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2. Question Paper & Answer keys
ANALYSIS OF GATE 2016
Civil Engineering

- Geotechnical Engineering: 15%
- Environmental Engineering: 10%
- Surveying: 5%
- Transportation Engineering: 6%
- Structural Analysis: 3%
- Mechanics: 3%
- Steel Structure: 3%
- Water Resource Engineering: 11%
- General Aptitude: 15%
- Mathematics: 13%
- SOM: 5%
- CMM: 6%
- RCC: 5%
- SOM: 5%
- CMM: 6%
## GATE-2016- CE 6-Feb 9 AM-12 PM

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<tr>
<th>SUBJECT</th>
<th>NO OF QUESTION</th>
<th>Topics Asked in Paper</th>
<th>Level of Toughness</th>
<th>Total Marks</th>
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<tr>
<td>Environmental Engineering</td>
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<td>Moderate</td>
<td>10</td>
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<tr>
<td>Structural Analysis</td>
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<td>Deflection of beam; truss &amp; Strain</td>
<td>Tough</td>
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<tr>
<td>Water Resources Engineering</td>
<td>1 M: 3; 2 M: 4</td>
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<td>11</td>
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<tr>
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<td>1 M: 1; 2 M: 2</td>
<td>Struss; Deflection of Beams</td>
<td>Easy</td>
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<tr>
<td>R.C.C.</td>
<td>1 M: 1; 2 M: 2</td>
<td>Concrete Technology; shear; compression and torsion by limit state methods</td>
<td>Easy</td>
<td>5</td>
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<tr>
<td>Geomatics/ Surveying Engineering</td>
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<td>Moderate</td>
<td>5</td>
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<tr>
<td>Geotechnical Engineering</td>
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<td>Moderate</td>
<td>15</td>
</tr>
<tr>
<td>Transportation Engineering</td>
<td>1 M: 2; 2 M: 2</td>
<td>Traffic characteristics, Theory of traffic flow; pavements; GIS Remote sensing</td>
<td>Easy</td>
<td>6</td>
</tr>
<tr>
<td>* Construction Materials and Management</td>
<td>1 M: 0; 2 M: 3</td>
<td>*Construction Management; Analysis of beam sections at transfer and service loads</td>
<td>Tough</td>
<td>6</td>
</tr>
<tr>
<td>Engg. Mechanics</td>
<td>1 M: 1; 2 M: 1</td>
<td>Trusses and Frames; Kinematics of Rectilinear Motion</td>
<td>Tough</td>
<td>3</td>
</tr>
<tr>
<td>Steel Structure</td>
<td>1 M: 1; 2 M: 1</td>
<td>Plastic Analysis; Design of Tension Member; Beams</td>
<td>Moderate</td>
<td>3</td>
</tr>
<tr>
<td>Engineering Mathematics</td>
<td>1 M: 5; 2 M: 4</td>
<td>Numerical Method; Matrices; Complex Variable; Probability; Limit &amp; Continuity</td>
<td>Moderate</td>
<td>13</td>
</tr>
<tr>
<td>GA</td>
<td>1 M: 5; 2 M: 5</td>
<td>Time &amp; Work; Mixtures, Directions; Venn Diagram; Mensuration &amp; Area, clock</td>
<td>Easy</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>65</strong></td>
<td><strong>Moderate 100</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Indicates Questions from New Syllabus.

**Faculty Feedback:** Few questions came from New Syllabus; General Ability was pretty easy; many question from Geotechnical Engg, Water Resources Engg, Construction Materials and Management was scoring subject, qualifying is easy but scoring is tough. Practice previous question papers will be beneficial.
GATE-2016

Question Paper
&
Answer Keys
Section: General Aptitude

Q.No. 1

Out of the following four sentences, select the most suitable sentence with respect to grammar and usage.

(A) I will not leave the place until the minister does not meet me.

(B) I will not leave the place until the minister doesn’t meet me.

(C) I will not leave the place until the minister meet me.

(D) I will not leave the place until the minister meets me.

[Ans. D]
‘until’ itself is negative so it can’t take one more negative i.e., ‘does not’. Hence, Option (D) is the right answer

Q.No. 2

A rewording of something written or spoken is a ___________________.

(A) paraphrase  (B) paradox  (C) paradigm  (D) paraffin

[Ans. A]
‘paraphrase’ means a restatement of a text, passage or a rewording of something written or spoken.

Q.No. 3

Archimedes said, “Give me a lever long enough and a fulcrum on which to place it, and I will move the world.”

The sentence above is an example of a ___________ statement.

(A) figurative  (B) collateral  (C) literal  (D) figurine

[Ans. A]
‘figurative’ means representing by a figure or resemblance or expressing one thing in terms normally denoting another with which it may be regarded as analogous.

Q.No. 4

If ‘relftaga’ means carefree, ‘otaga’ means careful and ‘fertaga’ means careless, which of the following could mean ‘aftercare’?

(A) zentaga  (B) tagafer  (C) tagazen  (D) relffer

[Ans. C]
From given codes
Relftaga ⇒ carefree
Otaga ⇒ careful
Fertaga ⇒ careless
From these codes, clearly known that “care” means “taga,” from given alternatives, option ‘C’ is correct.

Q.No. 5
A cube is built using 64 cubic blocks of side one unit. After it is built, one cubic block is removed from every corner of the cube. The resulting surface area of the body (in square units) after the removal is ________.

(A) 56  
(B) 64  
(C) 72  
(D) 96

[Ans. D]

From given data, 64 cubic blocks of one unit sizes are formed.
No. of faces of the Cube is ‘6’
No. of corners of the Cube is ‘8’
After removing one Cubic block from Each corner,
The resulting surface area of the body = 6 × (4) = 96 sq. Units
Q.No. 6

A shaving set company sells 4 different types of razors, Elegance, Smooth, Soft and Executive. Elegance sells at Rs. 48, Smooth at Rs. 63, Soft at Rs. 78 and Executive at Rs. 173 per piece. The table below shows the numbers of each razor sold in each quarter of a year.

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Elegance</th>
<th>Smooth</th>
<th>Soft</th>
<th>Executive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>27300</td>
<td>20009</td>
<td>17602</td>
<td>9999</td>
</tr>
<tr>
<td>Q2</td>
<td>25222</td>
<td>19392</td>
<td>18445</td>
<td>8942</td>
</tr>
<tr>
<td>Q3</td>
<td>28976</td>
<td>22429</td>
<td>19544</td>
<td>10234</td>
</tr>
<tr>
<td>Q4</td>
<td>21012</td>
<td>18229</td>
<td>16595</td>
<td>10109</td>
</tr>
</tbody>
</table>

Which product contributes the greatest fraction to the revenue of the company in that year?

(A) Elegance (B) Executive (C) Smooth (D) Soft

[Ans. B]

Total No. of razors Elegance type from all four quarters = 27300 + 25222 + 28976 + 201012 = 10,2510
Total No. of razors of Smooth type from all four quarters = 20009 + 19392 + 22429 + 18229 = 8,0059
Total No. of razors of Soft type from all four Quarters = 17602 + 18445 + 19544 + 16595 = 7,2186
Total No. of razors of Executive type from all four Quarters = 9999 + 8942 + 10234 + 10109 = 3,9286

The revenue of the company in that year of 4 different types of razors
Elegance = 10,2510 × 48 = 492,0480
Smooth = 8,0059 × 63 = 50,43,717
Soft = 7,2186 × 78 = 56,30,508
Executive = 3,9284 × 173 = 67,96,132
∴ The Executive of razors contributes the greatest revenue of the company in that year.

Q.No. 7

Indian currency notes show the denomination indicated in at least seventeen languages. If this is not an indication of the nation’s diversity, nothing else is.

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

(A) India is a country of exactly seventeen languages.
(B) Linguistic pluralism is the only indicator of a nation’s diversity.
(C) Indian currency notes have sufficient space for all the Indian languages.
(D) Linguistic pluralism is strong evidence of India’s diversity.

[Ans. D]

If seventeen languages were not an indication of the nation’s diversity, nothing else is. If nothing else is so the best inference is option ‘D’.
Q.No. 8
Consider the following statements relating to the level of poker play of four players P, Q, R and S.

I. P always beats Q
II. R always beats S
III. S loses to P only sometimes
IV. R always loses to Q

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

(i) P is likely to beat all the three other players
(ii) S is the absolute worst player in the set

(A) (i) only  (B) (ii) only  (C) (i) and (ii)  (D) neither (i) nor (ii)

[Ans. D]

Q.No. 9
If \( f(x) = 2x^7 + 3x - 5 \), which of the following is a factor of \( f(x) \)?

(A) \( (x^3 + 8) \)  (B) \( (x - 1) \)  (C) \( (2x - 5) \)  (D) \( (x + 1) \)

[Ans. B]
\( f(x) = 2x^7 + 3x - 5 \) for \( x = 1 \) the equation is satisfied. The factor is \( (x - 1) \).

Q.No. 10
In a process, the number of cycles to failure decreases exponentially with an increase in load. At a load of 80 units, it takes 100 cycles for failure. When the load is halved, it takes 10000 cycles for failure. The load for which the failure will happen in 5000 cycles is ________.

(A) 40.00  (B) 46.02  (C) 60.01  (D) 92.02

[Ans. B]
\[ \text{↓ load cycles for failure \uparrow exponentially} \]
Eg: load = \( x \)
Cycles for failure = \( y \)
\[ \frac{x}{2} = y^2, \quad \frac{x}{3} = y^3, \quad \frac{x}{4} = y^4 \]
By elimination procedure from options,
Option (A)
Load = 40 units, it says that, the load is halved, it takes 10,000 cycles for failure.
80
\[ \frac{2}{2} = (100)^2 \]
40 units = 10,000 cycles, it is not
Option (D)
Load = 92.02 units means it is more than 80 units, so it is not.
Option (C)
Load = 60.01 units
\[ \frac{3}{4}(80 \text{ units}) = 60.01 \text{ units} \]

From the given relation

\[ \frac{3}{4}(80 \text{ units}) = (10)^{4/3} = (100)^{1/3} \times (100)^{1/3} = 100 \times 4.64 = 464 \]

It is not

\[ \therefore \text{ Option (B) only possible} \]

\[ \therefore \text{ At the load of 46.02 units, the failure will happen in 5000 cycles.} \]

**Section: Technical**

**Q.No. 1**

Newton-Raphson method is to be used to find root of equation \( 3x - e^x + \sin x = 0 \). If the initial trial value for the root is taken as 0.333, the next approximation for the root would be ________

(note: answer up to three decimal)

[Ans. *] Range: 0.355 to 0.365

**Q.No. 2**

The type of partial differential equation \( \frac{\partial^2 P}{\partial x^2} + \frac{\partial^2 P}{\partial y^2} + 3 \frac{\partial^2 P}{\partial x \partial y} + 2 \frac{\partial P}{\partial x} - \frac{\partial P}{\partial y} = 0 \) is

(A) elliptic  (B) parabolic  (C) hyperbolic  (D) none of these

[Ans. C]

**Q.No. 3**

If the entries in each column of a square matrix \( M \) add up to 1, then an eigenvalue of \( M \) is

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

[Ans. D]

**Q.No. 4**

Type II error in hypothesis testing is

(A) acceptance of the null hypothesis when it is false and should be rejected
(B) rejection of the null hypothesis when it is true and should be accepted
(C) rejection of the null hypothesis when it is false and should be rejected
(D) acceptance of the null hypothesis when it is true and should be accepted

[Ans. A]
Q.No. 5

The solution of the partial differential equation \( \frac{\partial u}{\partial t} = \alpha \frac{\partial^2 u}{\partial x^2} \) is of the form

(A) \( C \cos(kt) \left[ C_1 e^{(\sqrt{\frac{k}{\alpha}})x} + C_2 e^{-\sqrt{\frac{k}{\alpha}}x} \right] \)

(B) \( C \sin(kt) \left[ C_1 e^{(\sqrt{\frac{k}{\alpha}})x} + C_2 e^{-\sqrt{\frac{k}{\alpha}}x} \right] \)

(C) \( C \sin(kt) \left[ C_1 \cos(\sqrt{\frac{k}{\alpha}}x) + C_2 \sin(-\sqrt{\frac{k}{\alpha}}x) \right] \)

(D) \( C \cos(kt) \left[ C_1 \cos(\sqrt{\frac{k}{\alpha}}x) + C_2 \sin(-\sqrt{\frac{k}{\alpha}}x) \right] \)

[Ans. B]

Q.No. 6

Consider the plane truss with load \( P \) as shown in the figure. Let the horizontal and vertical reactions at the joint B be \( H_B \) and \( V_B \), respectively, and \( V_C \) be the vertical reaction at the joint C.

Which one of the following sets gives the correct values of \( V_B \), \( H_B \) and \( V_C \)?

(A) \( V_B = 0; H_B = 0; V_C = P \)

(B) \( V_B = P/2; H_B = 0; V_C = P/2 \)

(C) \( V_B = P/2; H_B = P (\sin 60^\circ); V_C = P/2 \)

(D) \( V_B = P; H_B = P (\cos 60^\circ); V_C = 0 \)

[Ans. A]

\[ \Sigma F_H = 0 \Rightarrow H_B = D \]
\[ \Sigma M_C = 0 \Rightarrow V_B \times 2L = 0 \Rightarrow V_B = 0 \]
\[ \Sigma V = 0 \Rightarrow V_C = P \]
Q.No. 7

In shear design of an RC beam, other than the allowable shear strength of concrete \( (\tau_c) \), there is also an additional check suggested in IS 456-2000 with respect to the maximum permissible shear stress \( (\tau_{c,\text{max}}) \). The check for \( \tau_{c,\text{max}} \) is required to take care of:

(A) additional shear resistance from reinforcing steel
(B) additional shear stress that comes from accidental loading
(C) possibility of failure of concrete by diagonal tension
(D) possibility of crushing of concrete by diagonal compression

[Ans. D]

Under No circumstances even with the shear reinforcement shall the nominal shear stress, \( \tau_V \) should exceed \( \tau_{c,\text{max}} \). This prevents the failure of section by diagonal compression.

Q.No. 8

The semi-compact section of a laterally unsupported steel beam has an elastic section modulus, plastic section modulus and design bending compressive stress of 500 cm\(^3\), 650 cm\(^3\) and 200 MPa, respectively. The design flexural capacity (expressed in kN-m) of the section is ________

[Ans. *] Range: 99.9 to 100.1

As per IS 800, the design bending strength of laterally unsupported beam as governed by lateral torsional buckling is:

\[
M_d = \beta_b Z_p f_{bd}
\]

\[
\beta_b = \frac{Z_e}{Z_p}; \text{ for semi compact section}
\]

So,

\[
M_d = \frac{Z_e}{Z_p} Z_p f_{bd} = Z_e f_{bd}
\]

\[
= 500 \times 10^3 \times 200 \times 10^{-6} = 100 \text{ kN-m}
\]

Q.No. 9

Bull’s trench kiln is used in the manufacturing of

(A) lime (B) cement (C) bricks (D) none of these

[Ans. C]

Bull’s trench kiln is used to manufacture bricks.

Q.No. 10

The compound which is largely responsible for initial setting and early strength gain of Ordinary Portland Cement is

(A) C\(_3\)A (B) C\(_3\)S (C) C\(_2\)S (D) C\(_4\)AF

[Ans. B]

Tri calcium silicate (C\(_3\)S) hydrates and hardens rapidly and is largely responsible for initial set and early strength.
### Q.No. 11

In the consolidated undrained triaxial test on a saturated soil sample, the pore water pressure is zero

- (A) during shearing stage only
- (B) at the end of consolidation stage only
- (C) both at the end of consolidation and during shearing stages
- (D) under none of the above conditions

**[Ans. B]**

Consolidate undrained test (CU) test, drainage is permitted in consolidation stage. So, pore water pressure = 0. However, in shear stage, No drainage is permitted. So, pore water pressure develops.

### Q.No. 12

A fine grained soil is found to be plastic in the water content range of 26-48%. As per Indian Standard Classification System, the soil is classified as

- (A) CL
- (B) CH
- (C) CL-ML
- (D) CI

**[Ans. D]**

Soil is plastic in range of 26% to 48%. So, plastic limit = 26%. Liquid limit = 48%

Since 35% < LL < 50%...... So, CL.

### Q.No. 13

A vertical cut is to be made in a soil mass having cohesion \( c \), angle of internal friction \( \phi \), and unit weight \( \gamma \). Considering \( K_a \) and \( K_p \) as the coefficients of active and passive earth pressures, respectively, the maximum depth of unsupported excavation is

- (A) \( \frac{4c}{\gamma \sqrt{K_p}} \)
- (B) \( \frac{2c \sqrt{K_p}}{\gamma} \)
- (C) \( \frac{4c \sqrt{K_a}}{\gamma} \)
- (D) \( \frac{4c}{\gamma \sqrt{K_a}} \)

**[Ans. D]**

\[ P(a) = K_a \gamma z - 2c \sqrt{K_a} = 0 \]

\[ Z_e = \frac{QC}{\gamma \sqrt{K_a}} \]

So, max depth of unsupported excavation = \( 2Z_e \)

\[ = \frac{4c}{\gamma \sqrt{K_a}} \]
Q.No. 14

The direct runoff hydrograph in response to 5 cm rainfall excess in a catchment is shown in the figure. The area of the catchment (expressed in hectares) is

![Graph showing discharge vs time](image)

[Ans.] Range: 21.5 to 21.7

Let area of the catchment be a hectares

\[
\frac{1}{2} \times 6 \times 1 \times 60 \times 60 = A \times 10^4 \times 5 \times 10^{-2}
\]

\[\Rightarrow A = 21.6 \text{ ha}\]

Q.No. 15

The type of flood routing (Group I) and the equation(s) used for the purpose (Group II) are given below.

<table>
<thead>
<tr>
<th>Group I</th>
<th>Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td>P Hydrologic flood routing</td>
<td>1. Continuity equation</td>
</tr>
<tr>
<td>Q Hydraulic flood routing</td>
<td>2. Momentum equation</td>
</tr>
<tr>
<td></td>
<td>3. Energy equation</td>
</tr>
</tbody>
</table>

The correct match is

(A) P - 1; Q - 1, 2 & 3
(B) P - 1; Q - 1 & 2
(C) P - 1 & 2; Q - 1
(D) P - 1 & 2; Q - 1 & 2

[Ans. B]
Q.No. 16
The pre-jump Froude Number for a particular flow in a horizontal rectangular channel is 10. The ratio of sequent depths (i.e., post-jump depth to pre-jump depth) is ________

\[ F_1 = 10 \]
\[ \frac{y_2}{y_1} = -\frac{1}{2} + \frac{1}{2} \sqrt{1 + 8 F_1^2} \]
\[ \Rightarrow \frac{y_2}{y_1} = -\frac{1}{2} + \frac{1}{2} \sqrt{1 + 8 \times 100} \]
\[ = 13.65 \]

Q.No. 17

Pre-cursors to photochemical oxidants are

(A) NOX, VOCs and sunlight
(B) SO2, CO2 and sunlight
(C) H2S, CO and sunlight
(D) SO2, NH3 and sunlight

[Ans. A]
Pre-Cursors to photochemical oxidants are NOX, VOCs and sunlight. Photochemical smooth is formed when pre-cursor pollutants undergo reaction in sunlight.

Q.No. 18

Crown corrosion in a reinforced concrete sewer is caused by:

(A) H2S  (B) CO2  (C) CH4  (D) NH3

[Ans. A]
Crown corrosion is caused due to H2S being released from waste water.

Q.No. 19

It was decided to construct a fabric filter, using bags of 0.45 m diameter and 7.5 m long, for removing industrial stack gas containing particulates. The expected rate of airflow into the filter is 10 m³/s. If the filtering velocity is 2.0 m/min, the minimum number of bags (rounded to nearest higher integer) required for continuous cleaning operation is

(A) 27  (B) 29  (C) 31  (D) 32

[Ans. B]
Given, D= 0.45 m, L= 7.5 m
No. of fabric filter bags, \( N = \frac{A_t}{A_b} \)
\( A_t = \text{Total area of filter} = \frac{10 \times 60}{2} \times 300 \text{m}^2 \)
\( A_b = \text{Area of one bag} = \pi dL \)
\[ = \pi \times 0.45 \times 7.5 = 10.6 \text{ m}^2 \]
\( N = \frac{300}{10.6} = 28.28 \approx 29 \)
Q.No. 20

Match the items in Group – I with those in Group – II and choose the right combination.

<table>
<thead>
<tr>
<th>Group - I</th>
<th>Group - II</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. Activated sludge process</td>
<td>1. Nitrifiers and denitrifiers</td>
</tr>
<tr>
<td>Q. Rising of sludge</td>
<td>2. Autotrophic bacteria</td>
</tr>
<tr>
<td>R. Conventional nitrification</td>
<td>3. Heterotrophic bacteria</td>
</tr>
<tr>
<td>S. Biological nitrogen removal</td>
<td>4. Denitrifiers</td>
</tr>
</tbody>
</table>

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

[Ans. A]

Biological Nitrogen Removal → Nitrifies and Denitrifies

Q.No. 21

During a forensic investigation of pavement failure, an engineer reconstructed the graphs P, Q, R and S, using partial and damaged old reports.

Theoretically plausible correct graphs according to the ‘Marshall mixture design output’ are

(A) P, Q, R  
(B) P, Q, S  
(C) Q, R, S  
(D) R, S, P

[Ans. B]
Q.No. 22

In a one-lane one-way homogeneous traffic stream, the observed average headway is 3.0 s. The flow (expressed in vehicles/hr) in this traffic stream is ________

[Ans. *] Range: 1199 to 1201

Flow, \( q = \frac{3600}{t_H} = \frac{3600}{3} = 1200 \text{ veh/hr} \)

Q.No. 23

The minimum number of satellites needed for a GPS to determine its position precisely is

(A) 2  (B) 3  (C) 4  (D) 24

[Ans. C]

Min No. of satellites needed for a GPS to determine the position precisely = 4

Q.No. 24

The system that uses the Sun as a source of electromagnetic energy and records the naturally radiated and reflected energy from the object is called

(A) Geographical Information System  (B) Global Positioning System  (C) Passive Remote Sensing  (D) Active Remote Sensing

[Ans. C]

Passive Remote sensing uses sun as a source of EM energy and records the energy that is naturally radiated or reflected from objects

Q.No. 25

The staff reading taken on a workshop floor using a level is 0.645 m. The inverted staff reading taken to the bottom of a beam is 2.960 m. The reduced level of the floor is 40.500 m. The reduced level (expressed in m) of the bottom of the beam is

(A) 44.105  (B) 43.460  (C) 42.815  (D) 41.145

[Ans. A]

RL of bottom of beam = 40.5 + 2.96 + 0.645

= 44.105 m
Q.No. 26

Probability density function of a random variable \( X \) is given below

\[
f(x) = \begin{cases} 
0.25 & \text{if } 1 \leq x \leq 5 \\
0 & \text{otherwise}
\end{cases}
\]

\( P(X \leq 4) \) is

(A) \( \frac{3}{4} \)  
(B) \( \frac{1}{2} \)  
(C) \( \frac{1}{4} \)  
(D) \( \frac{1}{8} \)

[Ans. A]

Q.No. 27

The value of \( \int_{0}^{\infty} \frac{1}{1+x^2} \, dx + \int_{0}^{\infty} \frac{\sin x}{x} \, dx \) is

(A) \( \frac{\pi}{2} \)  
(B) \( \pi \)  
(C) \( \frac{3\pi}{2} \)  
(D) 1

[Ans. B]

Q.No. 28

The area of the region bounded by the parabola \( y = x^2 + 1 \) and the straight line \( x + y = 3 \) is

(A) \( \frac{59}{8} \)  
(B) \( \frac{9}{2} \)  
(C) \( \frac{10}{3} \)  
(D) \( \frac{7}{6} \)

[Ans. B]

Q.No. 29

The magnitudes of vectors \( P, Q \) and \( R \) are 100 kN, 250 kN and 150 kN, respectively as shown in the figure.

The respective values of the magnitude (in kN) and the direction (with respect to the x-axis) of the resultant vector are

(A) 290.9 and 96.0°  
(B) 368.1 and 94.7°  
(C) 330.4 and 118.9°  
(D) 400.1 and 113.5°

[Ans. C]
Q.No. 30

The respective expressions for complimentary function and particular integral part of the solution of the differential equation \( \frac{d^4 y}{dx^4} + 3 \frac{d^2 y}{dx^2} = 108 x^2 \) are

(A) \( [c_1 + c_2 x + c_3 \sin \sqrt{3} x + c_4 \cos \sqrt{3} x] \) and \( [3x^4 - 12x^2 + c] \)

(B) \( [c_2 x + c_3 \sin \sqrt{3} x + c_4 \cos \sqrt{3} x] \) and \( [5x^4 - 12x^2 + c] \)

(C) \( [c_1 + c_2 \sin \sqrt{3} x + c_4 \cos \sqrt{3} x] \) and \( [3x^4 - 12x^2 + c] \)

(D) \( [c_1 + c_2 x + c_3 \sin \sqrt{3} x + c_4 \cos \sqrt{3} x] \) and \( [5x^4 - 12x^2 + c] \)

[Ans. A]

Q.No. 31

A 3 m long simply supported beam of uniform cross section is subjected to a uniformly distributed load of \( w = 20 \text{ kN/m} \) in the central 1 m as shown in the figure.

\[
egin{align*}
\text{w} &= 20 \text{ kN/m} \\
\text{EI} &= 30 \times 10^6 \text{ N.m}^2
\end{align*}
\]

If the flexural rigidity (EI) of the beam is \( 30 \times 10^6 \text{ N.m}^2 \), the maximum slope (expressed in radians) of the deformed beam is

(A) \( 0.681 \times 10^{-7} \)  (B) \( 0.943 \times 10^{-7} \)  (C) \( 4.310 \times 10^{-7} \)  (D) \( 5.910 \times 10^{-7} \)

[Ans. *]
\[ C_1 = -9.583 \]

So, \[
\begin{align*}
\frac{dy}{dx}_{\text{max}} &= \frac{C_1}{EI} = \frac{-9.583}{30 \times 10^6} = 3.19 \times 10^{-7}
\end{align*}
\]

Q.No. 32

Two beams PQ (fixed at P and with a roller support at Q, as shown in Figure I, which allows vertical movement) and XZ (with a hinge at Y) are shown in the Figures I and II respectively. The spans of PQ and XZ are L and 2L respectively. Both the beams are under the action of uniformly distributed load \(W\) and have the same flexural stiffness, \(EI\) (where, \(E\) and \(I\) respectively denote modulus of elasticity and moment of inertia about axis of bending). Let the maximum deflection and maximum rotation be \(\delta_{\text{max}}\) and \(\theta_{\text{max}}\), respectively, in the case of beam PQ and the corresponding quantities for the beam XZ be \(\delta_{\text{max}}\) and \(\theta_{\text{max}}\), respectively.

![Figure I](image1)

![Figure II](image2)

Which one of the following relationships is true?

(A) \(\delta_{\text{max}} \neq \delta_{\text{max}}\) and \(\theta_{\text{max}} \neq \theta_{\text{max}}\)
(B) \(\delta_{\text{max}} = \delta_{\text{max}}\) and \(\theta_{\text{max}} \neq \theta_{\text{max}}\)
(C) \(\delta_{\text{max}} \neq \delta_{\text{max}}\) and \(\theta_{\text{max}} = \theta_{\text{max}}\)
(D) \(\delta_{\text{max}} = \delta_{\text{max}}\) and \(\theta_{\text{max}} = \theta_{\text{max}}\)

[Ans. D]

By Principal of superposition
\[ \delta_{\text{max}} = \delta_{\text{max}} \text{ and } \theta_{\text{max}} = \theta_{\text{max}} \]
Q.No. 33
A plane truss with applied loads is shown in the figure.

The members which do not carry any force are

(A) FT, TG, HU, MP, PL  
(B) ET, GS, UR, VR, QL  
(C) FT, GS, HU, MP, QL  
(D) MP, PL, HU, FT, UR

[Ans. A]
At any joint of a truss, if there is no external force, and if two members are collinear then third member carries the zero force
So, F = 0 in FT, TG, HU, MP, PL
Q.No. 34

A rigid member ACB is shown in the figure. The member is supported at A and B by pinned and guided roller supports, respectively. A force $P$ acts at C as shown. Let $R_{Ah}$ and $R_{Bh}$ be the horizontal reactions at supports A and B, respectively, and $R_{Av}$ be the vertical reaction at support A. Self-weight of the member may be ignored.

Which one of the following sets gives the correct magnitudes of $R_{Av}$, $R_{Bh}$ and $R_{Ah}$?

(A) $R_{Av} = 0$; $R_{Bh} = \frac{1}{3}P$, and $R_{Ah} = \frac{2}{3}P$

(B) $R_{Av} = 0$; $R_{Bh} = \frac{2}{3}P$, and $R_{Ah} = \frac{1}{3}P$

(C) $R_{Av} = P$; $R_{Bh} = \frac{3}{8}P$, and $R_{Ah} = \frac{1.5}{8}P$

(D) $R_{Av} = P$; $R_{Bh} = \frac{1.5}{8}P$, and $R_{Ah} = \frac{1.5}{8}P$

[Ans. D]

Taking moments about A = 0

$\Rightarrow R_{Bh} \times 8 + P \times 1.5 = 0$

$\Rightarrow R_{Bh} = -\frac{1.5P}{8}$

$\Sigma F_h = 0$

$\Rightarrow R_{Ah} = R_{Bh} = \frac{1.5P}{8}$

$\Sigma F_v = 0$

$\Rightarrow R_{AV} = P$
Q.No. 35

A reinforced concrete (RC) beam with width of 250 mm and effective depth of 400 mm is reinforced with Fe415 steel. As per the provisions of IS 456-2000, the minimum and maximum amount of tensile reinforcement (expressed in mm²) for the section are, respectively

(A) 250 and 3500  
(B) 205 and 4000  
(C) 270 and 2000  
(D) 300 and 2500

[Ans. B]

As per IS 456 : 2000,

Min tensile reinforcement, \( \frac{A_{st}}{bd} = \frac{0.85}{f_y} \)

\[ A_{st} = \frac{85}{f_y} \times bd = \frac{0.85}{415} \times 250 \times 400 \]

\[ = 204.81 \text{ mm}^2 \]

\[ \approx 205 \text{ mm}^2 \]

\( (A_{st})_{max} = 0.4 \% \text{ of } bd \)

\[ = \frac{0.4}{100} \times 250 \times 400 = 4000 \text{ mm}^2 \]

Q.No. 36

For M25 concrete with creep coefficient of 1.5, the long-term static modulus of elasticity (expressed in MPa) as per the provisions of IS:456-2000 is _______

[Ans. *] Range: 9999 to 10001

\[ E_l = \frac{E_s}{1 + \theta} \]

Where, \( E_s = 5000 \times \sqrt{f_{ck}} = 5000 \times \sqrt{25} = 25000 \text{ MPa} \)

\( \theta = \text{Creep coefficient} = 1.5 \)

\[ E_l = \frac{25000}{1 + 1.5} = 10000 \text{ MPa} \]
Q.No. 37

A propped cantilever of span $L$ carries a vertical concentrated load at the mid-span. If the plastic moment capacity of the section is $M_p$, the magnitude of the collapse load is

\[
\begin{align*}
\text{(A)} & \quad \frac{8M_p}{L} \\
\text{(B)} & \quad \frac{6M_p}{L} \\
\text{(C)} & \quad \frac{4M_p}{L} \\
\text{(D)} & \quad \frac{2M_p}{L}
\end{align*}
\]

[Ans. B]

By virtual work method

Work done by external force = work done by internal moments

\[
\Rightarrow M_p \theta + M_p (2\theta) = P \cdot \frac{L}{2\theta}
\]

\[
\Rightarrow P_U = \frac{6M_p}{L}
\]
Q.No. 38

Two plates are connected by fillet welds of size 10 mm and subjected to tension, as shown in the figure. The thickness of each plate is 12 mm. The yield stress and the ultimate tensile stress of steel are 250 MPa and 410 MPa, respectively. The welding is done in the workshop ($f_{\text{w}} = 1.25$).

As per the Limit State Method of IS 800: 2007, the minimum length (rounded off to the nearest higher multiple of 5 mm) of each weld to transmit a force $P$ equal to 270 kN (factored) is

(A) 90 mm  
(B) 105 mm  
(C) 110 mm  
(D) 115 mm

[Ans. B]

Max force carried by plates

$$P = A_y f_y = \frac{100 \times 12 \times 250}{1.1} = 272.7 \text{ kN}$$

Load carried by each weld $= \frac{P}{2} = 136.36 \text{ kN}$

For minimum length of weld

Strength of weld $= \frac{P}{2} = 136.36 \text{ kN}$

$$l_w \times t \times \frac{f_u}{\sqrt{3} Y_{mw}} = 136.36 \times 10^3$$

$$\Rightarrow l_w \times (10 \times 0.7) \times \frac{410}{\sqrt{3} \times 1.2} = 136.36 \times 10^3$$

$$l_w = 102.9 \text{ mm} \approx 105 \text{ mm}$$
Q.No. 39
The Optimistic Time (O), Most likely Time (M) and Pessimistic Time (P) (in days) of the activities in the critical path are given below in the format O-M-P.

\[ \text{t}_E = t_O + 4t_M + t_P \]

\[ \begin{align*}
\text{E-F: } t_E &= \frac{6 + 4 \times 10 + 14}{6} = 62 \\
\text{F-G: } t_E &= \frac{6 + 4 \times 8 + 11}{6} = 49 \\
\text{G-H: } t_E &= \frac{6 + 4 \times 7 + 10}{6} = 43 \\
\text{H-I: } t_E &= \frac{6 + 4 \times 12 + 18}{6} = 73 \\
\text{t}_E &= \frac{62}{6} + \frac{49}{6} + \frac{43}{6} + \frac{73}{6} = 37.83 \text{ days}
\end{align*} \]

[Ans. *] Range: 37 to 38

Q.No. 40
The porosity (\(n\)) and the degree of saturation (\(S\)) of a soil sample are 0.7 and 40%, respectively. In a 100 m\(^3\) volume of the soil, the volume (expressed in m\(^3\)) of air is __________

[Ans. *] Range: 41 to 43
\[ n = 0.7, S = 40\% \]
\[ V_v \]
\[ n = \frac{V}{V_v} \]
\[ \Rightarrow V_v = n \times V = 0.7 \times 100 = 70 \text{ m}^3 \]
\[ V_w = \frac{V}{V_v} \Rightarrow V_w = 0.4 \times 70 = 28 \text{ m}^3 \]
\[ V_w + V_a = V_v \]
\[ \Rightarrow 28 + V_a = 70 \]
\[ \Rightarrow V_a = 42 \text{ m}^3 \]
Q.No. 41

A homogeneous gravity retaining wall supporting a cohesionless backfill is shown in the figure. The lateral active earth pressure at the bottom of the wall is 40 kPa.

\[
K_a \cdot \gamma \cdot H = 40
\]

So,

\[
Pa = \frac{1}{2} \cdot K_a \cdot \gamma \cdot H^2 = 20 \cdot H = 120 \text{ kN}
\]

Taking moment about \( P = 0 \)

\[
Pa \times 2 = W \times 2
\]

\[
Pa = W = 120 \text{ kN}
\]
Q.No. 42

An undisturbed soil sample was taken from the middle of a clay layer (i.e., 1.5 m below GL), as shown in figure. The water table was at the top of clay layer. Laboratory test results are as follows:

- Natural water content of clay: 25%
- Preconsolidation pressure of clay: 60 kPa
- Compression index of clay: 0.50
- Recompression index of clay: 0.05
- Specific gravity of clay: 2.70
- Bulk unit weight of sand: 17 kN/m³

A compacted fill of 2.5 m height with unit weight of 20 kN/m³ is placed at the ground level.

Assuming unit weight of water as 10 kN/m³, the ultimate consolidation settlement (expressed in mm) of the clay layer is ____________

[Ans. *] Range: 36 to 38

\[
S = C_r H_o \log \frac{\sigma_c}{\sigma} + C_c H_o \log \frac{\sigma_o + \Delta \sigma}{\sigma_o}
\]

Where,
- \( C_r = 0.05 \), \( C_c = 0.50 \), \( H_o = 1 \) m
- Far clay, \( e_o = 2.7 \times 0.25 = 0.675 \)
- \( \sigma_o = 60 \text{ kPa} \), \( \sigma_o = 17 \times 1 + (20.15 - 10) \times 0.5 = 22.075 \text{ kPa} \)
- \( \gamma_{clay} = \frac{G + e}{1 + e} \times \gamma_w = \frac{2.7 + 0.675}{1.675} \times 10 = 20.15 \text{ kN/m}^3 \)
- \( \Delta \sigma_o = 20 \times 2.5 = 50 \text{ kN/m}^2 \)

\[
\Delta \sigma_o = 20 \times 2.5 = 50 \text{ kN/m}^2
\]

\[
S = 0.05 \times 1 \log \frac{60}{22.075} + 0.5 \times 1 \log \frac{22.075 + 50}{60}
\]

\[
= 0.01296 + 0.02377 \text{ m}
\]

\[
= 0.0367 \text{ m} = 36.74 \text{ mm}
\]
Q.No. 43

A seepage flow condition is shown in the figure. The saturated unit weight of the soil $\gamma_{sat} = 18$ kN/m$^3$. Using unit weight of water, $\gamma_w = 9.81$ kN/m$^3$, the effective vertical stress (expressed in kN/m$^2$) on plane $XX'$ is ________.

[Ans. *] Range: 65.3 to 65.6
Q.No. 44

A drained triaxial compression test on a saturated clay yielded the effective shear strength parameters as \(c' = 15\) kPa and \(\phi' = 22^\circ\). Consolidated Undrained triaxial test on an identical sample of this clay at a cell pressure of 200 kPa developed a pore water pressure of 150 kPa at failure. The deviator stress (expressed in kPa) at failure is __________

[Ans.*] Range: 100 to 110

CD test: \(\phi = 22^\circ, C' = 15\) KPa

CU test:

\[
\sigma_1 - U = (\sigma_3 - U)\tan^2 \left(45 + \frac{\phi}{2}\right) + 2c\tan \left(45 + \frac{\phi}{2}\right)
\]

\[
\Rightarrow \sigma_1 - 150 = (200 - 150)\tan^2(45 + 11) + 2 \times 15 \tan(45 + 11)
\]

\[
\Rightarrow \sigma_1 - 150 = 50\tan^2 56^\circ + 30 \tan(56^\circ)
\]

\[
\Rightarrow \sigma_1 - 150 = 50 \times (1.484)^2 + 30 \times 1.484
\]

\[
\Rightarrow \sigma_1 = 150 + 110.11 + 44.52 = 304.63\text{ kN/m}^2
\]

So, Deviator Stress = \(\sigma_1 - \sigma_3\)

\[
= 304.63 - 200
\]

\[
= 104.63\text{ kN/m}^2
\]
Q.No. 45

A concrete gravity dam section is shown in the figure. Assuming unit weight of water as 10 kN/m$^3$ and unit weight of concrete as 24 kN/m$^3$, the uplift force per unit length of the dam (expressed in kN/m) at PQ is __________

\[ \gamma_w H_2 = 10 \times 5 = 50 \text{ kN/m}^2 \]
\[ \gamma_w H_1 = 10 \times 65 = 650 \text{ kN/m}^2 \]
\[ \gamma_w H_2 + \frac{1}{3} \cdot \gamma_w (H_2 - H_1) = 50 + \frac{1}{3} \times 10 \times 60 = 250 \text{ kN/m}^2 \]
\[ P = \frac{1}{2} \times (650 + 250) \times 10 + \frac{1}{2} \times (250 + 50) \times 40 \]
\[ = 4500 + 6000 \]
\[ = 10500 \text{ kN/m} \]

[Ans.*] Range: 10490 to 10510
Q.No. 46

Seepage is occurring through a porous media shown in the figure. The hydraulic conductivity values \((k_1, k_2, k_3)\) are in m/day.

\[
\begin{align*}
\Sigma \tau_1 & = 20 + 30 + 10 \\
\Sigma \tau_1 & = \frac{20}{3} + \frac{30}{3} + \frac{10}{3} \\
\end{align*}
\]

\[
K_{avg} = \frac{\Sigma \tau_1}{\Sigma k_i} = \frac{2}{3} \approx 2 \text{ m/day}
\]

\[
n = \frac{15 - 10}{60} = \frac{1}{12}
\]

\[
q = K_{avg} \times n \times A
\]

\[
= 2 \times \frac{1}{12} \times 3 \times 1
\]

\[
= 0.5 \text{ m}^3/\text{day}/\text{m}
\]
Q.No. 47

A 4 m wide rectangular channel, having bed slope of 0.001 carries a discharge of 16 m$^3$/s. Considering Manning’s roughness coefficient = 0.012 and $g = 10$ m/s$^2$, the category of the channel slope is

(A) horizontal  (B) mild  (C) critical  (D) steep

[Ans. B]

For Rectangular channel, $y_c = \left(\frac{q^2}{g}\right)^{\frac{1}{3}}$

Where, $q = \frac{Q}{B} = \frac{16}{4} = 4$ m$^2$/s

$y_c = \left[\frac{(4)^2}{10}\right]^{1/3} = 1.17$ m

By Manning’s method

$Q = \frac{1}{n} \times A \times (R)^{\frac{2}{3}} \times (S)^{\frac{1}{2}}$

$\Rightarrow 16 = \frac{1}{0.012} \times (4) \times y_n \times (y_n)^{\frac{2}{3}} \times (0.001)^{\frac{1}{2}}$

$\Rightarrow y_n = 1.28$ m

$y_n > y_c & s_0 < s_c$

so mild slope
Q.No. 48

A sector gate is provided on a spillway as shown in the figure. Assuming \( g = 10 \text{ m/s}^2 \), the resultant force per meter length (expressed in kN/m) on the gate will be

\[ F_H = \frac{1}{2} \times 1000 \times 10 \times (5)^2 \text{ kN} \]

\[ = \frac{100000}{1000} \text{ kN} \]

\[ = 125 \text{ kN} \]

\( F_H \) acts a distance \( \frac{5}{3} = 1.67 \text{ m} \) from the base

\( F_v \) weight of water enclosed or supported (actual or imaginary) by the curved surface

\[ = \rho g \times \text{volume of portion ABC} \]

\[ = 1000 \times 10 \times \left[ \frac{1}{2} \times 25 \times \frac{60}{180} \times \pi - \frac{1}{2} \times \frac{5}{2} \times \frac{5\sqrt{3}}{2} \right] \]

\[ = 1000 \times 10 \times \left[ \frac{25}{6} \times \pi - 1.25 \times 5\sqrt{3} \right] \]

\[ = 1000 \times 10 \times 2.27 \times 1 \]

[Ans. *] Range: 126 to 128
Q.No. 49
A hydraulically efficient trapezoidal channel section has a uniform flow depth of 2 m. The bed width (expressed in m) of the channel is

[Ans. *] Range: 2.29 to 2.32

For hydraulically efficient channel,

\[ B = \frac{2}{\sqrt{3}} \times \frac{y}{\sqrt{3}} \times 2 = \frac{4}{\sqrt{3}} = 2.31 \text{ m} \]

Q.No. 50
Effluent from an industry 'A' has a pH of 4.2. The effluent from another industry 'B' has double the hydroxyl (OH\(^-\)) ion concentration than the effluent from industry 'A'. pH of effluent from the industry 'B' will be

[Ans. *] Range: 4.4 to 4.6

A
\[ \text{pH} = 4.2 \]
\[ \text{pOH} = 9.8 \]
\[ \Rightarrow [\text{OH}^-] = 10^{-9.8} \text{ mol/l} \]

B
\[ [\text{OH}^-] = 2 \times 10^{-9.8} \text{ mol/L} \]
\[ \Rightarrow \text{pOH} = 9.8 - \log_{10}(2) \]
\[ = 9.5 \]
\[ \Rightarrow \text{pH} = 4.5 \]

Q.No. 51
An electrostatic precipitator (ESP) with 5600 m\(^2\) of collector plate area is 96 percent efficient in treating 185 m\(^3\)/s of flue gas from a 200 MW thermal power plant. It was found that in order to achieve 97 percent efficiency, the collector plate area should be 6100 m\(^2\). In order to increase the efficiency to 99 percent, the ESP collector plate area (expressed in m\(^2\)) would be

[Ans. *] Range: 8000 to 8020

So,
\[ \frac{A_1}{A_2} = \frac{\ln(1 - \eta_1)}{\ln(1 - \eta_2)} \]
\[ \Rightarrow \frac{\ln(1 - 0.96)}{\ln(1 - 0.99)} = \frac{A}{5600} \]
\[ \Rightarrow A = 8011.8 \text{ m}^2 \]
Q.No. 52

The 2-day and 4-day BOD values of a sewage sample are 100 mg/L and 155 mg/L, respectively. The value of BOD rate constant (expressed in per day) is ________

[Ans.⁎] Range: 0.29 to 0.31

\[ \text{BOD}_2 = L_0 \times (1 - e^{-k \times 2}) \]

\[ 100 = L_0 \times (1 - e^{-2k}) \quad (i) \]

Also

\[ 155 = L_0 \times (1 - e^{-4k}) \quad (ii) \]

\[(i)/(ii) \Rightarrow 100 \times 1-4k = 155 \times (1-2k) \]

\[ e^{-4k} - 1.55 \times e^{-2k} + 0.55 = 0 \]

Let \( e^{-2k} = x \)

\[ x^2 - 1.55x + 0.55 = 0 \]

\[ x = 0.55 \]

\[ e^{-2k} = 0.55 \]

\[ \Rightarrow K = 0.3 \text{ day}^{-1} \]

Q.No. 53

A two lane, one-way road with radius of 50 m is predominantly carrying lorries with wheelbase of 5 m. The speed of lorries is restricted to be between 60 kmph and 80 kmph. The mechanical widening and psychological widening required at 60 kmph are designated as \( w_{me,60} \) and \( w_{ps,60} \), respectively. The mechanical widening and psychological widening required at 80 kmph are designated as \( w_{me,80} \) and \( w_{ps,80} \), respectively. The correct values of \( w_{me,60}, w_{ps,60}, w_{me,80}, w_{ps,80} \), respectively are

(A) 0.89 m, 0.50 m, 1.19 m, and 0.50 m

(B) 0.50 m, 0.89 m, 0.50 m, and 1.19 m

(C) 0.50 m, 1.19 m, 0.50 m, and 0.89 m

(D) 1.19 m, 0.50 m, 0.89 m, and 0.50 m

[Ans. B]

\[ w_{me,60} = \frac{n.l^2}{2R} = \frac{2 \times (5)^2}{2 \times 50 \times 60} = 0.5 \text{ m} \]

\[ w_{ps} = \frac{V}{9.5\sqrt{R}} = \frac{9.5 \times \sqrt{50}}{9.5 \times \sqrt{50}} = 0.89 \text{ m} \]

\[ w_{me,80} = \frac{2 \times (5)^2}{2 \times 50 \times 80} = 0.50 \text{ m} \]

\[ w_{ps,80} = \frac{9.5 \times \sqrt{80}}{9.5 \times \sqrt{80}} = 1.19 \text{ m} \]
Q.No. 54

While traveling along and against the traffic stream, a moving observer measured the relative flows as 50 vehicles/hr and 200 vehicles/hr, respectively. The average speeds of the moving observer while traveling along and against the stream are 20 km/hr and 30 km/hr, respectively. The density of the traffic stream (expressed in vehicles/km) is

[Ans. *] Range: 2.9 to 3.1

Q.No. 55

The vertical angles subtended by the top of a tower T at two instrument stations set up at P and Q, are shown in the figure. The two stations are in line with the tower and spaced at a distance of 60 m. Readings taken from these two stations on a leveling staff placed at the benchmark (BM = 450.000 m) are also shown in the figure. The reduced level of the top of the tower T (expressed in m) is

[Ans. *] Range: 476.500 to 477.500

\[
\Delta TST', \tan 16.5^\circ = \frac{T'T}{x} \quad \ldots (1)
\]
\[
\Delta TRT'', \tan(10.5^\circ) = \frac{T'T''}{x + 60} = \frac{T'T + 2}{x + 60} \quad \ldots (2)
\]
From (1) and (2)
\[
x \times \tan 16.5^\circ = (x + 10) \times \tan(10.5^\circ) - 2
\]
\[
\Rightarrow x \times 0.296 = (x + 10) \times 0.185 - 2
\]
\[
\Rightarrow x = 82.25 \text{ m}
\]
So, T'T = 82.25 \times 0.296 = 24.35 \text{ m}
So, RL of top of tower = 450 + 2.555 + 24.35
= 476.305 \text{ m}