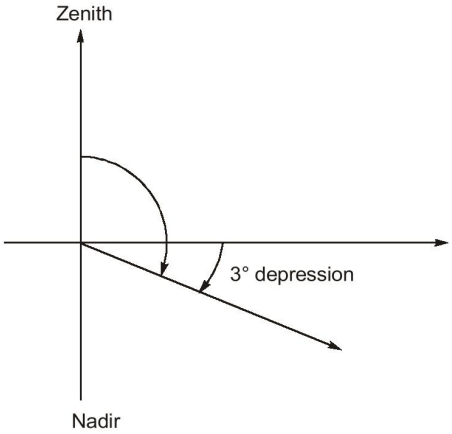
Q.15 A surveyor observes a zenith angle of 93° 00' 00" during a theodolite survey The corresponding vertical angle is

(a) 87° 00'00" (b) +03° 00'00"

(c) 87° 00'00" (d) –03° 00' 00"

Ans. **(d)**

Zenith = 93° 0′ 00″



End of Solution

Q.16 Which one of the following statements related to bitumen is FALSE?

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

(b) Kinematic Viscosity is a measure of resistance to the flow of molten bitumen under gravity

(c) 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.

(d) Ductility test is carried out on bitumen to test its adhesive property and ability to stretch

Ans. **(a)**

Softer grade bitumen has a lower softening point, while harder grade bitumen has a higher softening point. Hence statement A is false.

End of Solution

Q.17 The elements that DO NOT increase the strength of structural steel are

(a) Carbon (b) Chlorine

(c) Manganese (d) Sulphur

Ans. **(b, d)**

End of Solution

Q.18 The following table 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

(a) P-iv. Q-iii, R-ii, S-i

(b) P-iii, Q-iv, R-ii, S-i

(c) P-iii, Q-iv, R-i, S-ii

(d) P-iv, Q-iii, R-i, S-ii

Ans. **(a)**

End of Solution

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

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

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

Ans. (0.17)(0.16 - 0.18)

It is based on 2nd order interpolation

$$f(x) = y_1 + \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$$

$$f(x) = y_1 + \frac{y_2 - y_1}{x_2 - x_1}(x - x_1) + \frac{\frac{y_3 - y_2}{x_3 - x_2} - \frac{y_2 - y_1}{x_2 - x_1}}{x_3 - x_1}(x - x_1)(x - x_2)$$

Here, $y_1 = 0$, $x_1 = 1$ | $y_2 = 0.3010$, $x_2 = 2$ | $y_3 = 0.4771$, $x_3 = 3$

$$f(x) = 0 + \left[\frac{0.3010 - 0}{2 - 1}\right](x - 1) + \left[\frac{\frac{0.4771 - 0.3010}{3 - 2} - \frac{0.3010 - 0}{2 - 1}}{3 - 1}\right](x - 1)(x - 2)$$

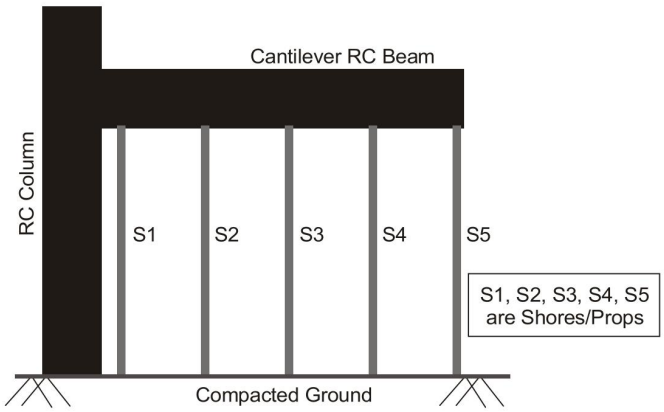
$$f(x) = 0.3010(x - 1) + \left(\frac{-0.1249}{2}\right)(x - 1)(x - 2)$$

$$f(x) = 0.3010(1.5 - 1) + \frac{-0.1249}{2}(1.5 - 1)(1.5 - 2)$$

$$f(1.5) = 0.1505 + 0.0156 = 0.1661$$

End of Solution

Q.20 The following figure shows the arrangement of formwork for casting a cantilever RC beam.



(a) S3 → S4 → S2 → S5 → S1 (b) S5 → S4 → S3 → S2 → S1

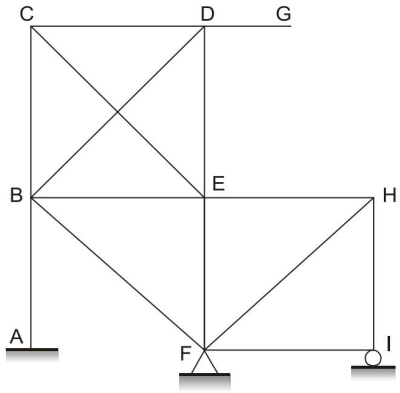
(c) S1 → S2 → S3 → S4 → S4 (d) S3 → S2 → S4 → S1 → S5

Ans. (b)

Form work should be removed in such a way that the cantilever beam should remain cantilever.

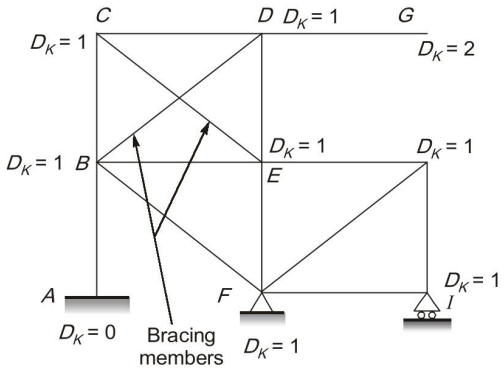
End of Solution

Q.21 The plane frame shown in the figure has fixed support at joint A, hinge support at joint F, and roller support at joint 1. In the figure, A to I indicate joints of the frame.



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

Ans. **(9)(9 - 9)**



$\Rightarrow$ $D_K = 9$

NOTE: A rigid jointed structure is kept on hinge support at F and on a roller support at I.

If axial deformations are neglected and bracing is done, only rotations are possible at the joints.

End of Solution

Q.22 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 car 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) 41 to 45 (b) 126 to 130

(c) 33 to 37 (d) 75 to 79

Ans. **(d)**

Given, $V = 60$ km/hr, $t_R = 2.5$ sec

Braking efficiency, $\eta = 60\%$

Coefficient of friction, $\mu = 0.7\%$

Down grace, $s = 2\%$

Stopping sight distance = Lag distance + Braking distance

$$= 0.278 \times V \times t_r + \frac{V^2}{254(\eta f - s)}$$

$$= 0.278 \times 60 \times 2.5 + \frac{60^2}{254(0.6\,(0.7) - 0.02)}$$

$$= 41.7 + 35.4$$

$$= 77.1 \text{ m}$$

End of Solution

Q.23 A 2 m wide strip footing is founded at a depth of 1.5 m below the ground level in a homey, pure clay bed. The clay bed has unit cohesion 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

(a) decrease
(b) become zero
(c) remain the same
(d) increase

Ans. **(c)**

Ultimate bearing capacity, $q_u = CN_c^{5.7} + \gamma Df N_q^{1} + 0.5\, B\gamma N_\gamma^{0}$

$$q_u = 5.7C + \gamma Df$$

$$q_{nu} = 5.7C \qquad [\because q_{nu} = (q_u - r_f)_f]$$

Net ultimate bearing capacity,

So, q_{nu} does not depend on presence of water table.

End of Solution

Q.24 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 increased.
(b) Area of tension reinforcement is increased.
(c) Area of compression reinforcement is decreased.
(d) Area of tension reinforcement is decreased.

Ans. **(d, a)**

For URS, $x_u < x_{u,\ lim}$

For Doubly reinforced beam,

$$x_v = \frac{0.87 f_y A_{st} - (fsc - 0.45fck)A_{sc}}{0.36fck\ B}$$

$x_v(\downarrow)$ if $A_{st}(\downarrow)$ and $A_{sc}(\uparrow)$

End of Solution

Q.25 The smallest positive root of the equation

$x^5 - 5x^4 - 10x^3 + 50x^2 + 9x - 45 = 0$ lies in the range

(a) $0 < x \le 2$ (b) $6 \le x \le 8$

(c) $10 \le x \le 100$ (d) $2 < x \le 4$

Ans. **(a)**

Taking option (a) $0 \le x \le 2$

$$f(0) = 0 - 45 < 0$$

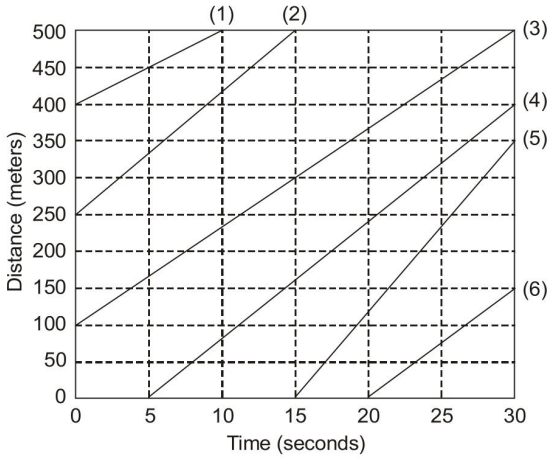
$$f(2) = 2^5 - 5(2)^4 - 10(2)^3 + 50(2)^2 + 9 \times 2 - 45$$

$$= +45 > 0$$

$\left.\begin{matrix} f(0) < 0 \\ f(2) > 0 \end{matrix}\right] \Rightarrow$ hence there will be one root in this interval which will be smallest root as per the given option.

End of Solution

Q.26 The figure presents the trajectories of six vehicles within a time-space domain. The number in the parentheses represents unique identification of each vehicle



(Figure NOT to scale)

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

Ans. **(57)(54 - 58)**

$$\text{Mean speed, } V_t = \frac{\text{Total distance}}{\text{Total time}}$$

$$= \frac{D_1 + D_2 + D_3 + D_4 + D_5 + D_6}{t_1 + t_2 + t_3 + t_4 + t_5 + t_6}$$

$$= \frac{(500-400)+(500-250)+(500-100)+(400-0)+(350-0)+(150-0)}{(10-0)+(15-0)+(30-0)+(30-5)+(30-15)+(30-20)}$$

$$= 15.71 \text{ m/s}$$

$$= 15.71 \times \frac{18}{5} \text{km/h}$$

$$= 56.556 \text{ kmph}$$

End of Solution

Q.27 A 2 m × 2 m tank of 3 m height has inflow, outflow and stirring mechanisms. Initially, the tank was half filled with fresh water. At t = 0, an inflow of salt a 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 litre/s are initiated. This process can be modelled using the following differential equation.

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

where m is the mass (grams) of 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).

Ans. **(25.5)(24.50 - 25.50)**

Total capacity of tank = 2 × 2 × 3 = 12 m^3

At 50% capacity,

$$\text{Volume } (V_{50}) = 0.5 \times 12 = 6 \text{ m}^3$$

At 75% capacity,

$$\text{Volume } (V_{75}) = 0.75 \times 12 \text{ m}^3 = 9 \text{ m}^3$$

Now, increase in volume $\Delta V = V_{75} - V_{50} = (9 - 6)\text{m}^3 = 3 \text{ m}^3$

Also, Inflow (I) = 2 l/s

Outflow (Q) = 1 l/s

Rate of change storage,

$$\frac{\Delta S}{\Delta t} = I - Q = 2 - 1 = 1 \text{ } l/\text{s}$$

$$= \frac{3000l}{1l/\text{s}} = 3000 \text{ sec}$$

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

$\Rightarrow$ $$\frac{dm}{dt} + \frac{m}{6000 + 3000} = 0.01$$

$$\Rightarrow \quad \frac{dm}{dt} + \frac{m}{9000} = 0.01$$

$$\Rightarrow \quad \frac{dm}{0.01 - \frac{m}{9000}} = dt$$

Integrating both sides

$$\Rightarrow \quad \int_{m_o = 0}^{m} \frac{dm}{0.01 - \frac{m}{9000}} = \int_{t=0}^{t=3000} dt$$

$$\Rightarrow \quad \frac{\left[\ln\left(0.01 - \frac{m}{9000}\right)\right]_0^m}{-\frac{1}{9000}} = (3000 - 0)$$

$$\Rightarrow \quad \ln\left(0.01 - \frac{m}{9000}\right) - \ln 0.01 = -\frac{1}{9000} \times 3000$$

$$\Rightarrow \quad \ln\left(0.01 - \frac{m}{9000}\right) = -4.938$$

$$\Rightarrow \quad 0.01 - \frac{m}{9000} = 7.165 \times 10^{-3}$$

$$\Rightarrow \quad m = 25.5 \text{ gm}$$

End of Solution

Q.28 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) 1, 2, 5

(c) –5, 1, 2 (d) –5, –1, 2

Ans. **(b)**

$$\lambda_1 + \lambda_2 + \lambda_3 = 8$$

$$\lambda_1 \lambda_2 \lambda_3 = |A| = 10$$

Only option (b) satisfied above condition.

$$1 + 2 + 5 = 8$$

$$1 \times 2 \times 5 = 10$$

End of Solution

Q.29 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 _____ (round off to 2 decimal places).

Ans. **(0.1)(0.09 - 0.11) or (0.55 to 0.65)**

Given: $\sigma_3 = 20\ \text{kN/m}^2$

Back pressure $= 10\ \text{kN/m}^2$

$\Delta u_c = 1\ \text{kPa}$

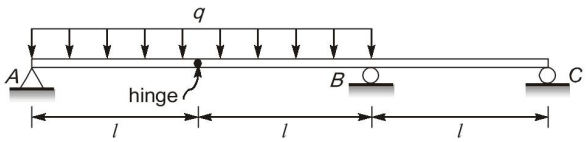
$\sigma_3' = 30\ \text{kN/m}^3$

$\Delta\sigma_3 = (30 - 20)\ \text{kN/m}^2 = 10\ \text{kN/m}^2$

$$B = \frac{\Delta u_c}{\Delta\sigma_3} = \frac{1}{10} = 0.1$$

End of Solution

Q.30 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

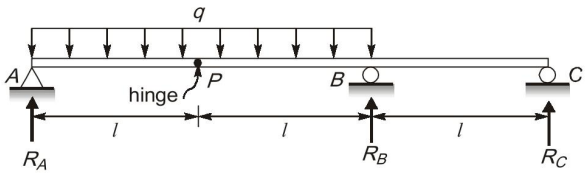
(a) $R_A = \frac{ql}{2}; R_B = \frac{5ql}{2}; R_C = 0$

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

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

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

Ans. (b)



$$BM_P = 0$$

$$R_A(l) = q \cdot l \cdot \frac{l}{2} \quad ...(1)$$

$$-R_C(2l) + (-R_B \times l) + \left(q \times l \times \frac{l}{2}\right) = 0 \quad ...(2)$$

$$R_A + R_B + R_C = q\,(2l) \quad ...(3)$$

From 1, 2 and 3

$$R_A = \frac{ql}{2},\ R_B = \frac{5ql}{2},\ R_C = -ql$$

End of Solution

Q.31 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 bicarbonates ($Ca(HCO_3)_2$) is required based on alum dosage.
Consider the atomic weight as: Ca-40, H-1, C-12, O-16.
The quantity of pure quick lime CaO (in kg) required for this process per day is _____ (round off to 2 decimal places)

Ans. **(99.55)(99 - 100)**

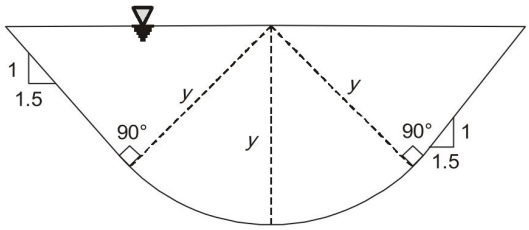
Alkalinity present in water = 4 mg/L
Discharge of raw water = 25 MLD
So,Alkalinity present in water (as $CaCO_3$) = $4 \times 10^{-6} \times 25 \times 10^6$
= 100 kg/day
Now, requirement of $Ca(HCO_3)_2$ = 450 kg/day

Requirement of of $Ca(HCO_3)_2$ as $CaCO_3$ = $\frac{450 \times 50}{81}$ = 277.78 kg/day

Now, additional alkalinity required as $CaCO_3$ = 277.78 – 100 = 177.78 kg/day
100 gm of $CaCO_3$ is equivalent to 56 gm of CaO.
So, 177.78 kg/day of $CaCO_3$ is equivalent to (56/100) × 177.78 i.e. 99.55 kg/day of CaO.
NOTE: In the qiven question,it is not clear whether we should subtract the initially present alkalinity or not.

End of Solution

Q.32 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 $150^{1/2}$/s.



(Figure NOT to scale)

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

Ans. **(1.10)(1.09 - 1.12)**

$$\text{Discharge, } Q = A \times V$$

Now, $$\text{Cross-section area, } A = y^2 (\theta_{\text{radian}} + \cot\theta) = y^2 (0.588 + 1.5)$$
$$= 2.088\, y^2$$

$$\text{Perimeter, } P = 2y (\theta_{\text{radian}} + \cot\theta)$$

$$\text{Hydraulic radius, } R = \frac{A}{P}$$

$$= \frac{y^2 (\theta_{\text{radian}} + \cot\theta)}{2y (\theta_{\text{radian}} + \cot\theta)} = \frac{y}{2}$$

Now, $$\text{Velocity, } V = C\sqrt{R.S} = 150\sqrt{\left(\frac{y}{2}\right) \times \frac{1}{200}} = \frac{150}{20} y^{1/2}$$

Now, $$Q = A \times V$$

$$20 = 2.088\, y^2 \times \frac{150}{20} \cdot y^{1/2}$$

$\Rightarrow$ $$y = 1.10 \text{ m}$$

End of Solution

Q.33 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).

Ans. **(1575)(1550 - 1600)**

As we know, $(T_v)_{50} = \dfrac{C_v t}{d^2}$ where, C_v is coefficient of consolidation

$$\frac{\pi}{4}(0.5)^2 = \frac{C_v}{d^2} \times t_2 \qquad ...(1)$$

For 10 mm settlement, $\%U = \dfrac{\Delta h}{\Delta H} \times 100 = \dfrac{10}{50} \times 100\% = 20\%$

$$(T_v)_{20} = \frac{C_v}{d^2} \times t$$

$$\Rightarrow \quad \frac{\pi}{4}(0.2)^2 = \frac{C_v}{d^2} \times 300 \qquad ...(2)$$

$$\Rightarrow \quad \frac{\frac{\pi}{4}(0.5)^2}{\frac{\pi}{4}(0.2)^2} = \frac{\frac{C_v}{d^2} \times t_2}{\frac{C_v}{d^2} \times 300}$$

$$\Rightarrow \quad t_2 = \left(\frac{0.5}{0.2}\right)^2 \times 300 = 1875 \text{ days}$$

Additional number of days = (1875 – 300) days = 1575 days

End of Solution

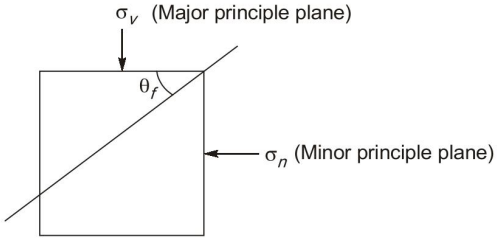
Q.34 A vertical smooth rigid retaining wall is supporting horizontal ground with dry cohesionless backfill having a friction angle of 30°. The inclinations of failure planes with respect to the major principal plane for Rankine's active and passive earth pressure condition, respectively are ____.

(a) 30° and 30° (b) 30° and 60°

(c) 60° and 60° (d) 60° and 30°

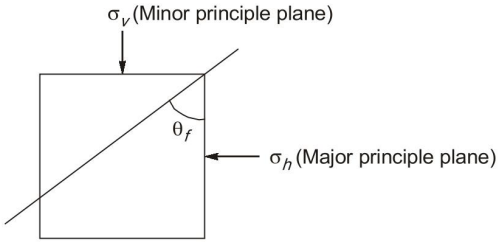
Ans. **(c)**

For Rankine's active pressure condition



where, $\theta_f = 45° + \dfrac{\phi}{2} = 45° + \dfrac{30°}{2} = 60°$

For Rankine's passive pressure condition



where, $\theta_f = 45° + \frac{\phi}{2} = 45° + \frac{30°}{2} = 60°$

End of Solution

Q.35 An infinite slope is made up of cohesionless soil with seepage parallel to and upto the sloping surface. The angle of slope is 30° with respect to horizontal ground surface. The unit weight of the saturated soil and water are 20 kN/m^3 and 10 kN/m^3 respectively.

The minimum angle of shearing resistance of soil (in degrees) for the critically stable condition of the slope is _____. (rounded off to the nearest integer).

Ans. **(49.10)(48.00 - 50.00)**

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

Here, $\beta = 30°$

$\gamma_{sat} = 20$ kN/m^3

$\gamma_w = 10$ kN/m^3

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

$= 20 - 10 = 10$ kN/m^3

For critically stable condition, FOS = 1

$\because \quad 1 = \frac{20-10}{20} \times \frac{\tan\phi}{\tan 30°}$

$\Rightarrow \quad \phi = 49.10°$

End of Solution

Q.36 The number of trains and their corresponding speeds for a curved Broad Gauge section with 437 m radius are

- 20 trains at a speed of 40 kmph
- 15 trains at a speed of 50 kmph
- 12 trains at a speed of 60 kmph
- 8 trains at a speed of 70 kmph
- 3 trains at a speed of 80 kmph

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

Ans. **(88)(86 - 90)**

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

$$= \frac{3070}{58}$$

$$= 52.93 \text{ kmph}$$

$$\text{Gauge } (G) = 1750 \text{ mm}$$

$$\therefore \quad \text{Equilibrium cant, } e_{th} = \frac{GV_{avg}^2}{127\,R} = \frac{1750 \times (52.93)^2}{127 \times 437}$$

$$= 88.34$$

$$= 88 \text{ mm (to nearest integer)}$$

End of Solution

Q.37 A vector field $\vec{p}$ and a scalar field r are given by

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

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

Consider the statement 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) Both P and Q are TRUE.
(b) Both P and Q are FALSE
(c) P is TRUE and Q FALSE.
(d) P is FALSE and Q is TRUE.

Ans. **(a)**

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

$$\text{grad } r = \hat{i}\frac{\partial r}{\partial x} + \hat{j}\frac{\partial r}{\partial y} + \hat{k}\frac{\partial r}{\partial z}$$

$$= \hat{i}(12x - 9yz - 2y + 3z) + \hat{j}(8y - 9xz - 2x - z) + \hat{k}(-2z - 9xy + 3x - y)$$

$$\text{So, curl}(\text{grad } \vec{r}) = \vec{\nabla} \times \text{grad } \vec{r}$$

$$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \dfrac{\partial}{\partial x} & \dfrac{\partial}{\partial y} & \dfrac{\partial}{\partial z} \\ (12x - 9yz - 2y + 3z) & (8y - 9xz - 2x - z) & (-2z - 9xy + 3x - y) \end{vmatrix}$$

$$= \hat{i}(-9x - 1 + 9x + 1) - \hat{j}(-9y + 3 + 9y - 3) + \hat{k}(-9z - 2 + 9z + 2)$$

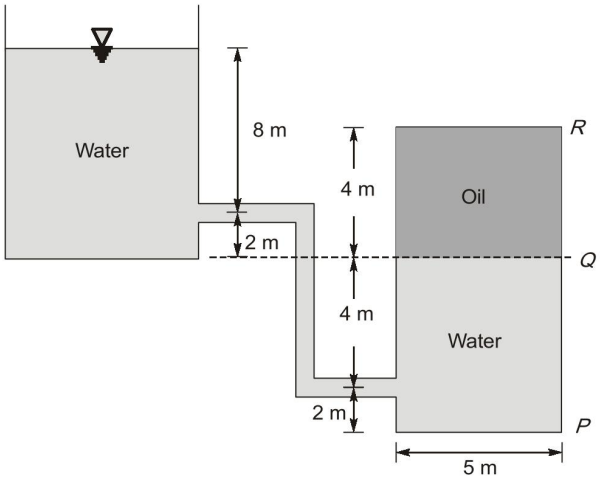
$$P = \vec{0} \text{ i.e. } P = \text{curl (grad } \vec{r}) = \vec{0}$$

$$Q = \text{div (curl } \vec{P}) = 0 \text{ (By vector identity)}$$

Hence both are true. Hence option (a).

End of Solution

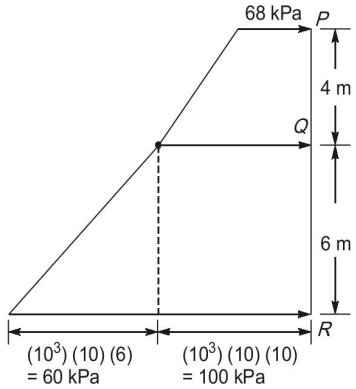
Q.38 A 5 m × 5 m closed tank of 10 m height contains water and oil, is connected to an overhead water reservoir as shown in the figure.
Use γ_w = 10 kN/m^3 and specific gravity of oil = 0.8.



(Figure NOT to scale)

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

Ans. **(5580)(5575 - 5585)**



$P_P + (800)(10)(4) = (10^3)(10)(10)$, where P_p is pressure at P

$P_P + (32 \times 10^3) = (100 \times 10^3)$

$P_P = 68 \times 10^3$ Pa

$P_P = 68$ kPa

Now, force on PQR, $F = \left[\frac{1}{2}(68+100)4 + \frac{1}{2}(100+160)6\right]5$

$= (336 + 780)5$

$= 5580$ kN

End of Solution

Q.39 For assessing the compliance with the emissions standards of incineration plants, correction needs to be applied to the measured concentrations of air pollutants. The emission standard (based on 11% Oxygen) for HCl is 50 mg/Nm^3 and the measured concentrations of HCl 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 the emission standard

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

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

Ans. **(d)**

As per CPCB, oxygen correction factor is calculated as shown below–

$$E_s = \frac{(21 - 0_s)E_m}{21 - 0_m} \quad \text{...(i)}$$

Where

E_s = Calculated emission concentration in % at the standard percentage oxygen concentration in %

E_m = Measured emission concentration in %

0_s = Standard oxygen concentration in %

0_m = Measured oxygen concentration in %

Note : This correction is done only when measured % oxygen concentration is higher than standard % oxygen (i.e. 11%)

So, $$E_s = \frac{21-11}{21-13} \times 42 = 52.5 \text{ Mg/Nm}^3$$

Hence, no compliance, the corrected HCl emission is greater than emission standard i.e. 50 mg/Nm^3.

End of Solution

Q.40 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 incompressible and the flow is irrotational.

(b) The fluid is compressible and the flow is rotational.

(c) The fluid is incompressible and the flow is rotational.

(d) The fluid is compressible and the flow is irrotational.

Ans. (c)

Continuity equation for incompressible flow :

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y} = 0$$

$$\frac{\partial}{\partial x}(3)+\frac{\partial}{\partial y}(5x) = 0 + 0$$

$$= 0 \text{ (Incompressible Flow)}$$

$$\omega_z = \frac{1}{2}\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right) = \frac{1}{2}\left[\frac{\partial}{\partial x}(5x)-\frac{\partial}{\partial y}(3)\right]$$

$$= \frac{1}{2}(5) = 2.5 \neq 0 \text{ (Flow is rotational)}$$

End of Solution

Q.41 A spillway has unit discharge of 7.5 $m^3/s/m$. The flow depth at the downstream horizontal apron is 0.5 m. The tail water depth (in meters) required to form a hydraulic jump is _____. (rounded off to 2 decimal places).

Ans. **(4.54)(4.40 - 4.70)**

Unit discharge(q) = 7.5 $m^3/s/m$

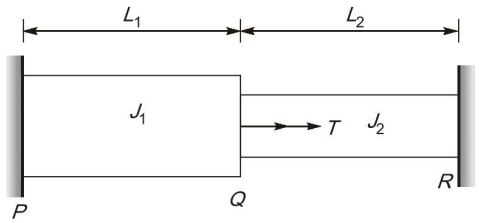
$$\frac{q^2}{g} = \frac{y_1 y_2 (y_1 + y_2)}{2}$$

$$\frac{7.5^2}{9.81} = 0.5y_2\left(\frac{0.5 + y_2}{2}\right)$$

Tail water depth, y_2 = 4.54 m

End of Solution

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.



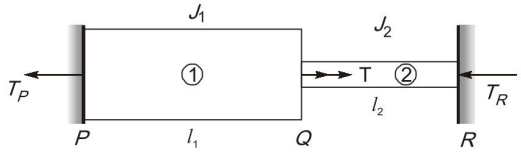
(Figure NOT to scale)

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

(a) 4.00 (b) 2.00

(c) 0.50 (d) 0.25

Ans. (c)



Let T_P and T_R be the resistive torques at support P and R respectively
From equilibrium. Condition,

$$T_P + T_R = T$$

$\because$ $$T_P = 4\ T_R$$

$\Rightarrow$ $$T_R = \frac{T}{5} \text{ and } T_P = \frac{4T}{5}$$

$$\theta_{PQ} + \theta_{QR} = 0$$

$$\frac{T_P L_1}{GJ_1} + \frac{T_R L_2}{GJ_2} = 0$$

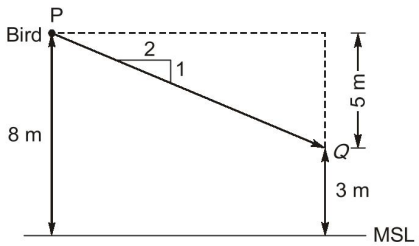
$$\frac{4T/5\, L_1}{J_1} + \frac{T/5\, L_2}{J_2} = 0$$

For $J_1 = 2\ J_2$, $$\frac{L_1}{L_2} = \frac{1}{2}$$

End of Solution

Q.43 A bird is resting on a point P at a height of 8 m 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 m 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).

Ans. (10)(10.0 - 10.0)



For a falling gradient of 1 in 2,
$\therefore$ For vertical distance of 5 m between P and Q,
Horizontal distance between P and Q

$$= 5 \times 2$$
$$= 10 \text{ m}$$

End of Solution

Q.44 The free mean speed is 60 km/hr on a given road. The average space headway at jam density on the road is 8 m. For a linear speed density relationship the maximum flow (in veh/hr/lane) expected on the road is

(a) 2075 (b) 1875

(c) 938 (d) 1038

Ans. **(b)**

Given, Free mean speed, $V_f = 60$ kmph

Speed headway, $s = 8$ m

$$\text{At jam density, } k = k_j = \frac{1000}{s} = \frac{1000}{8} = 125 \text{ veh/km}$$

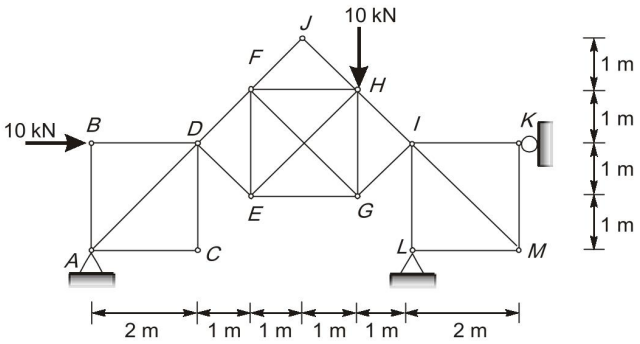
For linear speed density relationship,

$$\text{Maximum flow, } q_{max} = \frac{V_f k_j}{4}$$

$$= \frac{60 \times 125}{4} = 1875 \text{ veh/hr}$$

End of Solution

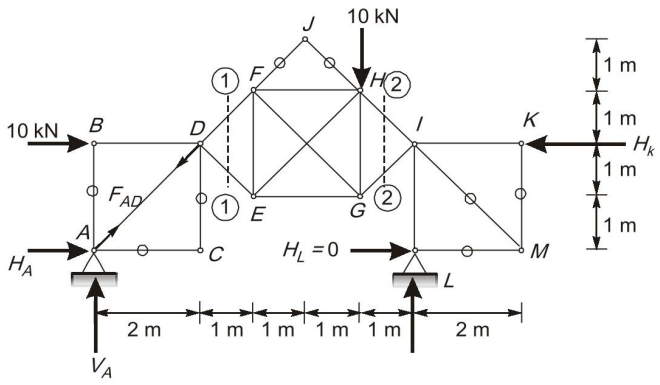
Q.45 The plane truss shown in the figure has 13 joints and 22 members. The truss is made of a homogeneous, prismatic, linearly elastic material. All members have identical axial rigidity. A to M indicate the joints of the truss. The truss has pin supports at joints A and L and roller support at joint 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



(Figure NOT to scale)

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

Ans. (7.5)(7 - 8)



Considering left portion of section 1-1

$$\Sigma M_D = 0$$

$$\Rightarrow \quad V_A \times 2 - H_A \times 2 = 0$$

$$\Rightarrow \quad V_A = H_A \qquad \ldots(i)$$

Considering right portion of section 2 - 2

$$\Sigma M_I = 0 \Rightarrow H_L \times 2 = 0$$

$$\Rightarrow \quad H_L \times 2 = 0$$

Considering left portion of section 2 - 2

$$\Sigma M_I = 0 \Rightarrow V_A \times 6 - H_A \times - 10 \times 1 = 0$$

$$\Rightarrow \quad 6V_A - 2H_A = 10$$

$$\Rightarrow \quad V_A = 2.5 \text{ kN} \qquad [\because H_A = V_A]$$

Now, $\Sigma F_y = 0$

$$\Rightarrow \quad V_A + V_L - 10 = 0$$

$$\Rightarrow \quad V_L = 7.5 \text{ kN}$$

End of Solution

Q.46 Activated carbon is used to remove a pollution 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).

Ans. (7.9)(7.8 - 8.0)

For first order kinetics,

$$N_t = N_0 e^{-kt}$$

For efficiency of 95%,

$$N_t = \left(1 - \frac{95}{100}\right) L_0$$

$$= 0.05\, N_0$$

$$\therefore \quad 0.05 = e^{-0.38t}$$

Taking ln on both sides,

$$\ln 0.05 = -0.38t \times \ln e$$

$$\Rightarrow \quad t = 7.9 \text{ days}$$

End of Solution

Q.47 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) 35%

(c) 10% (d) 30%

Ans. **(c)**

Given, contour Interval = 1 m

Distance between contour in map = 10 mm

$$\text{Map scale} = \frac{1}{1000}$$

$\therefore$ Distance between contour = 10×1000

$= 10{,}000$ mm

$$\Rightarrow \quad \text{Gradient} = \frac{\text{Contour Interval}}{\text{Distance between contour}}$$

$$= \frac{1000 \text{ mm}}{10{,}000 \text{ mm}}$$

$$= \frac{1}{10} = \frac{1}{10} \times 100 = 10\%$$

End of Solution

Q.48 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).

Ans. **(22)(21 - 23)**

$$\Rightarrow \quad \text{Risk} = 1 - \left[\frac{\lambda^r \cdot e^{-\lambda}}{r!}\right]$$

$$= 1 - \left[\frac{\lambda^0 \cdot e^{-\lambda}}{0!}\right]$$

$$\lambda = np = 50 \times \frac{1}{200} = 0.25$$

Now, $\text{Risk} = 1 - [e^{-0.25}]$

$= 0.2211$ or 22.11%

End of Solution

Q.49 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).

Ans. **(100)(99 - 102)**

Effective depth, $d = 250$ mm

Reinforcement, $A_{st} = 0.2\%$

Diameter of bar, $\phi = 8$ mm

$S = ?$

$$A_{st}(\text{in } \%) = \frac{A_{st}}{B.d} \times 100$$

$$\Rightarrow \quad 0.2 = \frac{\left(n \times \frac{\pi}{4}\phi^2\right) \times 100}{B.d}$$

$$\Rightarrow \quad \frac{0.2}{100} = \frac{\left(\frac{B}{S}\right) \times \frac{\pi}{4} \times 8^2}{B \times 250}$$

where S is spacing

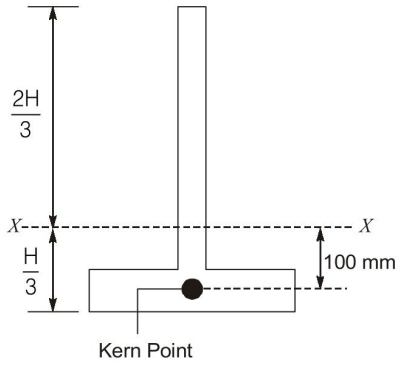
$$\Rightarrow \quad S = \frac{\frac{\pi}{4} \times 8^2 \times 100}{0.2 \times 250}$$

$$S = 100.53 \text{ mm}$$

Provide spacing 100 mm.

End of Solution

Q.50 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.



(Figure NOT to scale)

The additional cracking moment (in KNm) that can be carried by beam B1 m comparison to beam B2 is _____. (rounded off to the nearest integer).

Ans. **(300)(299 - 301)**

At bottom fibre,

$$\frac{P}{A}+\frac{Pey_b}{I}-\frac{M_{cr}}{I}y_b = 0 \qquad \text{...(i)}$$

where P = Prestressing force

e = Eccentricity of P-force

M_{cr} = cracking moment for beam B1

y_t and y_b are distance of top and bottom fibre from neutral axis respectively,

At top fibre

$$\frac{P}{A}-\frac{Pey_t}{I} = 0 \qquad \text{[P-force is at kern point]}$$

$$\Rightarrow \quad \frac{I}{A} = ey_t \qquad \text{...(ii)}$$

Putting (ii) in (i)

$$\frac{M_{cr}}{I}y_b = \frac{P}{A}+\frac{Pey_t}{I}$$

$$\Rightarrow \quad M_{cr} = \frac{Pl}{Ay_b}+Pe$$

$$= \frac{Pey_t}{y_b}+Pe$$

$$= \frac{Pe(2H/3)}{(H/3)}+Pe$$

$$= 3Pe = 3\times 1000\times\frac{100}{1000} = 300 \text{ kNm}$$

End of Solution

Q.51 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).

Ans. (87)(86.0 – 88.0)

	(I)	(II)	(III)	(IV)	(V) = IV/3
Time (hr)	Ordinate (m^3/s)	Lagged by 1 Hrs	Lagged by 2 Hrs	Ordinate of 3 Hrs DRH	Ordinate of 3 H UH
0	0	–	–	0	0
1	13	0	–	13	4.33
2	50	13	0	63	21
3	80	50	13	143	47.67
4	95	80	50	225	75
5	85	95	80	260	86.67
6	55	85	95	235	78.33
7	35	55	85	175	58.33
8	15	35	55	105	35
9	10	15	35	60	20
10	3	10	15	28	9.33
11	0	3	10	13	4.33
12		0	3	3	1
13			0	0	0
14					

Maximum ordinate of 3H UH is 86.67 m^3/s

Maximum ordinate is 87 m^3/s (to nearest integer)

End of Solution

Q.52 Which of the following statement(s) is/are CORRECT?

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

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

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

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

Ans. (a, d)

(i) Lower is the shrinkage → Higher is the swelling and shrinkage

(ii)

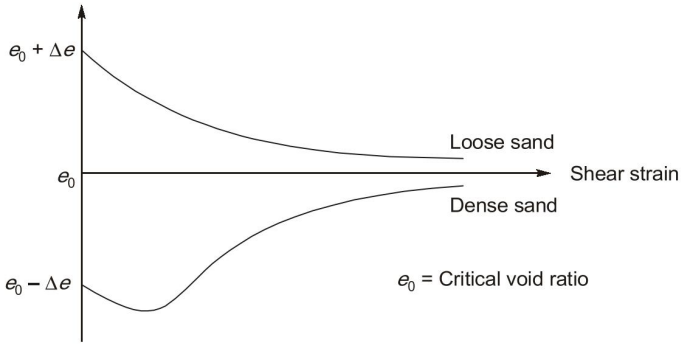


Fig. Shear strain vs Void ratio curve

(iii) Over burden correction is applied before dilatancy correction.

End of Solution

Q.53 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 Drainage Factor (VDF) are equal

The cumulative standard axle (in msa) for the pavement design is _____. (rounded off to 2 decimal places)

Ans. **(33.22)(33.10 - 33.30)**

Number of commercial vehicles = 800 vehicles per day
For vehicle growth rate of 4%,
Number of commercial vehicles after construction period,

$$A = 800 \times [1 + 0.04]^5 = 973.32 \text{ veh}$$

$$\text{Vehicle damage factor, } F = \left(\frac{L_0}{L_5}\right)^4 = \left(\frac{12000}{8160}\right)^4 = 4.67$$

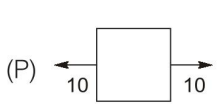
$\therefore$ Cumulative standard axle (in msa)

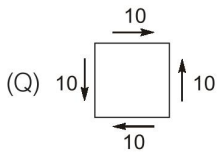
$$= \frac{365\,ADF\left((1+r)^n - 1\right)}{r \times 10^6} \times LSF = \frac{365 \times 973.32 \times 1 \times 4.67 \times \left[1.04^{15} - 1\right]}{0.04 \times 10^6} = 33.22 \text{ msa}$$

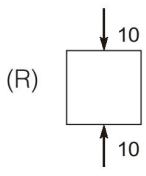
NOTE: As per GATE answer key, anwer is given as 40.60 which is incorrect.

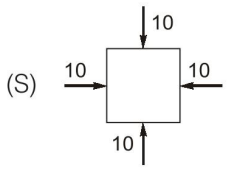
End of Solution

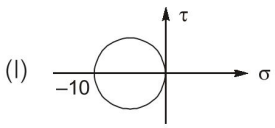
Q.54 Find the correct match between the plane stress states and the Mohr's circles.

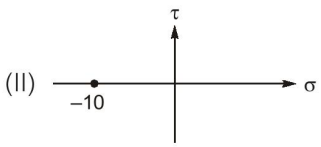


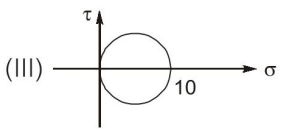


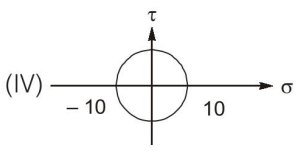












(a) (P)-(III): (Q)-(IV); (R)-(I); (S)-(II)
(b) (P)-(III); (Q)-(II): (R)-(I): (S)-(IV)
(c) (P)-(I): (Q)-(IV): (R)-(III). (S)-(II)
(d) (P)-(I) (Q)-(II). (R)-(III); (S)-(IV)

Ans. **(a)**

End of Solution

Q.55 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)

Ans. **(6000)(6000 - 6000)**

Given:

Initial cost, C_i = Rs. 1,00,000

Salvage value, C_s = Rs. 10,000

Useful life, n = 5 years

Straight line method,

Depreciation, $D = \dfrac{C_i - C_s}{n}$

$= \dfrac{10^5 - 10^4}{5}$

= Rs.18,000

As per double declining method,

Fixed factor, FDDB $= \dfrac{2}{n} = \dfrac{2}{5} = 0.4$

$\therefore$ D_1 = FDDB × C_i = 0.4 × 1,00,000 = 40,000 Rs

Book value, B_1 = Rs.1,00,000 – Rs.40,000 = Rs.60,000

Now, D_2 = FDDB × B_1 = 0.4 × 60,000

= Rs.24,000

$\therefore$ Difference in depreciation = Rs.24,000 – Rs.18,000

= Rs.6000

End of Solution

■■■■