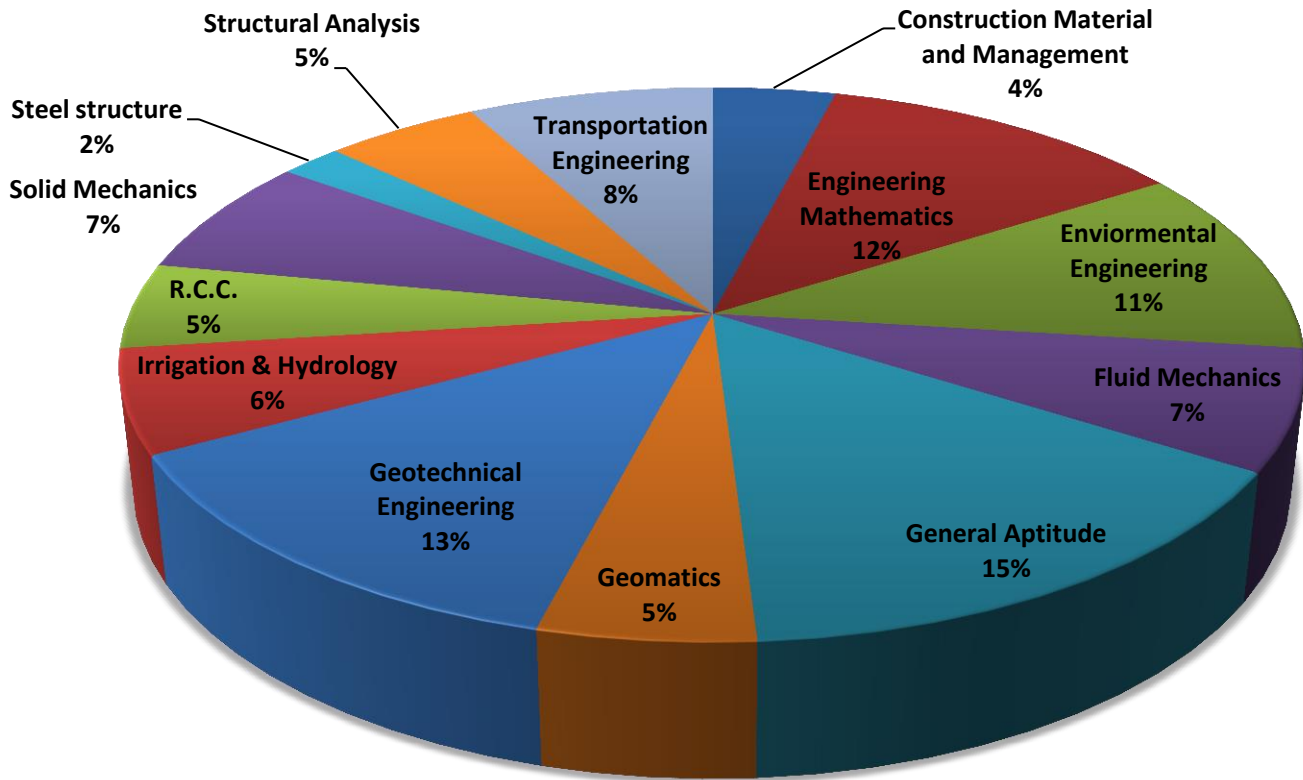


ANALYSIS OF GATE 2017* Civil Engineering



CE ANALYSIS-2017_12-Feb_Afternoon

SUBJECT	No. of Ques.	Topics Asked in Paper(Memory Based)	Level of Ques.	Total Marks
Engineering Mathematics	1 Marks:4 2 Marks:4	Vector, Probability, Matrix, Definite Integrals, Differential Equation	Medium	12
Fluid Mechanics	1 Marks:1 2 Marks:3	Centrifugal Pump, Open Channel Flow	Tough	7
Environmental Engineering	1 Marks:3 2 Marks:4	Noise Pollution, Activated Sludge Process, Air Pollution, Solid Waste Management, Characteristics of Sewage, Quality Control of Water, Water Treatment	Tough	11
Structural Analysis	1 Marks:1 2 Marks:2	Kinematics Indeterminacy	Easy	5
R.C.C.	1 Marks:1 2 Marks:2	Concrete Technology, PSC	Medium	5
Geotechnical Engineering	1 Marks:5 2 Marks:4	Seepage Analysis, Bearing Capacity, Compaction, Earth Pressure, Shear Strength, Stability of Slopes, Pile Foundations, Stress Distribution	Medium	13
Transportation Engineering	1 Marks:4 2 Marks:2	Railway Engineering, Rigid Pavements	Easy	8
CMM	1 Marks:2 2 Marks:1	CPM & PERT	Medium	4
Irrigation & Hydrology	1 Marks:2 2 Marks:2	Infiltration, Thiessen Polygon Method, Water Requirement of Crops	Easy	6
Solid Mechanics	1 Marks:1 2 Marks:3	Stress & Strain	Medium	7
Steel structure	1 Marks:0 2 Marks:1	Miscellaneous	Easy	2
Geomatics	1 Marks:1 2 Marks:2	Plane Table surveying, Levelling	Easy	5
General Aptitude	1 Marks:5 2 Marks:5	Dice,	Medium	15
Total	65			100
Faculty Feedback	Majority of the question were concept based. GT, ENV, Trans. and Hydrology weightage was comparatively high. GA was medium as compared to the last year and overall paper was easy.			

GATE 2017 Examination*
Civil Engineering

Test Date: 12/02/2017
Test Time: 2:00 PM 5:00 PM
Subject Name: Civil Engineering

Section I General Aptitude

1. What is the value of x when $81 \times \left(\frac{16}{25}\right)^{x+2} \div \left(\frac{3}{5}\right)^{2x+4} = 144$?

- (A) 1 (C) -2
(B) -1 (D) Cannot be determined

[Ans. B]

$$81 \times \left(\frac{16}{25}\right)^{x+2} \div \left(\frac{3}{5}\right)^{2x+4} = 144$$

$$\frac{\left(\frac{16}{25}\right)^{x+2}}{\left(\frac{3}{5}\right)^{2x+4}} = \frac{144}{81} = \frac{(12)^2}{(9)^2} = \left(\frac{12}{9}\right)^2$$

$$\frac{\left(\frac{4}{5}\right)^{2x+4}}{\left(\frac{3}{5}\right)^{2x+4}} = \left(\frac{12}{9}\right)^2$$

$$\frac{(4)^{2x+4}}{(5)^{2x+4}} \times \frac{(5)^{2x+4}}{(3)^{2x+4}} = \left(\frac{12}{9}\right)^2$$

$$\frac{(4)^{2x+4}}{(3)^{2x+4}} = \left(\frac{12}{9}\right)^2 = \left(\frac{4}{3}\right)^2$$

$$\left(\frac{4}{3}\right)^{2x+4} = \left(\frac{4}{3}\right)^2$$

$$2x + 4 = 2$$

$$2x = -2$$

$$x = -1$$

2. Two dice are thrown simultaneously. The probability that the product of the numbers appearing on the top faces of the dice is a perfect square is

- (A) 1/9 (C) 1/3
(B) 2/9 (D) 4/9

[Ans. B]

Total chances = $6 \times 6 = 36$ events

Product of numbers on 2 dice have to perfect square = Favorable chances

= (1,1), (2,2), (1,4), (3,3), (4,1), (5,5), (4,4), (6,6) = 8

$$\text{Probability} = \frac{\text{Favourable chances}}{\text{Total chances}} = \frac{8}{36} = \frac{2}{9}$$

3. The event would have been successful if you _____ able to come.
 (A) are (C) have been
 (B) had been (D) Would have been

[Ans. B]

Conditional tense type (3 had+V3 +would have +V3)

4. Four cards lie on a table. Each card has a number printed on one side and a colour on the other.

The faces visible on the cards are 2,3, red, and blue.

Proposition: If a card has an even value on one side, then its opposite face is red.

The cards which MUST be turned over to verify the above proposition are

- (A) 2, red (C) 2, blue
 (B) 2, 3, red (D) 2 red, blue

[Ans. C]

Total number of cards = 4

Visible numbers on the cards = 2 and 3

Visible colours on the cards = red and blue

If numbers on the cards = 1,2,3 and 4 then possible colours are blue, red, blue and red respectively.

In order to verify the proposition, we have to turn to card 2 then opposite must be red. In all options except 'C' 2 and red are present

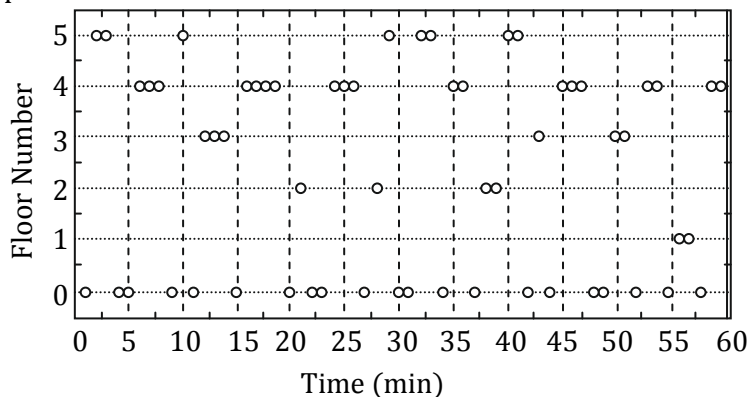
5. There was no doubt that their work was thorough
 Which of the words below is closet in meaning to the underlined word above?

- (A) pretty (C) sloppy
 (B) complete (D) haphazard

[Ans. B]

Thorough means including every possible detail, parts or complete or absolute.

6. The points in the graph below represent the halts of a lift for durations of 1 minute, over a period of 1 hour.



Which of the following statements are correct?

- i. The elevator never moves directly from any non-ground floor to another non-ground floor over the one hour period

ii. The elevator stays on the fourth floor for the longest duration over the one hour period

- (A) Only i (C) Both i and ii
(B) Only ii (D) Neither i nor ii

[Ans. D]

(i) is in correct as it has move directly

(ii) is incorrect as it stayed for maximum duration on the ground floor

7. P, Q, R, S, T and U are seated around a circular table , R is seated two places to the right of Q, P is seated three places to the left of R.S is seated opposite U. If P and U now switch seats, which of the following must necessarily be true?

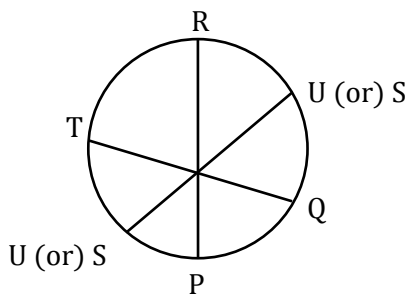
- (A) P is immediately to the right of R
(B) T is immediately to the left of P
(C) T is immediately to the left of P or P is immediately to the right of Q
(D) U is immediately to the right of R or P is immediately to the left of T

[Ans. C]

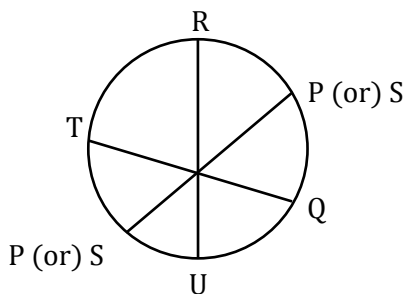
From the given data, all are seated around a circular table as follows

P Q – R

S is opposite to U



P and U are switch seated means, they are interchange their places



In option (C), before interchange T is immediately to the left of P and After interchange P is immediately to the right of Q

8. A map shows the elevation of Darjeeling, Gangtok, Kalimpong, Pelling, and Siliguri. Kalimpong is at a lower elevation than Gangtok. Pelling is at a lower elevation than Gangtok. Pelling is at a higher elevation than siliguri. Darjeeling is at a higher elevation than Gangtok. Which of the following statements can be inferred from the paragraph above?
- Pelling is at a higher elevation than Kalimpong
 - Kalimpong is at a lower elevation than Darjeeling
 - Kalimpong is at a higher elevation than Siliguri
 - Siliguri is at lower elevation than Gangtok
- (A) Only ii (C) Only ii and iv
(B) Only ii and iii (D) Only iii and iv

[Ans. C]

9. Budhan covers a distance of 19 km in 2 hours by cycling one fourth of the time and walking the rest. The next day he cycles (at the same speed as before) for half the time and walks the rest (at the same speed as before) and covers 26 km in 2 hours. The speed in km/h at which Budhan walks is
- (A) 1 (C) 5
(B) 4 (D) 6

[Ans. D]

$$19 \text{ km} \rightarrow 2 \text{ hours} \left\{ \begin{array}{l} \text{Cycling} \Rightarrow \frac{1}{4} \text{th} = 2 \times \frac{1}{4} = \frac{1}{2} \\ \text{Walking} \Rightarrow \frac{3}{4} \text{th} = 2 \times \frac{3}{4} = \frac{3}{2} \end{array} \right.$$

Let cycling speed = C

Walking speed = W

$$\frac{C}{2} + \frac{3W}{2} = 19 \dots\dots \textcircled{1}$$

$$26 \text{ km} \rightarrow 2 \text{ hours} \left\{ \begin{array}{l} \text{Cycling} \Rightarrow \frac{1}{2} \text{th} = 2 \times \frac{1}{2} = 1 \\ \text{Walking} \Rightarrow \frac{1}{2} \text{th} = 2 \times \frac{1}{2} = 1 \end{array} \right.$$

$$C + W = 26 \dots\dots \textcircled{2}$$

By solving equation number ① and ②

$$W = 6 \text{ km/hr}$$

∴ The speed at which Budhan walks = 6 kmph

10. Bhaichung was observing the pattern of people entering and leaving a car service centre. There was a single window where customers were being served. He saw that people inevitably came out of the centre in the order that they went in. However, the time they spent inside seemed to vary a lot:
Some people came out in a matter of minutes while for others it took much longer.
From this, what can one conclude?
- (A) The centre operates on a first-come –first-served basis, but with variable service times, depending on specific customer needs.

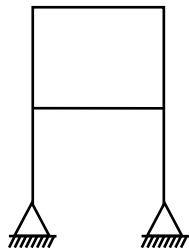
- (B) Customers were served in an arbitrary order, since they took varying amounts of time for service completion in the centre.
- (C) Since some people came out within a few minutes of entering the centre, the system is likely to operate on a last-come-first-served basis.
- (D) Entering the centre early ensured that one would have shorter service times and most people attempted to do this.

[Ans. A]

The key sentence is “the order that they went in”

Section II Technical

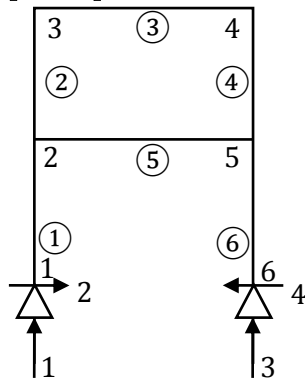
1. Consider the frame shown in the figure.



If the axial and shear deformations in different members of the frame are assumed to be negligible, the reduction in the degree of kinematical indeterminacy would be equal to

- (A) 5
- (B) 6
- (C) 7
- (D) 8

[Ans. B]



$r = 4; j = 6; m = 6$

Members axially deformable

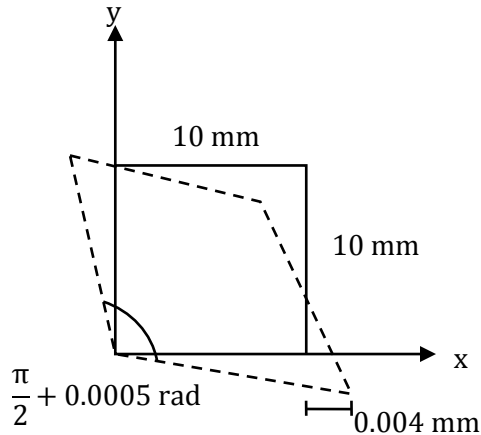
$D_K = 3j - r = 3 \times 6 - 4 = 14$

Members axially rigid

$D_K = 3j - (r + m) = 14 - 6 = 8$

Thus, Reduction in kinematic indeterminacy = $14 - 8 = 6$

2. In a material under a state of plane strain, a 10×10 mm square centered at a point gets deformed as shown in the figure.



If the shear strain γ_{xy} at this point is expressed as $0.001 k$ (in rad), the value of k is

- (A) 0.50 (C) -0.25
(B) 0.25 (D) -0.50

[Ans. D]

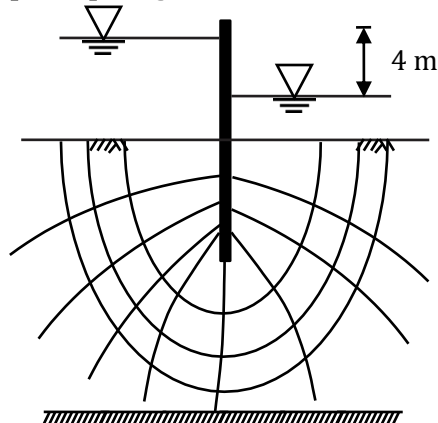
The shear strain = -0.0005

$$\gamma_{xy} = 0.001 (k) = 0.001 \times (-0.5)$$

$$\therefore k = (-)0.5$$

3. A sheet pile has an embedment depth of 12 m in a homogeneous soil stratum. The coefficient of permeability of soil is 10^{-6} m/s. Difference in the water levels between the two sides of the sheet pile is 4 m. The flow net is constructed with five number of flow lines and eleven number of equipotential lines. The quantity of seepage (in cm^3/s per m. up to one decimal place) under the sheet pile is _____

[Ans. *] Range: 1.6 to 1.6



$$K = 10^{-6} \text{ m/s}, H = 4 \text{ m}$$

Number of flow lines = 5 [including boundary flow lines]

$$\therefore \text{Number of flow channels, } N_f = 5 - 1 = 4$$

Number of equipotential lines = 11 (including boundary equipotential lines)

$$\therefore \text{Number of potential drops, } N_d = 11 - 1 = 10$$

$$\begin{aligned} \therefore Q &= kH \frac{N_f}{N_d} \\ &= 10^{-6} \times 4 \times \frac{4}{10} = 1.6 \times 10^{-6} \text{m}^3/\text{s}/\text{m} \\ &= 1.6 \times 10^{-6} \times 10^6 \text{cm}^3/\text{s}/\text{m} \\ &= 1.6 \text{cm}^3/\text{s}/\text{m} \end{aligned}$$

4. During a storm event in a certain period, the rainfall intensity is 3.5 cm/hour and the ϕ -index is 1.5 cm/hour. The intensity of effective rainfall (in cm/hour, up to one decimal place) for this period is__

[Ans. *] Range: 1.9 to 2.1

$$i = 3.5 \text{ cm/hr}$$

$$\phi\text{-Index} = 1.5 \text{ cm/hr}$$

$$\begin{aligned} \text{Effective rainfall intensify ERI} &= (i - \phi) \\ &= (3.5 - 1.5) \\ &= 2 \text{ cm/hr} \end{aligned}$$

5. The infiltration capacity of a soil follows the Horton's exponential model, $f = c_1 + c_2 e^{-kt}$. During an experiment, the initial infiltration capacity was observed to be 200 mm/h. After a long time, the infiltration capacity was reduced to 25 mm/h. If the infiltration capacity after 1 hour was 90 mm/h, the value of the decay rate constant, k (in h^{-1} , up to two decimal places) is_____

[Ans. *] Range: 0.98 to 1.00

$$f_{ct} = f_c + (f_{co} - f_c) e^{-kt}$$

$$f = C_1 + C_2 e^{-kt}$$

$$f = 25 + (200 - 25) e^{-kt}$$

$$f = 25 + 175 e^{-kt}$$

$$f_1 = 25 + 175 e^{-k \times 1} = 90$$

$$k = \ln \left[\frac{90 - 25}{175} \right] = 0.99 \text{ hr}^{-1}$$

6. As per Noise Pollution (Regulation and Control) Rules 2000 of India, the day time noise limit for a residential zone, expressed in dB (A) L_{eq} is

(A) 55

(C) 75

(B) 65

(D) 85

[Ans. A]

As per Indian standard, day time noise level at residential area limited to 55 dB.

7. The safety within a roundabout and the efficiency of a roundabout can be increased, respectively by.

(A) Increasing the entry radius and increasing the exit radius

(B) increasing the entry radius and decreasing the exit radius

(C) Decreasing the entry radius and increasing the exit radius

(D) Decreasing the entry radius and decreasing the exit radius

[Ans. C]

The safety of round about can be achieved by decreasing entry radius (decreases speed at entry) and increasing exit radius (increasing exit speed)

8. The method of orientation used, when the plane table occupies a position not yet located on the map, is called as

(A) Traversing (C) Levelling
(B) Radiation (D) Resection

[Ans. D]

Resection is the process of orientation which can be used to locate a point occupied by a plane table as the map with referring to well defined ground stations.

9. The most important type of species involved in the degradation of organic matter in the case of activated sludge process is

(A) autotrophs (C) prototrophs
(B) heterotrophs (D) photo-autotrophs

[Ans. B]

ASP host heterotrophic aerobic organisms.

10. The plate load test was conducted on a clayey strata by using a plate of 0.3 m × 0.3 m dimensions and the ultimate load per unit area for the plate was found to be 180 kPa. The ultimate bearing capacity (in kPa) of a 2 m wide square footing would be

(A) 27 (C) 1200
(B) 180 (D) 2000

[Ans. B]

For clayey soils, $q_F = q_P$

(i.e. For clayey soil, the bearing capacity is independent of the width.)

11. Let $w = f(x, y)$, where x and y are functions of t . Then, according to the chain rule, dw/dt is equal to

(A) $\frac{dw}{dx} \frac{dx}{dt} + \frac{dw}{dy} \frac{dy}{dt}$ (C) $\frac{\partial w}{\partial x} \frac{dx}{dt} + \frac{\partial w}{\partial y} \frac{dy}{dt}$
(B) $\frac{\partial w}{\partial x} \frac{\partial x}{\partial t} + \frac{\partial w}{\partial y} \frac{\partial y}{\partial t}$ (D) $\frac{dw}{dx} \frac{\partial x}{\partial t} + \frac{dw}{dy} \frac{\partial y}{\partial t}$

[Ans. C]

Let $w = f(x, y)$, where x & y are functions of t

By chain rule, $\frac{dw}{dt} = \frac{\partial w}{\partial x} \frac{dx}{dt} + \frac{\partial w}{\partial y} \frac{dy}{dt}$

12. If a centrifugal pump has an impeller speed of N (in rpm), discharge Q (in m^3/s) and the total head H (in m), the expression for the specific speed N_s of the pump is given by

(A) $N_s = \frac{NQ^{0.5}}{H^{0.5}}$

(C) $N_s = \frac{NQ^{0.5}}{H^{0.75}}$

(B) $N_s = \frac{NQ^{0.5}}{H}$

(D) $N_s = \frac{NQ}{H^{0.75}}$

[Ans. C]

Specific speed of a centrifugal pump

$$N_{SP} = \frac{N\sqrt{Q}}{(H)^{3/4}} = \frac{N \cdot Q^{0.5}}{H^{0.75}}$$

Where N = speed of an impeller (rpm)

Q = Discharge (m^3/sec)

H = Total head developed (m)

13. Let G be the specific gravity of soil solids, w the water content in the soil sample, γ_w the unit weight of water, and γ_d the dry unit weight of the soil. The equation for the zero air voids line in a compaction test plot is

(A) $\gamma_d = \frac{G\gamma_w}{1 + Gw}$

(C) $\gamma_d = \frac{Gw}{1 + \gamma_w}$

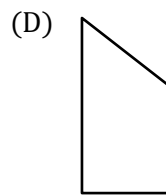
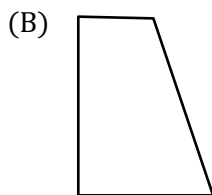
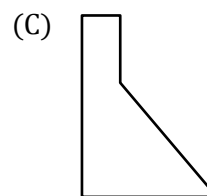
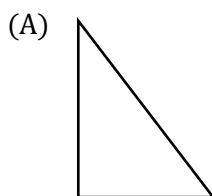
(B) $\gamma_d = \frac{G\gamma_w}{Gw}$

(D) $\gamma_d = \frac{Gw}{1 - \gamma_w}$

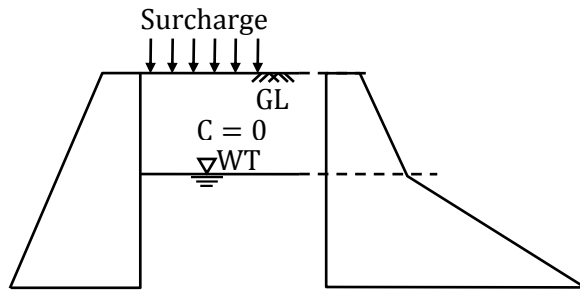
[Ans. A]

Equation of zero air voids line, $\gamma_d = \frac{\gamma_w G}{1 + wG}$

14. Consider a rigid retaining wall with partially submerged cohesionless backfill with a surcharge. Which one of the following diagrams closely represents the Rankine's active earth pressure distribution against this wall?



[Ans. *]



15. Given that the scope of the construction work is well-defined with all its drawings, specifications, quantities and estimates, which one of the following types of contract would be most preferred?

(A) EPC contract
(B) Percentage rate contract
(C) Item rate contract
(D) Lump sum contract

[Ans. D]

16. Following observations have been made for the elevation and temperature to ascertain the stability of the atmosphere

Elevation (in m)	Temperature (in °C)
10	15.5
60	15.0
130	14.3

The atmosphere is classified as

(A) Stable
(B) Unstable
(C) Neutral
(D) Inverse

[Ans. C]

$$ELR = \frac{dT}{dZ} = \frac{T_2 - T_1}{Z_2 - Z_1} = \frac{T_3 - T_2}{Z_3 - Z_1} \times 100$$

$$\frac{15.0 - 15.5}{60 - 10} \times 100 = \frac{14.3 - 15}{130 - 60} \times 100$$

$$ELR = -1^\circ\text{C}/100 \text{ m}$$

$$ALR = -9.8^\circ\text{C}/\text{km} \cong -10^\circ\text{C}/\text{km} = -1^\circ\text{C}/100 \text{ m}$$

$$\therefore ELR = ALR$$

\therefore Neutral atmospheric condition

17. The divergence of the vector field $V = x^2\vec{i} + 2y^3\vec{j} + z^4\vec{k}$ at $x = 1, y = 2, z = 3$ is _____

[Ans. *] Range: 133.9 to 134.1

$$\vec{V} = x^2\vec{i} + 2y^3\vec{j} + z^4\vec{k}$$

$$\text{div } \vec{V} = 2x + 6y^2 + 4z^3$$

$$\text{at } x = 1, y = 2, z = 3$$

$$\text{div } \vec{V} = 2(1) + 6(4) + 4(27) = 134$$

18. Consider the following statements related to the pore pressure parameters, A and B
- P. A always lies between 0 and 1.0
 - Q. A can be less than 0 or greater than 1.0
 - R. B always lies between 0 and 1.0
 - S. B can be less than 0 or greater than 1.0

For these statements, which one of the following options is correct?

- (A) P and R
- (B) P and S
- (C) Q and R
- (D) Q and S

[Ans. C]

$$0 \leq B \leq 1$$

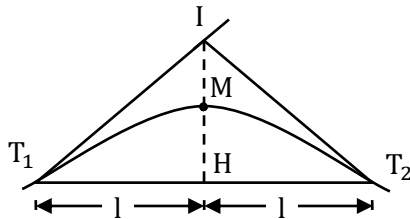
A can be < 0 (i.e. A can be -ve) for heavily OC clays and dense sands

$\left. \begin{array}{l} \text{A can be } > 0 \\ \text{Also A can be } > 1 \text{ also} \end{array} \right\}$ For sensitive clays, NC clays, lightly OC clays

19. The VPI (vertical point of intersection) is 100 m away (when measured along the horizontal) from the VPC (vertical point of curvature). If the vertical curve is parabolic, the length of the curve (in meters and measured along the horizontal) is _____

[Ans. *] Range: 199.99 to 200.01

Since a vertical curve is quite flat for a parabolic curve, a line IH drawn from I (point of intersection) parallel to the axis on the parabola bisects the long chord joining T_1 and T_2 i.e. $T_1H = HT_2$ (Shown in figure).



Vertical curve bisects the distance between I and H, the middle point of $T_1 T_2$ i.e. $IM = MH$

Since the curve is so flat, that the length of the vertical curve $T_1MT_2 = T_1HT_2$ &

$$T_1H = T_1M = IT_1 = IT_2$$

$$\text{Given } IT_1 = 100 \text{ m} = T_1H$$

$$\text{Length of curve} = MT_1 + MT_2 = 100 + 100 = 200$$

20. A two-faced fair coin has its faces designated as head (H) and tail (T). This coin is tossed three times in succession to record the following outcomes: H, H,H. If the coin is tossed one more time, the probability (up to one decimal place) of obtaining H again, given the previous realizations of H, H and H, would be _____

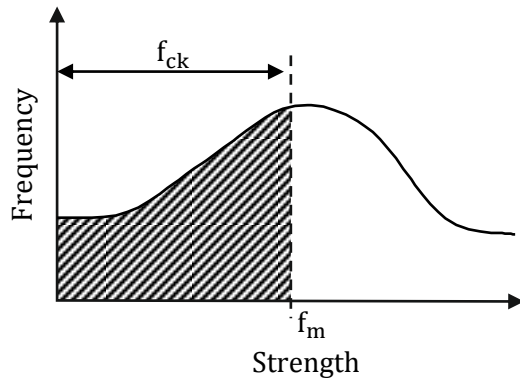
[Ans. *] Range: 0.5 to 0.5

Here, probability remains same for each toss.

$$\therefore \text{Probability of getting head in the 4}^{\text{th}} \text{ toss} = \frac{1}{2} = 0.5$$

21. Let the characteristic strength be defined as that value, below which not more than 50% of the results are expected to fall. Assuming a standard deviation of 4 MPa, the target mean strength (in MPa) to be considered in the mix design of a M25 concrete would be
- (A) 18.42 (C) 25.00
(B) 21.00 (D) 31.58

[Ans. C]



M25, $f_{ck} = 25 \text{ N/mm}^2$

$\sigma = 4 \text{ MPa}$

If 50% of test results are expected to fall then target means strength $f_m = f_{ck}$

$f_m = 25 \text{ N/mm}^2$

22. For a construction project, the mean and standard deviation of the completion time are 200 days and 6.1 days, respectively. Assume normal distribution and use the value of standard normal deviate $z = 1.64$ for the 95% confidence level. The maximum time required (in days) for the completion of the project would be_____

[Ans. *] Range: 209 to 211

Mean = $(\mu) = 200$ days

Std. deviation $(\sigma) = 6.1$ days

$Z = 1.64$ (95% confidence level)

Max time required to complete the project (due date) = ?

$$Z = \frac{X - \mu}{\sigma}$$

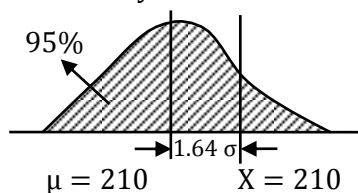
Where $X =$ due date; $\mu =$ mean

$\sigma =$ std. deviation

$$1.64 = \frac{X - 200}{6.1}$$

$$X = 210.004$$

$$X \approx 210 \text{ days}$$



23. For a broad gauge railway track on a horizontal curve of radius R (in m), the equilibrium cant e required for a train moving at a speed of V (in km per hour) is

(A) $e = 1.676 \frac{V^2}{R}$

(C) $e = 0.80 \frac{V^2}{R}$

(B) $e = 1.315 \frac{V^2}{R}$

(D) $e = 0.60 \frac{V^2}{R}$

[Ans. B]

Equilibrium cant = $\frac{GV^2}{127R}$

V in kmph and R in m.

For B.G track G = 1.676

Cant = $\frac{1.676V^2}{127R}$ m

$e = \frac{1.139V^2}{R}$ cm

The unit of e is not specified in question but option b is matching in cm units.

24. While aligning a hill road with a ruling gradient of 6%, a horizontal curve of radius 50 m is encountered. The grade compensation (in percentage, up to two decimal places) to be provided for this case would be _____

[Ans. *] Range: 1.49 to 1.51

Ruling gradient, G = 6% (> 4% grade compensation is allowed as per 1RC)

Radius of curve, R = 50 m

$$\begin{aligned} \text{Grade compensation, GC} &= \frac{30 + R}{R} \\ &= \frac{30 + 50}{50} = 1.6\% \\ &= \frac{75}{R} = \frac{75}{50} = 1.5 \end{aligned}$$

∴ Use min value of GC = 1.5%

25. Consider the following simultaneous equations (with c1 and c2 being constants):

$$3x_1 + 2x_2 = c_1$$

$$4x_1 + x_2 = c_2$$

The characteristic equation for these simultaneous equations is

(A) $\lambda^2 - 4\lambda - 5 = 0$

(C) $\lambda^2 + 4\lambda - 5 = 0$

(B) $\lambda^2 - 4\lambda + 5 = 0$

(D) $\lambda^2 + 4\lambda + 5 = 0$

[Ans. A]

Given

$$3x_1 + 2x_2 = c_1$$

$$4x_1 + x_2 = c_2$$

The given equations can be expressed as

$$\begin{bmatrix} 3 & 2 \\ 4 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix}$$

Where $A = \begin{bmatrix} 3 & 2 \\ 4 & 1 \end{bmatrix}$, $X = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$, $B = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix}$

The characteristic equation of matrix A is

$$|A - \lambda I| = 0$$

$$\Rightarrow \begin{vmatrix} 3 - \lambda & 2 \\ 4 & 1 - \lambda \end{vmatrix} = 0$$

$$\Rightarrow \lambda^2 - 4\lambda - 5 = 0$$

26. Group I gives a list of test methods and test apparatus for evaluating some of the properties of ordinary Portland cement (OPC) and concrete. Group II gives the list of these properties.

Group I	Group - II
P. Le Chatelier test	1. Soundness of OPC
Q. Vee-Bee test	2. Consistency and setting time of OPC
R. Blaine air permeability test	3. Consistency or workability of concrete
S. The Vicat apparatus	4. Fineness of OPC

The correct match of the items in Group I with items in Group II is

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

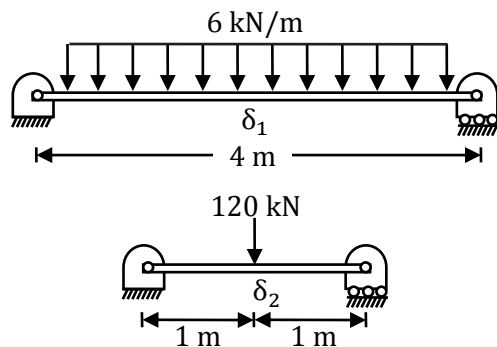
(C) P-4, Q-2, R-4, S-1

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

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

[Ans. A]

27. Two prismatic beams having the same flexural rigidity of 1000 kN-m^2 are shown in the figures.



If the mid-span deflections of these beams are denoted by δ_1 and δ_2 (as indicated in the figures), the correct option is

(A) $\delta_1 = \delta_2$

(C) $\delta_1 > \delta_2$

(B) $\delta_1 < \delta_2$

(D) $\delta_1 \gg \delta_2$

[Ans. A]

Central deflection of beam 1

$$\delta_1 = \frac{5 \times 6 \times 4^4}{384EI} = \frac{20}{EI}$$

Central deflection of beam 2

$$\delta_2 = \frac{120(2)^3}{48EI} = \frac{20}{EI}$$

$$\delta_1 = \delta_2$$

28. The composition of a municipal solid waste sample is given below:

Component	Percent by Mass	Moisture Content (%)	Energy content (kJ/kg, on as –discarded basis)
Food waste	20	70	2500
Paper	10	4	10000
Cardboard	10	4	8000
Plastics	10	1	14000
Garden Trimmings	40	60	3500
Wood	5	20	14000
Tin Cans	5	2	100

The difference between the energy content of the waste sample calculated on dry basis and as discarded basis (in kJ/kg) would be_____

[Ans. *] Range: 3850 to 3900

$$\text{Total energy as discarded} = \frac{\sum P_i E_i}{100} = \frac{P_1 E_1 + P_2 E_2 + \dots + P_n E_n}{100}$$

$$= \frac{[20 \times 2500 + 10 \times 10000 + 10 \times 8000 + 10 \times 14000 + 40 \times 3500 + 5 \times 14000 + 5 \times 100]}{100}$$

$$= 5805 \text{ kJ/kg}$$

$$\text{Moisture content of MSW} = \frac{[20 \times 70 + 10 \times 4 + 10 \times 4 + 10 \times 1 + 40 \times 60 + 5 \times 20 + 5 \times 2]}{100}$$

$$= 40\%$$

$$\text{Total energy on dry basis} = \text{energy as discarded} \times \frac{100}{100 - \%mc}$$

$$= 5805 \times \frac{100}{100 - 40} = 9675 \text{ kJ/kg}$$

$$\text{Difference in energy content} = 9675 - 5805 = 3870 \text{ kJ/kg}$$

29. If $A = \begin{bmatrix} 1 & 5 \\ 6 & 2 \end{bmatrix}$ and $B = \begin{bmatrix} 3 & 7 \\ 8 & 4 \end{bmatrix}$ AB^T is equal to

(A) $\begin{bmatrix} 38 & 28 \\ 32 & 56 \end{bmatrix}$

(C) $\begin{bmatrix} 43 & 27 \\ 34 & 50 \end{bmatrix}$

(B) $\begin{bmatrix} 3 & 40 \\ 42 & 8 \end{bmatrix}$

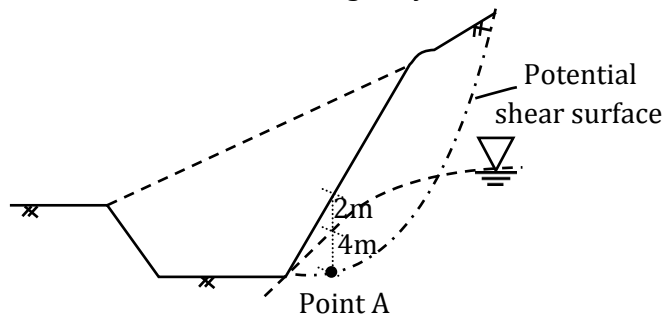
(D) $\begin{bmatrix} 38 & 32 \\ 28 & 56 \end{bmatrix}$

[Ans. A]

$$A = \begin{bmatrix} 1 & 5 \\ 6 & 2 \end{bmatrix} \quad B = \begin{bmatrix} 3 & 7 \\ 8 & 4 \end{bmatrix}, \quad B^T = \begin{bmatrix} 3 & 8 \\ 7 & 4 \end{bmatrix}$$

$$AB^T = \begin{bmatrix} 1 & 5 \\ 6 & 2 \end{bmatrix} \begin{bmatrix} 3 & 8 \\ 7 & 4 \end{bmatrix} = \begin{bmatrix} 3 + 35 & 8 + 20 \\ 18 + 14 & 48 + 8 \end{bmatrix} = \begin{bmatrix} 38 & 28 \\ 32 & 56 \end{bmatrix}$$

30. For the construction of a highway, a cut is to be made as shown in the figure



The soil exhibit $c' = 20$ kPa, $\phi' = 18^\circ$, and the undrained shear strength = 80 kPa. The unit weight of water is 9.81 kN/m³. The unit weights of the soil above and below the ground water table are 18 and 20 kN/m³, respectively. If the shear stress at Point A is 50 kPa, the factors of safety against the shear failure at this point, considering the undrained and drained conditions, respectively, would be

- (A) 1.6 and 0.9
(B) 0.9 and 1.6
(C) 0.6 and 1.2
(D) 1.2 and 0.6

[Ans. A]

The F.O. safety against shear failure, $F = \frac{S}{\tau}$

Given:

$$\tau = 50 \text{ kPa}, C' = 20 \text{ kPa}, \phi' = 18^\circ, S_u = 80 \text{ kPa}$$

$$\text{At point A, the total vertical stress, } \sigma = 2\gamma + 4\gamma_{\text{sat}}$$

$$\sigma = 2 \times 18 + 4 \times 20 = 116 \text{ kPa}$$

$$\text{At point A, the effective vertical stress, } \sigma' = 2\gamma + 4\gamma'$$

$$\sigma' = 2 \times \gamma + 4[\gamma_{\text{sat}} - \gamma_w]$$

$$= 2 \times 18 + 4[20 - 9.81] = 76.76 \text{ kPa}$$

$$\text{Considering undrained condition, } F = \frac{S_u}{\tau} = \frac{80}{50} = 1.6$$

$$\begin{aligned} \text{Considering drained condition, } F &= \frac{S}{\tau} = \frac{C' + \sigma' \tan \phi'}{C} \\ &= \frac{20 + 76.76 \tan 18^\circ}{50} = 0.9 \end{aligned}$$

31. Water is pumped at a steady uniform flow rate of 0.01 m³/s through a horizontal smooth circular pipe of 100 mm diameter. Given that the Reynolds number is 800 and g is 9.81 m/s², the head loss (in meters, up to one decimal place) per km length due to friction would be

[Ans. *] Range: 65.0 to 69.0

$$h_L = \frac{fv^2}{2gd} = \frac{fQ^2}{12.1 \times d^5}$$

For laminar flow ($Re < 2000$),

$$f = \frac{64}{Re} = \frac{64}{800} = 0.08$$

$$h_L = \frac{0.08 \times 1000 \times (0.01)^2}{12.1 \times (0.1)^5} = 66.1 \text{ m}$$

32. Two cars P and Q are moving in a racing track continuously for two hours. Assume that no other vehicles are using the track during this time. The expressions relating the distance travelled d (in km) and time t (in hour) for both the vehicles are given as

P: $d = 60 t$

Q: $d = 60 t^2$

Within the first one hour, the maximum space headway would be

- (A) 15 km at 30 minutes (C) 30 km at 30 minutes
(B) 15 km at 15 minutes (D) 30 km at 15 minutes

[Ans. A]

Two cars P and Q are moving continuously for 'two' hours

For P : $d = 60 t$

For Q : $d = 60 t^2$

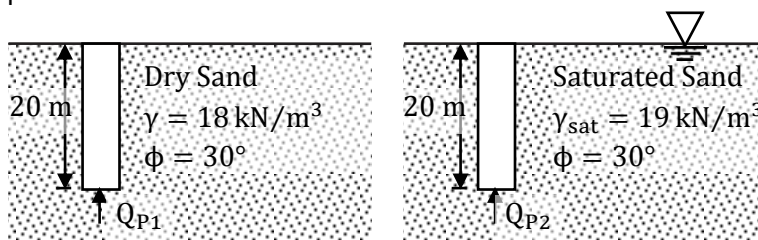
With $\frac{1}{2}$ hour the distance travelled are

For P: $d = 60 \times \frac{1}{2} = 30 \text{ km}$

For Q: $d = 60 \times \left(\frac{1}{2}\right)^2 = 15 \text{ km}$

Spacing at 30 min = 15 km

33. Two identical concrete piles having the plan dimensions 50 cm × 50 cm are driven into a homogeneous sandy layer as shown in the figures. Consider the bearing capacity factor N_q for $\phi = 30^\circ$ as 24.



If Q_{P1} and Q_{P2} represent the ultimate point bearing resistances of the piles under dry and submerged conditions, respectively, which one of the following statements is correct?

- (A) $Q_{P1} > Q_{P2}$ by about 100% (C) $Q_{P1} > Q_{P2}$ by about 5%
(B) $Q_{P1} < Q_{P2}$ by about 100% (D) $Q_{P1} < Q_{P2}$ by about 5%

[Ans. A]

The point bearing resistance of piles in sandy soils

$$Q_P = A_b \cdot \sigma'_v \cdot N_q$$

As the area at base (A_b) and N_q are same for both the piles given, $Q_P \propto \sigma'_v$

For dry sand condition, $\sigma'_v = \sigma_v = 20 \times \gamma$

For submerged condition $\sigma'_v = 20\gamma'$

Since $\gamma' \approx \frac{1}{2}$ of γ

$\therefore Q_{P2} \approx \frac{1}{2}$ of Q_{P1}

(Or) $Q_{P1} \approx 2Q_{P2}$

(or) $Q_{P1} > Q_{P2}$ by about 100 %

34. Consider the following statements:

P. Walls of one brick thick are measured in square meters

Q. Walls of one brick thick are measured in cubic meters

R. No deduction in the brickwork quantity is made for openings in walls up to 0.1 m² area.

S. For the measurement of excavation from the borrow pit in a fairly uniform ground, deadmen are left at suitable intervals.

For the above statements, the correct option is

(A) P-False Q-True; R- False; S-True

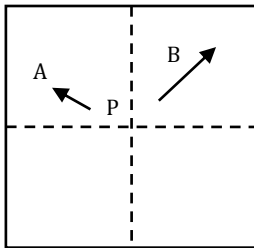
(C) P-True Q-False; R-True; S-False

(B) P-False Q-True; R- False; S-False

(D) P-True Q-False; R-True; S-True

[Ans. D]

35. Two towers, A and B, standing vertically on a horizontal ground, appear in a vertical aerial photograph as shown in the figure.



The length of the image of the tower A on the photograph is 1.5 cm and of the tower B is 2.0 cm. The distance of the top of the tower A (as shown by the arrowhead) is 4.0 cm and the distance of the top of the tower B is 6.0 cm, as measured from the principal point p of the photograph. If the height of the tower B is 80 m, the height (in meters) of the tower A is_____

[Ans. *] Range: 89 to 91

For Town 'A'

Relief displacement $d_A = 1.5$ cm ; $T_A = 4$ cm

$$\therefore d = \frac{h \cdot r}{(H - h_{avg})}$$

For tower B

$d_B = 2$ cm; $r_B = 6$ cm; $h_B = 80$ m

$$d_B = \frac{h_B \cdot r_B}{(H - h_{avg})} \Rightarrow (H - h_{avg}) = 80 \times \frac{6}{2} = 240$$

$$d_A = \frac{h_A r_A}{(H - h_{avg})} \Rightarrow h_A = \frac{1.5 \times 240}{4} = 90\text{m}$$

36. For a given water sample, the ratio between $BOD_{5\text{-day}, 20^\circ\text{C}}$ and the ultimate BOD is 0.68. The value of the reaction rate constant k (on base e) (in day^{-1} , up to two decimal places) is____

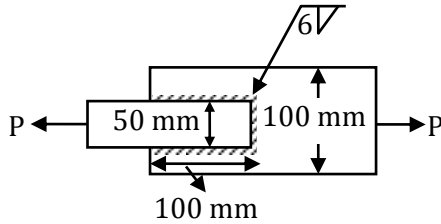
[Ans. *] Range: 0.22 to 0.24

$$\frac{5 \text{ day BOD } 20^\circ\text{C}}{\text{Ultimate BOD}} = \frac{y_5^{20^\circ\text{C}}}{L_0} = 0.68$$

$$\frac{L_0 [1 - e^{-k_{20} \times 5}]}{L_0} = 0.68$$

$$\Rightarrow K_{20} = 0.2278\text{d}^{-1}$$

37. Two plates of 8 mm thickness each are connected by a fillet weld of 6 mm thickness as shown in the figure.



The permissible stresses in the plate and the weld are 150 MPa and 110 MPa, respectively. Assuming the length of the weld shown in the figure to be the effective length, the permissible load P (in kN) is _____

[Ans. *] Range: 59 to 61

The permissible stress in the plate $\sigma_{at} = 150$ MPa

The permissible stress in the weld $\tau_{vf} = 110$ MPa

Strength of smaller width plate $P_t = A_g \times \sigma_{at} = 50 \times 8 \times 150 = 60 \times 10^3 \text{ N} = 60 \text{ kN}$

(A_g = Gross sectional area of smaller width plate = $50 \times 8 = 400 \text{ mm}^2$)

(Since smaller width plate has least sectional area and least strength)

Effective length of fillet weld $L_w = 2 \times 100 + 50 = 250 \text{ mm}$

Size of fillet weld $S = 6 \text{ mm}$

Effective throat thickness $t_t = 0.707 \times S = 0.707 \times 6 = 4.242 \text{ mm}$

Strength of fillet weld $P_s = L_w \times t_t \times \tau_{vf} = 250 \times 4.242 \times 110 = 116.65 \times 10^3 \text{ N}$
 $= 116.65 \text{ kN}$

The permissible load $P = \text{Smaller of } P_t \text{ and } P_s = 60 \text{ kN}$

The permissible load P (in kN) is 60 (Answer)

38. A hollow circular shaft has an outer diameter of 100 mm and inner diameter of 50 mm. If the allowable shear stress is 125 MPa, the maximum torque (in kN-m) that the shaft can resist is _____

[Ans. *] Range: 20 to 25

The maximum allowable shear stress on shaft, $\tau_m = 125$ MPa

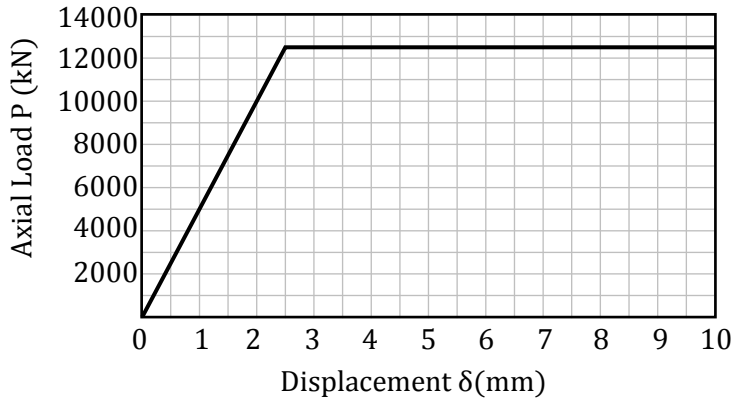
Outer diameter, $D = 100$ mm

Inner diameter, $d = 50$ mm

Torque allowed on the shaft

$$\begin{aligned} T &= \tau_m Z_p \\ &= \tau_m \left[\frac{\pi}{16D} (D^4 - d^4) \right] \\ &= 125 \left[\frac{\pi}{16 \times 100} (100^4 - 50^4) \right] \\ &= 23 \times 10^6 \text{ N-mm} = 23 \text{ kN-m} \end{aligned}$$

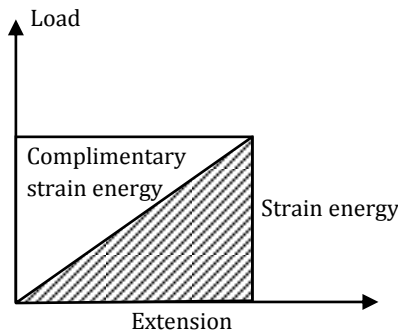
39. A 2m long, axially loaded mild steel rod of 8 mm diameter exhibits the load-displacement (P- δ) behavior as shown in figure.



Assume the yield stress of steel as 250 MPa. The complementary strain energy (in N-mm) stored in the bar up to its linear elastic behavior will be _____

[Ans. *] Range: 15625 to 15750

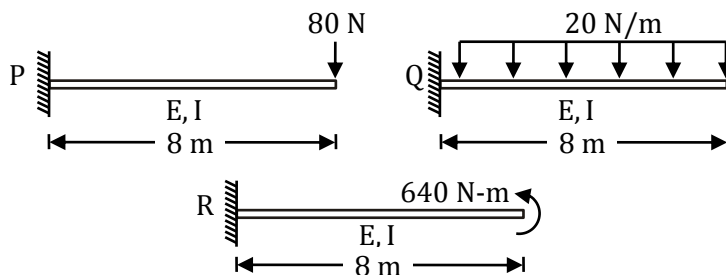
Complimentary strain energy for linear materials.



Complimentary strain energy = strain energy

$$\begin{aligned}
 &= \frac{1}{2} \sigma_y \times \epsilon \times A \times L \\
 &= \frac{1}{2} \times 250 \times \frac{2.5}{2000} \times \frac{\pi}{4} \times 8^2 \times 2000 \quad (\because \epsilon = \frac{\delta l}{l}) \\
 &= 15,707.963 \text{ N-mm}
 \end{aligned}$$

40. Consider the three prismatic beams with the clamped supports P, Q and R as shown in the figures.



Given that the modulus of elasticity, E is 2.5×10^4 MPa; and the moment of inertia, I is 8×10^8 mm⁴, the correct comparison of magnitudes of the shear force S and the bending moment M developed at the supports is

- | | |
|-------------------------------------------|-------------------------------------------|
| (A) $S_P < S_Q < S_R$; $M_P = M_Q = M_R$ | (C) $S_P < S_Q > S_R$; $M_P = M_Q = M_R$ |
| (B) $S_P = S_Q > S_R$; $M_P = M_Q > M_R$ | (D) $S_P < S_Q < S_R$; $M_P < M_Q < M_R$ |

[Ans. C]

Bending moments

$$M_P = 80 \times 8 = 640 \text{ kN-m}$$

$$M_Q = 20 \times 8 \times 4 = 640 \text{ kN-m}$$

$$M_R = 640 \text{ kN-m}$$

$$\therefore M_P = M_Q = M_R$$

Shear force values

$$S_P = 80 \text{ kN}$$

$$S_Q = 20 \times 8 = 160 \text{ kN}$$

$$S_R = 0$$

$$\therefore S_P < S_Q > S_R$$

41. Following are the statements related to the stress path in a triaxial testing of soils:

P. If $\sigma_1 = \sigma_3$, the stress point lies at the origin of the p-q plot.

Q. If $\sigma_1 = \sigma_3$, the stress point lies on the p-axis of the p-q plot.

R. If $\sigma_1 > \sigma_3$, both the stress points p and q are positive.

For the above statements, the correct combination is

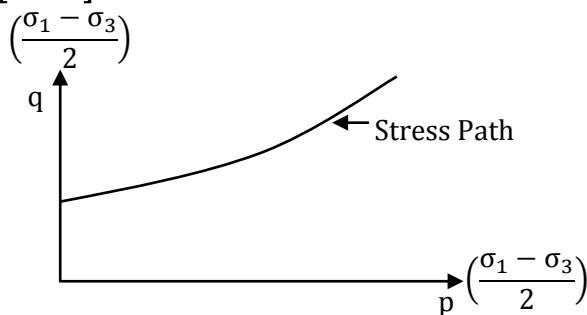
(A) P-False; Q-True; R-True

(C) P-False; Q-True; R-False

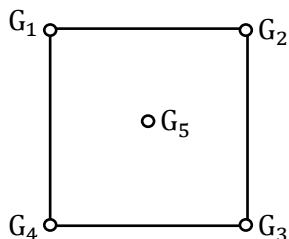
(B) P-True Q-False; R-True

(D) P-True; Q-False; R-False

[Ans. A]

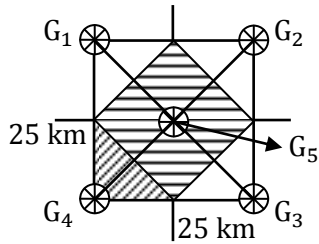


42. A catchment is idealized as a 25 km \times 25 km square. It has five rain gauges, one at each corner and one at the center, as shown in the figure.



During a month, the precipitation at these gauges is measured as $G_1=300$ mm, $G_2 = 285$ mm, $G_3 = 272$ mm, $G_4 = 290$ mm and $G_5 = 288$ mm. The average precipitation (in mm, up to one decimal place) over the catchment during this month by using the Thiessen polygon method is

[Ans. *] Range: 287.0 to 287.5



$$G_1 = 300 \text{ mm}$$

$$G_2 = 285 \text{ mm}$$

$$G_3 = 272 \text{ mm}$$

$$G_4 = 290 \text{ mm}$$

$$G_5 = 288 \text{ mm}$$

$$A_1 = A_2 = A_3 = A_4 = \frac{1}{2} \times 12.5 \times 12.5 = 78.125 \text{ km}^2$$

$$A_5 = 17.67 \times 17.67 = 312.5 \text{ km}^2$$

$$\bar{P} = \frac{78.125[300 + 285 + 272 + 290] + 312.5 \times 288}{(25 \times 25)} = 287.375 \text{ mm}$$

43. The tangent to the curve represented by $y = x \ln x$ is required to have 45° inclination with the x-axis. The coordinates of the tangent point would be

(A) (1,0)

(C) (1,1)

(B) (0,1)

(D) $(\sqrt{2}, \sqrt{2})$

[Ans. A]

$$y = x \log_e x$$

$$\frac{dy}{dx} = x \left(\frac{1}{x} \right) + (\log_e x)1 - 1 + \log_e x$$

$$\Rightarrow \tan 45^\circ = 1 + \log_e x$$

$$\Rightarrow 1 = 1 + \log_e x$$

$$\Rightarrow \log_e x = 0$$

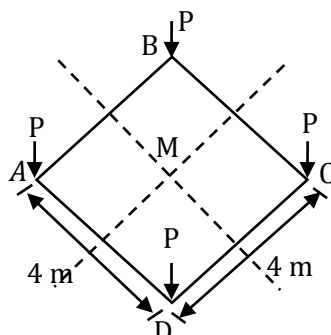
$$\Rightarrow \log_e x = 0$$

$$\Rightarrow x = e^0 = 1$$

$$x = 1 \Rightarrow y = 0 (\because y = x \log_e x)$$

\therefore The point is (1, 0)

44. Consider a square-shaped area ABCD on the ground with its centre at M as shown in the figure. Four concentrated vertical loads of $P = 5000 \text{ kN}$ are applied on this area, one at each corner.



The vertical stress increment (in kPa, up to one decimal place) due to these loads according to the Boussinesq's equation, at a point 5 m right below M, is _____

[Ans. *] Range: 187.0 to 192.0

Concentrated load $P = 5000$ kN

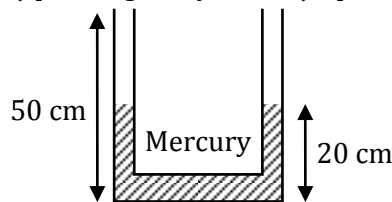
Depth $Z = 5$ m

Radial distance, $r = \sqrt{x^2 + y^2} = \sqrt{2^2 + 2^2} = 2.828$ m

In total, there are four concentrated loads and the stress at point M due to each load (P) is equal.

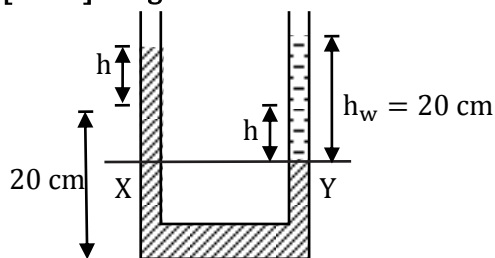
$$\begin{aligned} \therefore \text{Total Stress } \sigma_z &= 4 \times \frac{P}{Z^2} \cdot \frac{3}{2\pi} \left[\frac{1}{1 + \left(\frac{r}{z}\right)} \right]^{5/2} \\ &= 4 \times \frac{5000}{5^2} \times \frac{3}{2\pi} \left[\frac{1}{1 + \left(\frac{2.828}{5}\right)^2} \right]^{5/2} = 190.84 \text{ kPa} \end{aligned}$$

45. The figure shows a U-tube having a $5 \text{ mm} \times 5 \text{ mm}$ square cross-section filled with mercury (specific gravity = 13.6) up to a height of 20 cm in each limb (open to the atmosphere).



If 5 cm^3 of water is added to the right limb, the new height (in cm, up to two decimal places) of mercury in the LEFT limb will be _____

[Ans. *] Range: 20.70 to 20.76



Volume of water, $V = 5 \text{ cm}^3$

$$A \times h_w = 5$$

$$(0.5 \times 0.5) \times h_w = 5$$

$$h_w = 20 \text{ cm}$$

By the manometry principle

Pressure in left limb = pressure in right limb

$$P_x = P_y$$

$$\rho_w \times g \times h_w = \rho_{\text{Hg}} \times g \times h_{\text{Hg}}$$

$$S_w \times h_w = S_{\text{Hg}} \times h_{\text{Hg}}$$

$$1 \times 20 = 13.6 \times (2h)$$

$$h = 0.735$$

$$\begin{aligned} \text{New height} &= \text{initial mercury height} + h \\ &= 20 + 0.735 \\ &= 20.735 \approx 20.74 \end{aligned}$$

46. The analysis of a water sample produces the following results:

Ion	Milligram per milli-equivalent for the ion	Concentration (mg/L)
Ca ²⁺	20.0	60
Mg ²⁺	12.2	36.6
Na ⁺	23.0	92
K ⁺	39.1	78.2
Cl ⁻	35.5	71
SO ₄ ²⁻	48.0	72
HCO ₃ ⁻	61.0	122

The total hardness (in mg/L as CaCO₃) of the water sample is

[Ans. *] Range: 300 to 300

$$\begin{aligned} \text{Total hardness} &= \text{Ca}^{2+} \times \frac{50}{20} + \text{Mg}^{2+} \times \frac{50}{12.2} \\ &= 60 \times \frac{50}{20} + 36.6 \times \frac{50}{12.2} \\ &= 300 \text{ mg/l as CaCO}_3 \end{aligned}$$

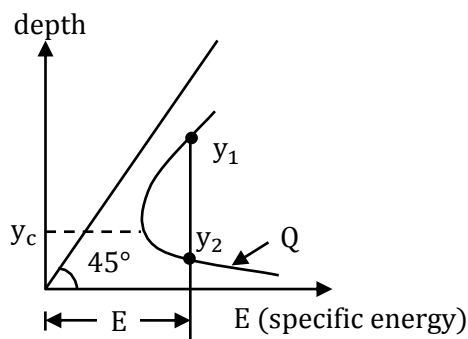
47. A 1 m wide rectangular channel carries a discharge of 2 m³/s. The specific energy –depth diagram is prepared for the channel. It is observed in this diagram that corresponding to a particular specific energy; the subcritical depth is twice the supercritical depth. The subcritical depth (in meters, up to two decimal places) is equal to _____

[Ans. *] Range: 1.06 to 1.08

Given:

$$Q = 2 \text{ m}^3/\text{s}$$

$$B = 4 \text{ m}$$



Given that at a particular specific energy. The sub critical depth is twice the super critical depth.

$$y_1 = 2y_2$$

$$y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g}$$

$$y_1 + \frac{Q^2}{2g(B \cdot y_1)^2} = y_2 + \frac{Q^2}{2g(B \cdot y_2)^2}$$

$$y_1 + \frac{Q^2}{2y(B \cdot y_1)^2} = \frac{y_1}{2} + \frac{Q^2}{2g\left(B \cdot \frac{y_1}{2}\right)^2}$$

$$y_1 + \frac{Q^2}{2g \cdot B^2 \cdot y_1^2} = \frac{y_1}{2} + \frac{2Q^2}{gB^2y_1^2}$$

$$\frac{y_1}{2} = \frac{2Q^2}{gB^2y_1^2} - \frac{Q^2}{gB^2y_1^2}$$

$$\frac{y_1}{2} = \frac{3}{2} \left(\frac{Q^2}{gB^2y_1^2} \right)$$

$$y_1^3 = \frac{3Q^2}{gB^2}$$

$$y_1 = \sqrt[3]{\frac{3Q^2}{gB^2}} = \sqrt[3]{\frac{3 \times 2^2}{9.81 \times 1^2}}$$

$$y_1 = 1.069 \approx 1.07$$

48. Consider the following definite integral

$$I = \int_0^1 \frac{(\sin^{-1} x)^2}{\sqrt{1-x^2}} dx$$

The value of the integral is

- (A) $\frac{\pi^3}{24}$ (C) $\frac{\pi^3}{48}$
(B) $\frac{\pi^3}{12}$ (D) $\frac{\pi^3}{64}$

[Ans. A]

$$I = \int_0^1 \frac{(\sin^{-1} x)^2}{\sqrt{1-x^2}} dx \quad \text{put } \sin^{-1} x = t \Rightarrow \frac{1}{\sqrt{1-x^2}} dx = dt$$

$$\text{If } x = 0 \text{ then } t = 0, \text{ If } x = 1 \text{ then } t = \frac{\pi}{2}$$

$$I = \int_0^{\pi/2} (t)^2 dt = \left(\frac{t^3}{3} \right)_0^{\pi/2} = \frac{\pi^3}{24}$$

49. The culturable command area of a canal is 10,000 ha. The area grows only two crops-rice in the Kharif season and wheat in the Rabi season. The design discharge of the canal is based on the rice requirements, which has an irrigated area of 2500 ha, base period of 150 days and delta of 130 cm. The maximum permissible irrigated area (in ha) for wheat, with a base period of 120 days and delta of 50 cm is_____

[Ans. *] Range: 5150 to 5250

Rice	Wheat
A = 2500 ha	A = ?
B = 150 d	B = 120 d
Δ = 130 cm	Δ = 50 cm
Q = constant	

$$Q = \frac{A}{D} \text{ and } D = 8.64 \frac{B}{\Delta}$$

$$Q = \frac{A\Delta}{8.64B}$$

$$\frac{A_1\Delta}{B_1} = \frac{A_2\Delta_2}{B_2}$$

$$\frac{2500 \times 130}{150} = \frac{A_2 \times 50}{120}$$

$$A_2 = 130 \times 40 = 5200 \text{ ha}$$

50. A municipal corporation is required to treat $1000 \text{ m}^3/\text{day}$ of water. If it is found that an overflow rate of 20 m/day will produce a satisfactory removal of the discrete suspended particles at a depth of 3 m . The diameter (in meters, rounded to the nearest integer) of a circular settling tank designed for the removal of these particles would be _____

[Ans. *] Range: 8 to 8

$$Q = 1000 \text{ m}^3/\text{day}$$

$$\text{SOR} = 20 \text{ m/day}$$

Diameter of settling tank $d = ?$

$$\text{Surface area of settling tank} = \frac{Q}{\text{SOR}} = \frac{1000}{20} = 50 \text{ m}^2$$

$$\frac{\pi}{4} d^2 = 50$$

$$d = \sqrt{\frac{50 \times 4}{\pi}} = 7.978 \text{ m}$$

51. A simply supported rectangular concrete beam of span 8 m has to be prestressed with a force of 1600 kN . The tendon is of parabolic profile having zero eccentricity at the supports. The beam has to carry an external uniformly distributed load of intensity 30 kN/m . Neglecting the self-weight of the beam, the maximum dip (in meters, up to two decimal places) of the tendon at the mid-span to balance the external load should be _____

[Ans. *] Range: 0.14 to 0.16

Given:

$$l = 8 \text{ m}$$

$$P = 1600 \text{ kN}$$

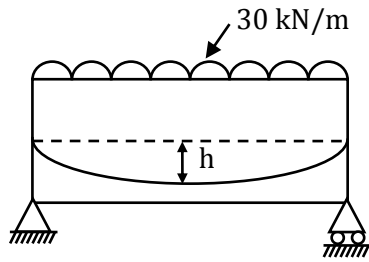
$$h = ?$$

From the load balancing concept

$$m_E = m_P$$

$$\frac{wl^2}{8} = Ph$$

$$h = \frac{wl^2}{8P} = \frac{30 \times 8^2}{8 \times 1600} = 0.15 \text{ m}$$



52. An observer standing on the deck of a ship just sees the top of a lighthouse. The top of the lighthouse is 40 m above the sea level and the height of the observer's eye is 5 m above the sea level. The distance (in km, up to one decimal place) of the observer from the lighthouse is

[Ans. *] Range: 32.5 to 33.5

$$d_1 = 3.8553\sqrt{40}$$

$$d_1 = 24.38 \text{ km}$$

$$d_2 = 3.8553\sqrt{5}$$

$$d_2 = 8.62 \text{ km}$$

$$d = d_1 + d_2$$

$$d = 33.00 \text{ km}$$

Alternative Solution

$$\text{Distance to visible horizon} = D = \sqrt{\frac{h}{0.06735}}$$

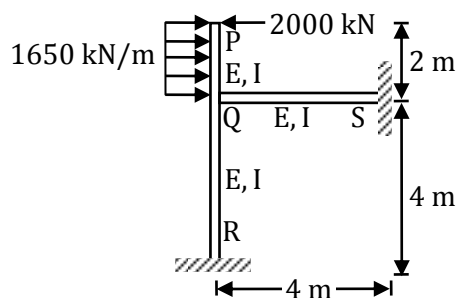
'h' 'm' and 'D' \Rightarrow 'km'

$$\therefore D = D_1 + D_2$$

$$= \sqrt{\frac{40}{0.06735}} + \sqrt{\frac{5}{0.06735}}$$

$$= 24.370 + 8.616 = 32.986 \text{ km}$$

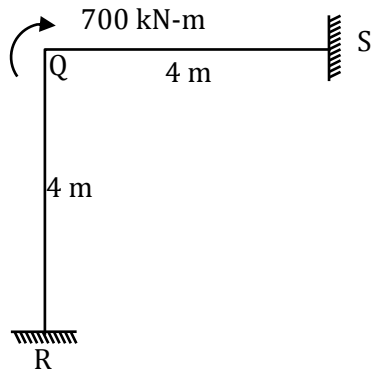
53. Consider the portal frame shown in the figure and assume the modulus of elasticity, $E = 2.5 \times 10^4 \text{ MPa}$ and the moment of inertia, $I = 8 \times 10^8 \text{ mm}^4$ for all the members of the frame.



The rotation (in degrees, up to decimal place) at the rigid joint Q would be _____

[Ans. *] Range: 0.9 to 1.1

$$M = 4000 - 3300 = 700 \text{ kN-m}$$



$$M_{FQS} = M_{FSQ} = M_{FQR} = M_{FRQ} = 0$$

Fixed end moments

$$\theta_s = \theta_R = 0 \rightarrow \text{Fixed supports}$$

$$M_{QS} = M_{FQS} + \frac{2EI}{4} [2\theta_Q + \theta_s]$$

$$M_{QS} = EI\theta_Q$$

$$E = 2.5 \times 10^4 \times 10^3 \text{ kN/m}^2$$

$$I = \frac{1}{1250} \text{ m}^4$$

$$M_{QR} = M_{FQR} + \frac{2EI}{4} [2\theta_Q + \theta_R]$$

$$M_{QR} = EI\theta_Q$$

$$M_{QR} + M_{QS} = 700 = 0$$

$$EI\theta_Q + EI\theta_Q = -700$$

$$EI\theta_Q = -350$$

$$\theta_Q = \frac{-350}{2.5 \times 10^4 \times 10^3 \times \frac{1}{1250}} = -1.75 \times 10^{-2} \text{ radians}$$

$$= -1.75 \times 10^{-2} \times \frac{180}{\pi} = 1.002 \approx 1$$

54. The radii of relative stiffness of the rigid pavements P and Q are denoted by l_P and l_Q respectively. The geometric and material properties of the concrete slab and underlying soil are given below:

Pavement	Concrete					Soil
	Length of Slab	Breadth of Slab	Thickness of Slab	Modulus of Elasticity	Poisson's ratio	Subgrade Reaction Modulus
P	L	B	h	E	μ	K
Q	L	B	0.5h	E	μ	2K

The ratio (up to one decimal place) of l_P/l_Q is _____

[Ans. *] Range: 1.9 to 2.1

Westergaard defined the term radius of relative stiffness, l which is expressed as

$$l = \left[\frac{Eh^3}{12k(1 - \mu^2)} \right]^{1/4}$$

$$l_P = \left[\frac{Eh^3}{12k(1-\mu^2)} \right]^{1/4}$$

$$l_Q = \left[\frac{E(0.5h)^3}{12(2k)(1-\mu^2)} \right]^{1/4}$$

$$= \left[\frac{(0.5)^3}{2} \times \frac{Eh^3}{12k(1-\mu^2)} \right]^{1/4}$$

$$= \left[\frac{(0.5)^3}{2} \right]^{1/4} \left[\frac{Eh^3}{12k(1-\mu^2)} \right]^{1/4}$$

$$\frac{l_P}{l_Q} = \frac{\left[\frac{Eh^3}{12k(1-\mu^2)} \right]^{1/4}}{\left[\frac{(0.5)^3}{2} \right]^{1/4} \left[\frac{Eh^3}{12k(1-\mu^2)} \right]^{1/4}} = \left[\frac{2}{(0.5)^3} \right]^{1/4}$$

$$\frac{l_P}{l_Q} = 2$$

55. Consider the following second –order differential equation:

$$y'' - 4y' + 3y = 2t - 3t^2$$

The particular solution of the differential equation is

(A) $-2 - 2t - t^2$

(C) $2t - 3t^2$

(B) $-2t - t^2$

(D) $-2 - 2t - 3t^2$

[Ans. A]

$$y'' - 4y' + 3y = 2t - 3t^2$$

$$(D^2 - 4D + 3)y = 2t - 3t^2$$

$$PI = \frac{1}{(D^2 - 4D + 3)} (2t - 3t^2)$$

$$= \frac{1}{3 \left[1 + \left(\frac{D^2 - 4D}{3} \right) \right]} (2t - 3t^2)$$

$$= \frac{1}{3} \left\{ 1 + \left(\frac{D^2 - 4D}{3} \right) \right\}^{-1} (2t - 3t^2)$$

$$= \frac{1}{3} \left\{ 1 - \left(\frac{D^2 - 4D}{3} \right) + \left(\frac{D^2 - 4D}{3} \right)^2 \right\} (2t - 3t^2)$$

(Expanding by binomial theorem up to D^2 terms)

$$= \frac{1}{3} \left\{ (2t - 3t^2) - \left[\frac{-6 - 4(2 - 6t)}{3} \right] + \frac{16}{9}(-6) \right\}$$

$$= -2 - 2t - t^2$$