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GATE 2017
Civil Engineering
(Forenoon Session: 12-02-2017)

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CIVIL ENGINEERING

Q.1
A uniformly distributed line load of 500 kN/m is acting on the ground surface. Based on Boussinesq’s theory, the ratio of vertical stress at depth 2 m to that at 4 m, right below the line of loading, is
(a) 0.25  
(b) 0.5  
(c) 2.0  
(d) 4.0

Ans.  (c)

\[
q' = 500 \text{ kN/m} \quad x = 0 \text{ (Just below the line load)}
\]

\[
\sigma_z = \frac{2q'}{\pi z} \left( \frac{1}{1 + \frac{x^2}{z^2}} \right)^2 = \frac{2q'}{\pi z}
\]

\[
\text{Ratio} = \frac{\sigma_z}{\text{at, 2m}} = \frac{2q'}{\pi \times 2} = \frac{2q'}{\pi \times 4}
\]

Q.2

\[
\lim_{x \to 0} \left( \frac{\tan x}{x^2 - x} \right)
\]

is equal to ________.

Ans.  (-1)

\[
\lim_{x \to 0} \frac{\tan x}{x^2 - x} = \lim_{x \to 0} \frac{\sec^2 x}{2x - 1} = \frac{\sec^2 0}{2 \times 0 - 1} = \frac{1}{-1} = -1
\]

Q.3
Consider the following partial differential equation:

\[
3 \frac{\partial^2 \phi}{\partial x^2} + B \frac{\partial^2 \phi}{\partial x \partial y} + 3 \frac{\partial^2 \phi}{\partial y^2} + 4 \phi = 0
\]

For this equation to be classified as parabolic, the value of \(B^2\) must be ________.

Ans.  (36)

Given that the partial differential equation is parabolic.

\[
\therefore \quad B^2 - 4AC = 0 \\
\therefore \quad B^2 - 4(3)(3) = 0 \\
\therefore \quad B^2 - 36 = 0 \\
B^2 = 36
\]

Here \(A = 3\)

\(C = 3\)
Q.4 According to IS 456-2000, which one of the following statements about the depth of neutral axis $x_{u,bal}$ for a balanced reinforced concrete section is correct?
(a) $x_{u,bal}$ depends on the grade of concrete only
(b) $x_{u,bal}$ depends on the grade of steel only
(c) $x_{u,bal}$ depends on both the grade of concrete and grade of steel
(d) $x_{u,bal}$ does not depend on the grade of concrete and grade of steel

Ans. (b)

$$x_{u, bal} = \frac{700}{1100 + 0.87f_y} \times d$$

So it depends upon grade of steel only.

---

Q.5 For a steady incompressible laminar flow between two infinite parallel stationary plates, the shear stress variation is
(a) linear with zero value at the plates
(b) linear with zero value at the center
(c) quadratic with zero value at the plates
(d) quadratic with zero value at the center

Ans. (b)

Shear stress variation between parallel stationary plates.

---

Q.6 The accuracy of an Electronic Distance Measuring Instrument (EDMI) is specified as ± (a mm + b ppm). Which one of the following statements is correct?
(a) Both $a$ and $b$ remain constant, irrespective of the distance being measured.
(b) $a$ remains constant and $b$ varies in proportion to the distance being measured.
(c) $a$ varies in proportion to the distance being measured and $b$ remains constant.
(d) Both $a$ and $b$ vary in proportion to the distance being measured.

Ans. (b)

Accuracy of EDMI is generally stated in terms of constant instruments error and a measuring error proportional to the distance being measured: ± (a mm + b ppm). The first part indicates a constant instrument error that is independent of the length of the line measured. The second component is the distance related error.
Classroom Course is designed for comprehensive preparation of ESE, GATE and PSUs. The main feature of the course is that all the subjects are taught from basic level to advance level. There is due emphasis on solving objective and numerical questions in the class. High quality study material is provided during the classroom course with sufficient theory and practice test papers for objective and conventional questions along with regular assignments for practice. Classes are taken by highly experienced professors and ESE qualified toppers. MADE EASY team has developed very effective methodology of teaching and advance techniques and shortcuts to solve objective questions in limited time.”
Q. 7  The wastewater from a city, containing a high concentration of biodegradable organics, is being steadily discharged into a flowing river at a location S. If the rate of aeration of the river water is lower than the rate of degradation of the organics, then the dissolved oxygen of the river water.
(a) is lowest at the location S.
(b) is lowest at a point upstream of the location S.
(c) remains constant all along the length of the river.
(d) is lowest at a point downstream of the location S.

Ans.  (d)

As given rate of aeration is less than rate of degradation which decreases with time/distance, minimum DO is observed downstream of point of disposal ‘S’ where both rate of a reaction and degradation becomes equal.

Q. 8  Group I lists the type of gain or loss of strength in soils. Group II lists the property or process responsible for the loss or gain of strength in soils.

<table>
<thead>
<tr>
<th>Group I</th>
<th>Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. Regain of strength with time</td>
<td>1. Boiling</td>
</tr>
<tr>
<td>Q. Loss of strength due to cyclic loading</td>
<td>2. Liquefaction</td>
</tr>
<tr>
<td>R. Loss of strength due to upward seepage</td>
<td>3. Thixotropy</td>
</tr>
<tr>
<td>S. Loss of strength due to remoulding</td>
<td>4. Sensitivity</td>
</tr>
</tbody>
</table>

The correct match between Group I and Group II is:
(a)  P-4, Q-1, R-2, S-3  (b)  P-3, Q-1, R-2, S-4
(c)  P-3, Q-2, R-1, S-4  (d)  P-4, Q-2, R-1, S-3

Ans.  (c)

- Loss in strength of soil due to remoulding at same water content is termed as sensitivity.
- Over a period of time soil regain a part of its lost strength is termed as thixotropy.
- When seepage takes place in upward direction, seepage pressure acts in upward direction and effective stress is reduced, consequently shear strength is reduced.
- In liquefaction, due to dynamic/cyclic loading in loose saturated sand, effective stress decreases and decrease in shear strength is recorded.
Q.9 A soil sample is subjected to a hydrostatic pressure, $\sigma$. The Mohr circle for any point in the soil sample would be
(a) a circle of radius $\sigma$ and center at the origin
(b) a circle of radius $\sigma$ and center at a distance $\sigma$ from the origin
(c) a point at a distance $\sigma$ from the origin
(d) a circle of diameter $\sigma$ and center at the origin

Ans. (c)

Hydrostatic pressure acts equally in all directions.

---

Q.10 Vehicles arriving at an intersection from one of the approach roads follow the Poisson distribution. The mean rate of arrival is 900 vehicles per hour. If a gap is defined as the time difference between two successive vehicle arrivals (with vehicles assumed to be points), the probability (up to four decimal places) that the gap is greater than 8 seconds is 0.1353.

Ans. (0.1353)

\[
\lambda = \frac{900 \text{ veh/hour}}{3600} = \frac{1}{4} \text{ veh/sec}
\]

\[
P [t \geq 8 \text{ sec}] = e^{-\lambda t} = e^{-\frac{1}{4} \times 8} = e^{-2} = 0.1353
\]

---

Q.11 A 3 m thick clay layer is subjected to an initial uniform pore pressure of 145 kPa as shown in the figure.

For the given ground conditions, the time (in days, rounded to the nearest integer) required for 90% consolidation would be ________.
Ans. (1771)

As per Terzaghi’s 1-D consolidation theory,

\[ T_v = C_v \cdot \frac{f}{d^2} \]

One way drainage condition \( d = 3 \text{ m} \)

For 90\% consolidation

\[ (T_v)_{90} = C_v \cdot \frac{t_{90}}{d^2} \]

\[ 0.85 = 3 \times 10^{-6} \times \frac{t_{90}}{(3)^2} \]

\[ t_{90} = \frac{0.85 \times 9}{3 \times 10^{-5}} \text{ min} \]

\[ t_{90} = 1770.83 = 1771 \text{ days} \]

--- End of Solution ---

Q.12

A super-elevation \( e \) is provided on a circular horizontal curve such that a vehicle can be stopped on the curve without sliding. Assuming a design speed \( v \) and maximum coefficient of side friction \( f_{\text{max}} \), which one of the following criteria should be satisfied?

(a) \( e \leq f_{\text{max}} \)  
(b) \( e > f_{\text{max}} \)  
(c) no limit on \( e \) can be set  
(d) \( e = \frac{1-(f_{\text{max}})^2}{f_{\text{max}}} \)

Ans. (a)

Sliding occurs if

\[ f < e \]

and \( f < \frac{v^2}{gR} \)

Overturning occurs if

\[ f > e \]

and \( e < \frac{v^2}{gR} \)

Hence, option (a) is correct.

--- End of Solution ---
Q.13  The number of parameters in the univariate exponential and Gaussian distributions, respectively, are
(a) 2 and 2  (b) 1 and 2  
(c) 2 and 1  (d) 1 and 1

Ans.  (b)

In exponential, \( f(x) = \lambda e^{-\lambda x}; \ x = 0 \)
The parameter is \( \lambda \).

In Gaussian, \( f(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}; \ -\infty < x < \infty \)
The parameters are \( \mu \) and \( \sigma \).
Therefore, answer is (b).

Q.14  The figure shows a two-hinged parabolic arch span \( L \) subjected to a uniformly distributed load of intensity \( q \) per unit length.

![Diagram of a two-hinged parabolic arch](image)

The maximum bending moment in the arch is equal to
(a) \( \frac{qL^2}{8} \)  (b) \( \frac{qL^2}{12} \) 
(c) zero  (d) \( \frac{qL^2}{10} \)

Ans.  (c)

If a two hinged or three hinged parabolic arch is subjected to UDL throughout its length, bending moment is zero everywhere.

Q.15  The ordinates of a 2-hour unit hydrograph for a catchment are given as

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinate (m³/s)</td>
<td>0</td>
<td>5</td>
<td>12</td>
<td>25</td>
<td>41</td>
</tr>
</tbody>
</table>

The ordinate (in m³/s) of a 4-hour unit hydrograph for this catchment at the time of 3h would be_________.

Ans. (15)

<table>
<thead>
<tr>
<th>Time (hr)</th>
<th>Ordinate of 2 hr Unit Hydrograph</th>
<th>Ordinate of 2 hr Unit Hydrograph lag by 2 hr</th>
<th>Ordinate of 4 hr DRH</th>
<th>Ordinate of 4 hr Unit Hydrograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>-</td>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>0</td>
<td>12</td>
<td>6.0</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>5</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>41</td>
<td>12</td>
<td>53</td>
<td>26.5</td>
</tr>
</tbody>
</table>

\[ \therefore \text{Ordinate of 4 hr U.H. at 3 hr duration} = 15.0 \text{ m}^3/\text{sec}. \]

**Q.16** A runway is being constructed in a new airport as per the International Civil Aviation Organization (ICAO) recommendations. The elevation and the airport reference temperature of this airport are 535 m above the mean sea level and 22.65°C, respectively. Consider the effective gradient of runway as 1%. The length of runway required for a design-aircraft under the standard conditions is 2000 m. Within the framework of applying sequential corrections as per the ICAO recommendations, the length of runway corrected for the temperature is

(a) 2223 m  
(b) 2250 m  
(c) 2500 m  
(d) 2750 m

**Ans. (c)**

Elevation = 535 m

Airport Reference Temperature = 22.65°C

Effective Gradient = 1%

Runway length = 2000 m under standard conditions.

Runway length correction for T°C.

\[ \Rightarrow \text{Correction for elevation} = \frac{7}{100} \times 2000 \times \frac{535}{300} = 249.67 \text{ m} \]

Corrected runway length = 2249.67 m

\[ \Rightarrow \text{Corrected standard T° at 535 m elevation} = 15°C - (0.0065 \times 535) = 11.52°C \]

Correction for T° = \[ \frac{1}{100} \times 2249.67 \times \frac{\Delta T°C}{1°C} \]
\[ \Delta T°C = 22.65 - 11.52 = 11.13°C \]

\[ = \frac{1}{100} \times 2249.67 \times \frac{11.13°C}{1°C} = 250.39 \text{ m} \]

Corrected Runway length = 2249.67 + 250.39 = 2500.06 m

End of Solution
Q.17 A simply supported beam is subjected to a uniformly distributed load. Which one of the following statements is true?
(a) Maximum or minimum shear force occurs where the curvature is zero.
(b) Maximum or minimum bending moment occurs where the shear force is zero.
(c) Maximum or minimum bending moment occurs where the curvature is zero.
(d) Maximum bending moment and maximum shear force occur at the same section.

Ans. (b)

Q.18 A triangular pipe network is shown in the figure

![Diagram of a triangular pipe network with points A, B, and C, with flow rates Q = 100, Q = 70, and Q = 30, and radii r = 1, r = 2.]

The head loss in each pipe is given by \( h_f = rQ^{1.8} \), with the variables expressed in a consistent set of units. The value of \( r \) for the pipe \( AB \) is 1 and for the pipe \( BC \) is 2. If the discharge supplied at the point \( A \) (i.e., 100) is equally divided between the pipes \( AB \) and \( AC \), the value of \( r \) (up to 2 decimal places) for the pipe \( AC \) should be ________

Ans. (0.62)

Given \( h_f = r \cdot Q^{1.8} \)
Because of the given condition of equal discharge distribution in pipe \( AB \) & \( AC \), the discharge in \( AB \) and \( AC \) will be 50 and 50. Now satisfy continuity at point \( B \) and \( C \)
For close loop \( ABCA \)
\[ \sum h_f = 0 \]
\[ \Rightarrow 1(50)^{1.8} - 2(20)^{1.8} - r(50)^{1.8} = 0 \]
\[ \Rightarrow 1143.26 - 439.42 = r(50)^{1.8} \]
\[ r = 0.62 \]

Q.19 A strip footing is resting on the ground surface of a pure clay bed having an undrained cohesion \( c_u \). The ultimate bearing capacity of the footing is equal to
(a) \( 2\pi c_u \)
(b) \( \pi c_u \)
(c) \( (\pi + 1) c_u \)
(d) \( (\pi + 2) c_u \)

Ans. (d)

Footing is at surface
Hence, \( D_f = 0 \)
\[ q_u = CN_c + \gamma D_f N_q + 0.5 \gamma N_q \]
\[ \Rightarrow \text{For clay} \quad N_f = 0, \ N_q = 1 \]
\[ q_u = C N_c \]

As per Terzaghi, \( N_c = 5.7 \)

and as per Meyerhoff and Prandtl, \( N_c = 5.14 \)

\[ q_u = (\pi + 2)C_u = (3.14 + 2)C_u = 5.14 \ C_u \]

**Q.20** Let \( x \) be a continuous variable defined over the interval \((-\infty, \infty)\), and \( f(x) = e^{-x}e^{-x} \).

The integral \( g(x) = \int f(x)dx \) is equal to

(a) \( e^{-x}\)  
(b) \( e^{-x-x} \)

(c) \( e^{-x} \)  
(d) \( e^{-x} \)

**Ans.** (b)

\[
\int f(x)dx = e^{-x}e^{-x} = e^{-x}e^{-x}
\]

\[
y(x) = \int f(x)dx = \int e^{-x}e^{-x}dx
\]

Let \( e^{-x} = t \)

\[
-e^{x} \ dx = dt
\]

\[
\int f(x)dx = \int e^{-x}(-dt)
\]

\[
= \frac{-e^{-t}}{-1}(-dt)
\]

\[
= e^{-t}
\]

\[
= e^{-(e^{-x})} = e^{-e^{-x}}
\]

**Q.21** The reaction rate involving reactants \( A \) and \( B \) is given by \(-k[A]^\alpha [B]^\beta\). Which one of the following statements is valid for the reaction to be a first-order reaction?

(a) \( \alpha = 0 \) and \( \beta = 0 \)  
(b) \( \alpha = 1 \) and \( \beta = 0 \)

(c) \( \alpha = 1 \) and \( \beta = 1 \)  
(d) \( \alpha = 1 \) and \( \beta = 2 \)

**Ans.** (b)

The order of reaction is the exponent to which its concentration term in the rate equation is raised.

\[
\text{Rate, } r = k[A]^\alpha [B]^\beta
\]

For first order reaction,

\[
\alpha + \beta = 1
\]
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Q.22 The number of spectral bands in the Enhanced Thematic Mapper sensor on the remote sensing satellite Landsat-7 is
(a) 64 (b) 10
(c) 8 (d) 15

Ans. (c)
Total number of spectrum band in Enhanced Thematic Mapper sensor = 8

Q.23 Which one of the following is NOT present in the acid rain?
(a) HNO₃ (b) H₂SO₄
(c) H₂CO₃ (d) CH₃COOH

Ans. (d)
Acid rain primarily consist of HNO₃, H₂SO₄ and H₂CO₃.

Q.24 An elastic bar length L, uniform cross-sectional area A, coefficient of thermal expansion α, and Young’s modulus E is fixed at the two ends. The temperature of the bar is increased by T, resulting in an axial stress σ. Keeping all other parameters unchanged, if the length of the bar is doubled, the axial stress would be
(a) σ (b) 2σ
(c) 0.5 σ (d) 0.25 α σ

Ans. (a)

\[ \sigma = \alpha LE \]
\[ \therefore \text{Length have no effect on thermal stress.} \]
\[ \therefore \text{Axial stress is only } \sigma. \]

Q.25 The matrix P is the inverse of a matrix Q. If I denotes the identity matrix, which one of the following options is correct?
(a) \( PQ = I \) but \( QP \neq I \)
(b) \( QP = I \) but \( PQ \neq I \)
(c) \( PQ = I \) and \( QP = I \)
(d) \( PQ - QP = I \)

Ans. (c)

Given that \( P \) is inverse of \( Q \),
\[ P = Q^{-1} \quad P = Q^{-1} \]
\[ PQ = Q^{-1}Q \quad QP = QQ^{-1} \]
\[ PQ = I \quad QP = I \]
\[ \therefore \quad PQ = QP = I \]
Q.26 Water flows through a 90° bend in a horizontal plane as depicted in the figure.

A pressure of 140 kPa is measured at section 1-1. The inlet diameter marked at section 1-1 is \( \frac{27}{\sqrt{\pi}} \) cm, while the nozzle diameter marked at section 2-2 is \( \frac{14}{\sqrt{\pi}} \) cm. Assume the following:

(i) Acceleration due to gravity = 10 m/s\(^2\).
(ii) Weights of both the bent pipe segment as well as water are negligible.
(iii) Friction across the bend is negligible.

The magnitude of the force (in kN, up to two decimal places) that would be required to hold the pipe section is _________.

Ans. \( 397.25 \)
14 = \frac{1}{2 \times 10} \left[ v_2^2 - v_1^2 \right] \\
14 \times 2 \times 10 = Q^2 \left[ \frac{1}{A_2^2} - \frac{1}{A_1^2} \right] \\
280 = Q^2 \left[ \frac{1}{\pi (0.14)^2} - \frac{1}{\pi (0.27)^2} \right] \\
Q = \frac{1}{3} \text{ m}^3/\text{sec} \\

Momentum equation in x-direction \\
P_t A_t - F_x = m \left[ v_{2x} - v_{1x} \right] \\
\quad v_{2x} = 0; \quad v_{1x} = \frac{Q}{A_1} \\
P_t A_t - F_x = \rho Q \left[ 0 - \frac{Q}{A_1} \right] \\
F_x = P_t A_t + \frac{\rho Q^2}{A_1} \\
\quad = \left\{ 140 \times 10^3 \times \frac{\pi}{4} \times \frac{0.27^2}{\pi} \right\} + \left\{ \frac{1000 \times 1.3699^2}{\pi} \right\} \\
\quad = 105.52 \text{ kN} \\

Moment equation in y-direction \\
F_y = m \left[ v_{2y} - v_{1y} \right] \\
\quad v_{1y} = 0; \quad v_{2y} = \frac{Q}{A_2} \\
F_y = \rho Q \left[ \frac{Q}{A_2} \right] \\
\quad = 10^3 \times 1.3699^2 \times \frac{1}{\pi} \times \frac{0.14^2}{\pi} \\
\quad = 382.98 \text{ kN} \\

Resultant force, \\
F_R = \sqrt{F_x^2 + F_y^2} \\
\quad = \sqrt{105.52^2 + 382.98^2} \\
\quad = 397.25 \text{ kN}
Q.27 The laboratory tests on a soil sample yield the following results; natural moisture content = 18%, liquid limit = 60%, plastic limit = 25%, percentage of clay sized fraction = 25%. The liquidity index and activity (as per the expression proposed by Skempton) of the soil, respectively, are
(a) −0.2 and 1.4  
(b) 0.2 and 1.4  
(c) −1.2 and 0.714  
(d) 1.2 and 0.714

Ans. (a)
Given data: \( w_n = 18\% \), \( w_l = 60\% \), \( w_p = 25\% \)
% of clay size particle = 25%

Liquidity index \( I_L = \frac{w_n - w_p}{w_l - w_p} = \frac{0.18 - 0.25}{0.60 - 0.25} = -0.2 \)

Activity = \( \frac{I_p}{\% C} = \frac{w_l - w_p}{\% C} = \frac{60 - 25}{25} = 1.4 \)

Q.28 A consolidated undrained \( (CU) \) triaxial compression test is conducted on a normally consolidated clay at a confining pressure of 100 kPa. The deviator stress at failure is 80 kPa, and the pore-water pressure measured at failure is 50 kPa. The effective angle of internal friction (in degrees, up to one decimal place) of the soil is ________.

Ans. (26.4)

CU test is conducted.

\( \sigma_3 = 100 \text{ kPa} \), \( \sigma_d = 80 \text{ kPa} \), \( u = 50 \text{ kPa} \)

\( \sigma_1 = \sigma_3 + \sigma_d = 100 + 80 = 180 \text{ kPa} \)

\( \bar{\sigma}_1 = \sigma_1 - u = 180 - 50 = 130 \text{ kPa} \)

\( \bar{\sigma}_3 = \sigma_3 - u = 100 - 50 = 50 \text{ kPa} \)

\( \bar{\sigma}_1 = \bar{\sigma}_3 \tan^2 \left( \frac{45 + \phi'}{2} \right) + 2C' \tan \left( \frac{45 + \phi'}{2} \right) \)

Assume \( C' = 0 \)

\( \bar{\sigma}_1 = \bar{\sigma}_3 \tan^2 \left( \frac{45 + \phi'}{2} \right) \)

\( 130 = 50 \tan^2 \left( \frac{45 + \phi'}{2} \right) \)

\( \phi' = 26.4^\circ \)
Q.29 For the function \( f(x) = a + bx, \, 0 \leq x \leq 1 \), to be a valid probability density function, which one of the following statements is correct?

(a) \( a = 1, \, b = 4 \)  \hspace{1cm} (b) \( a = 0.5, \, b = 1 \)  
(c) \( a = 0, \, b = 1 \)  \hspace{1cm} (d) \( a = 1, \, b = -1 \)

Ans. \( \text{(b)} \)

\[
\int_{0}^{1} f(x) \, dx = 1 \\
\int_{0}^{1} (a + bx) \, dx = 1 \\
\left[ ax + \frac{bx^2}{2} \right]_{0}^{1} = 1 \\
\frac{a + b}{2} = 1
\]

Option (b) is satisfying the above equation.

Q.30 Two wastewater streams \( A \) and \( B \), having an indentical ultimate BOD are getting mixed to form the stream \( C \). The temperature of the stream \( A \) is 20°C and the temperature of the stream \( C \) is 10°C. It is given that

- the 5-day BOD of the stream \( A \) measured at 20°C = 50 mg/l
- BOD rate constant (base 10) at 20°C = 0.115 per day
- temperature coefficient = 1.135

The 5-day BOD (in mg/l, up to one decimal place) of the stream \( C \), calculated at 10°C, is

Ans. (21.21)  

At \( A \), \( \text{BOD}_{5}^{20°C} = L(1 - 10^{-k_{D}^{20°C} \times 5}) \)  
\[
50 = L \left( 1 - 10^{-0.115 \times 5} \right) \\
L = 68.129 \text{ mg/l}
\]

Here, \( k_{D_{10}} = k_{D_{20}} \times \left[ 1.135 \right]^{10-20} \)  
\[
= 0.115 \times (1.135)^{-10} = 0.0324
\]

For \( C \), \( \text{BOD}_{5}^{10°C} = L \left[ 1 - 10^{-k_{D_{10}} \times x} \right] \)  
\[
= 68.13 \left[ 1 - 10^{-0.0324 \times 5} \right] \\
= 21.21 \text{ mg/l}
\]
Q.31  Group I contains three broad classes of irrigation supply canal outlets. Group II presents hydraulic performance attributes.

**Group I**

- P. Non-modular outlet
- Q. Semi-modular outlet
- R. Modular outlet

**Group II**

1. Outlet discharge depends on the water levels in both the supply canal as well as the receiving water course
2. Outlet discharge is fixed and is independent of the water levels in both the supply canal as well as the receiving water course
3. Outlet discharge depends only on the water level in the supply canal

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

(a) P-1; Q-2; R-3  
(b) P-3; Q-1; R-2  
(c) P-2; Q-3; R-1  
(d) P-1; Q-3; R-2

**Ans. (d)**

**Non-modular outlet**: These are the outlets whose discharge depends on the difference in water levels in the distributing channel and the water course. The discharge of such outlets, therefore, varies with the variation of the water levels in the distributing channel and the water course.

**Semi-modular outlet**: These are the outlets whose discharge varies with the variation of the water level in the distribution channel but it is independent of the water level in the water course, so long as the minimum working head required for their working is available.

**Modular outlet**: These are the outlets whose discharge is independent of the water levels in the distributing channel and the water course, within reasonable working limits. In other words, modular outlets maintain a constant discharge irrespective of variation of the water levels in the distributing channel and the water course.

---

**End of Solution**

Q.32  A pre-tensioned rectangular concrete beam 150 mm wide and 300 depth is prestressed with three straight tendons, each having a cross-sectional area of 50 mm$^2$, to an initial stress of 1200 N/mm$^2$. The tendons are located at 100 mm from the sofit of the beam. If the modular ratio is 6, the loss of prestressing force (in kN, up to one decimal place) due to the elastic deformation of concrete only is

**Ans. (4.8)**

![Diagram of concrete beam with prestressing force](image)

Prestressing force: $P = 3 \times 50 \times 1200 = 180000$ N.

Deformation: $\delta = \left( \frac{D}{2} - 100 \right) = \left( \frac{300}{2} - 100 \right) = 50$ mm
Stress in concrete at the location of steel

\[ \frac{P}{A} + \frac{P \cdot e}{I} = \frac{180000}{150 \times 300} + \frac{180000 \times 50^2}{150 \times 300^3 \times 12} \]

\[ = 4.0 + 1.33 = 5.333 \]

Loss of stress = \( m \times f_c \)

\[ = 6 \times 5.3333 = 32 \text{ N/mm}^2 \]

Loss of prestressing force

\[ \frac{3 \times 50 \times 32}{1000} \text{ kN} = 4.8 \text{ kN} \]

---

**Q.33** The spherical grit particles, having a radius of 0.01 mm and specific gravity of 3.0, need to be separated in a settling chamber. It is given that

- \( g = 9.81 \text{ m/s}^2 \)
- the density of the liquid in the settling chamber = 1000 kg/m³
- the kinematic viscosity of the liquid in the settling chamber = \( 10^{-6} \text{ m}^2/\text{s} \)

Assuming laminar conditions, the settling velocity (in mm/s, up to one decimal place) is ________

**Ans. (0.436)**

\[ v_s = \frac{(G - 1)g\delta^2}{18v} = \frac{(3 - 1)9.81(0.02 \times 10^{-3})^2}{18 \times 10^{-6}} \times 10^3 \]

\[ = 0.436 \text{ mm/sec} \]

---

**Q.34** The value of M in the beam ABC shown in the figure is such that the joint B does not rotate.

![Beam ABC Diagram]

The value of support reaction (in kN) at B should be equal to ________.

**Ans. (60)**

![Beam ABC Diagram with Support Reaction]
As the slope $\theta_B$ is an anticlockwise sense hence the moment at joint B must be applied in clockwise sense $= 40 \text{ kNm}$ to make $\theta_B = 0$

\[
\begin{array}{c|c|c}
-40 & 40 & 0 \\
\hline
-40 & +40 & 0 \\
\end{array}
\]

\(M_{BA} + M_{BC} = 40\)  
(Joint B balanced)  
\((\theta_B = 0)\)

\[
\begin{array}{c}
A \quad 30 \text{ kNm} \\
40 \quad 60 \\
B \quad 40 \quad 60 \\
C \quad 0 \\
\hline
\end{array}
\]

\[R_B = 60 \text{ kN}\]

Q.35 The activity details of a project are given below:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Depends on</th>
<th>Duration (in days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>--</td>
<td>6</td>
</tr>
<tr>
<td>Q</td>
<td>P</td>
<td>15</td>
</tr>
<tr>
<td>R</td>
<td>Q, T</td>
<td>12</td>
</tr>
<tr>
<td>S</td>
<td>R</td>
<td>16</td>
</tr>
<tr>
<td>T</td>
<td>P</td>
<td>10</td>
</tr>
<tr>
<td>U</td>
<td>Q, T</td>
<td>14</td>
</tr>
<tr>
<td>V</td>
<td>U</td>
<td>16</td>
</tr>
</tbody>
</table>

The estimated minimum time (in days) for the completion of the project will be _____.

Ans. (51)

The minimum time for project completion is with respect to critical path.  
Critical Path $\rightarrow P \rightarrow Q \rightarrow U \rightarrow V$  
\(T_{cp} = 6 + 15 + 14 + 16 = 51 \text{ days}\)
MADE EASY Students Top in ESE-2016
84% Selections in ESE 2016

Civil
Jatin Kumar
AIR-1

Mechanical
M. Idul Ahmad
AIR-1

Electrical
Gaurav
AIR-1

Electronics & Tel.
Naveen Sharma
AIR-1

4 Streams, 4 Toppers all 4 MADE EASY Students

39 Selections in Top 10
76 Selections in Top 20
505 Selections out of total 604 vacancies

Civil
Jatin Kumar
AIR-1

Mechanical
M. Idul Ahmad
AIR-1

Electrical
Gaurav
AIR-1

Electronics & Tel.
Naveen Sharma
AIR-1

Selections in Top 10
CE 10
ME 9
EE 10
E&T 10

MADE EASY Selections
CE 182 Out of 225 Vacancies
ME 159 Out of 179 Vacancies
EE 86 Out of 106 Vacancies
E&T 78 Out of 94 Vacancies

MADE EASY Percentage
CE 81%
ME 89%
EE 81%
E&T 83%

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Q.36 The solution of the equation \( \frac{dQ}{dt} + Q = 1 \) with \( Q = 0 \) at \( t = 0 \) is

(a) \( Q(t) = e^t - 1 \) \hspace{1cm} (b) \( Q(t) = 1 + e^t \) \\
(c) \( Q(t) = 1 - e^{t} \) \hspace{1cm} (d) \( Q(t) = 1 - e^{-t} \)

Ans. (d)

\[
\frac{dQ}{dt} + Q = 1
\]

Comparing with standard form

I.F. = \( e^{\int 1\,dt} = e^t \)

Solution is

\[
Q(e^t) = \int 1\,e^t \,dt
\]

\[
= e^t + C
\]

\[Q = 1 + Ce^{-t}\] ... (i)

When \( t = 0, \ Q = 0\)

\[0 = 1 + C\]

\[C = -1\]

Therefore, \( Q(t) = 1 - e^{-t} \)

Q.37 The radius of a horizontal circular curve on a highway is 120 m. The design speed is 60 km/hour, and the design coefficient of lateral friction between the tyre and the road surface is 0.15. The estimated value of superelevation required (if full lateral friction is assumed to develop), and the value of coefficient of friction needed (if no superelevation is provided) will, respectively, be

(a) \( \frac{1}{11.6} \) and 0.10 \hspace{1cm} (b) \( \frac{1}{10.5} \) and 0.37 \\
(c) \( \frac{1}{11.6} \) and 0.24 \hspace{1cm} (d) \( \frac{1}{12.9} \) and 0.24

Ans. (c)

Given, \( R = 120 \) m, \( V = 60 \) kmph and \( f = 0.15 \)

\[e + f = \frac{V^2}{127R}\]

\[e + 0.15 = \frac{60^2}{127 \times 120}\]

\[\Rightarrow \quad e = \frac{1}{11.6}\]

Also, if \( e = 0 \)

\[f = \frac{V^2}{127R} = \frac{60^2}{127 \times 120} \approx 0.24\]
Q.38 A sluice gate used to control the flow in a horizontal channel of unit width is shown in the figure.

![Diagram of sluice gate with d1 = 1.0 m, d2 = 0.2 m](image)

It is observed that the depth of flow is 1.0 m upstream of the gate, while the depth is 0.2 m downstream of the gate. Assuming a smooth flow transition across the sluice gate, i.e., without any energy loss, and the acceleration due to gravity as 10 m/s², the discharge (in m³/s, up to two decimal places) passing under the sluice gate is \( \boxed{0.816} \).

**Ans. \( \boxed{0.816} \)**

Applying Bernoulli’s energy balance equation

\[
y_1 + \frac{Q^2}{2gA_1^2} = y_2 + \frac{Q^2}{2gA_2^2}
\]

Given \( y_1 = 1 \text{ m} \), \( b = 1 \text{ m} \), \( y_2 = 0.2 \)

\[
\Rightarrow 1 + \frac{q^2 \times 1^2}{2g(1 \times 1)^2} = 0.2 + \frac{q^2 \times 1^2}{2g(0.2 \times 1)^2}
\]

\[
\Rightarrow 0.8 = \frac{q^2}{2g}\left(\frac{1}{(0.2)^2} - 1\right)
\]

\[
0.8 = \frac{q^2}{20} \times 24
\]

\[
q = 0.816 \text{ m}^3/\text{s}
\]

---

Q.39 The observed bearings of a traverse are given below:

<table>
<thead>
<tr>
<th>Line</th>
<th>Bearing</th>
<th>Line</th>
<th>Bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>PQ</td>
<td>46°15’</td>
<td>QP</td>
<td>226°15’</td>
</tr>
<tr>
<td>QR</td>
<td>108°15’</td>
<td>RQ</td>
<td>266°15’</td>
</tr>
<tr>
<td>RS</td>
<td>201°30’</td>
<td>SR</td>
<td>20°30’</td>
</tr>
<tr>
<td>ST</td>
<td>321°45’</td>
<td>TS</td>
<td>141°45’</td>
</tr>
</tbody>
</table>

The station(s) most likely to be affected by the local attraction is/are

(a) Only R  
(b) Only S  
(c) R and S  
(d) P and Q
Ans. (a)

<table>
<thead>
<tr>
<th>Line</th>
<th>FB</th>
<th>BB</th>
<th>Δ =</th>
<th>FB – BB</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PQ</td>
<td>46°15'</td>
<td>226°15'</td>
<td>180°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QR</td>
<td>108°15'</td>
<td>266°15'</td>
<td>178°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RS</td>
<td>201°30'</td>
<td>20°30'</td>
<td>181°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST</td>
<td>321°45'</td>
<td>141°45'</td>
<td>180°</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Station R is most likely to be affected.

Q.40 The following observations are made while testing aggregate for its suitability in pavement construction:
(i) Mass of oven-dry aggregate in air = 1000 g
(ii) Mass of saturated surface-dry aggregate in air = 1025 g
(iii) Mass of saturated surface-dry aggregate under water = 625 g
Based on the above observations, the correct statement is
(a) bulk specific gravity of aggregate = 2.5 and water absorption = 2.5%
(b) bulk specific gravity of aggregate = 2.5 and water absorption = 2.4%
(c) apparent specific gravity of aggregate = 2.5 and water absorption = 2.5%
(d) apparent specific gravity of aggregate = 2.5 and water absorption = 2.4%

Ans. (a)

Bulk specific gravity = \( \frac{A}{B - C} \)

Apparent specific gravity = \( \frac{A}{A - C} \)

Where,

\( A \) = Mass of oven dry aggregate in air
\( B \) = Mass of Saturated surface dry aggregate in air
\( C \) = Mass of Saturated surface dry aggregate under water

\[ \therefore \] Bulk specific gravity = \( \frac{1000}{1025 - 625} = \frac{1000}{400} = 2.5 \)

Water absorption = \( \frac{1025 - 1000}{1000} \times 100 = 2.5\% \)

Q.41 Consider two axially loaded columns, namely, 1 and 2, made of a linear elastic material with Young’s modulus 2 x 10^6 MPa, square cross-section with side 10 mm, and length 1 m. For Column 1, one end is fixed and the other end is free. For Column 2, one end is fixed and the other end is pinned. Based on the Euler’s theory, the ratio (up to one decimal place) of the buckling load of Column 2 to the buckling load of Column 1 is ________.
Ans. (8)

\[ P_{cr1} = \frac{\pi^2 EI}{(2l)^2} = \frac{\pi^2 EI}{4l^2} \]

\[ P_{cr2} = \frac{\pi^2 EI}{\left(\frac{1}{\sqrt{2}}l\right)^2} = \frac{2\pi^2 EI}{l^2} \]

\[ \therefore \text{Required ratio} = \frac{P_{cr2}}{P_{cr1}} = \frac{\frac{2\pi^2 EI}{l^2}}{\frac{\pi^2 EI}{4l^2}} = 8 \]

Q.42 Consider the matrix \[
\begin{bmatrix}
5 & -1 \\
4 & 1
\end{bmatrix}
\]. Which one of the following statements is TRUE for the eigenvalues and eigenvectors of this matrix?

(a) Eigenvalue 3 has a multiplicity of 2, and only one independent eigenvector exists.
(b) Eigenvalue 3 has a multiplicity of 2, and two independent eigenvectors exist.
(c) Eigenvalue 3 has a multiplicity of 2, and no independent eigenvector exists.
(d) Eigenvalue are 3 and −3, and two independent eigenvectors exist.

Ans. (a)

\[ \lambda = \begin{bmatrix} 5 & -1 \\ 4 & 1 \end{bmatrix} \]

Ch. equation is \( |\lambda I - A| = 0 \)

\[
\begin{vmatrix}
5 - \lambda & -1 \\
4 & 1 - \lambda
\end{vmatrix} = 0
\]

\[ 5 - 5\lambda - \lambda + \lambda^2 + 4 = 0 \]

\[ \lambda^2 - 6\lambda + 9 = 0 \]

\[ \lambda = 3, 3 \]

Algebraic multiplicity of eigen value 3 is 2. It has only one independent eigenvector exists.
Q.43  The wastewater having an organic concentration of 54 mg/l is flowing at a steady rate of 0.8 m³/day through a detention tank of dimensions 2 m × 4 m × 2 m. If the contents of the tank are well mixed and the decay constant is 0.1 per day, the outlet concentration (in mg/l, up to one decimal place) is ________.

Ans.  (0.54)

\[
Q = 0.8 \text{ m}^3/\text{d}
\]

Detention time, \( D_t = \frac{V}{Q} = \frac{4 \times 2 \times 2 \text{ m}^3}{0.8 \text{ m}^3/\text{day}} = 20 \text{ days} \)

\[
\text{BOD consumed} = 54 \left( 1 - 10^{-0.1 \times 20} \right)
\]

\[
= 53.46 \text{ mg/l}
\]

\[\therefore \text{ BOD remaining} = 54 - 53.46 = 0.54 \text{ mg/l} \]

Q.44  It is proposed to drive H-piles up to a depth of 7 m at a construction site. The average surface area of the H-pile is 3 m² per meter length. The soil at the site is homogeneous sand, having an effective friction angle of 32°. The ground water table (GWT) is at a depth of 2 m below the ground surface. The unit weights of the soil above and below the GWT are 16 kN/m³ and 19 kN/m³, respectively. Assume the earth pressure coefficient, \( K = 1.0 \), and the angle of wall friction, \( \delta = 23^\circ \). The total axial frictional resistance (in kN, up to one decimal place) mobilized on the pile against the driving is ________.

Ans.  (390.8)

\[
Q_{sf} = \frac{1}{2} k \gamma L_1 \tan \delta A_{s1} + \frac{1}{2} K \left[ \gamma L_1 + \gamma L_2 \right] \tan \delta A_{s2}
\]

\[
= \frac{1}{2} \times 16 \times 2 \tan 23^\circ (3 \times 2) + \frac{1}{2} \times 1 \left[ 16 \times 2 + 77.95 \right] \times \tan 23^\circ (5 \times 3)
\]

\[= 390.8 \text{ kN} \]
Q.45  An effective rainfall of 2-hour duration produced a flood hydrograph peak of 200 m³/s. The flood hydrograph has a base flow of 20 m³/s. If the spatial average rainfall in the watershed for the duration of storm is 2 cm and the average loss rate is 0.4 cm/hour, the peak of 2-hour unit hydrograph (in m³/s-cm, up to one decimal place) is ________.

Ans.  (150)

Peak of 2 hr direct runoff hydrograph = Peak of 2 hr flood hydrograph – Base flow
= 200 – 20
= 180 m³/s

The rainfall excess depth for a given duration of 2 hr effective storm/rainfall is given by

\[
\text{Rainfall excess depth} = 2 \text{ cm} - 0.4 \text{ cm/hr} \times 2 \text{ hr}
\]

= 1.2 cm

\[
\therefore \quad \text{Peak of 2 hr UH} = \frac{180}{1.2} = 150 \text{ m³/s-cm}
\]

---

Q.46  The queue length (in number of vehicles) versus time (in seconds) plot for an approach to a signalized intersection with the cycle length of 96 seconds is shown in the figure (not drawn to scale).

At time, \( t = 0 \), the light has just turned red. The effective green time is 36 seconds, during which vehicles discharge at the saturation flow rate, \( s \) (in vph). Vehicles arrive at a uniform rate, \( v \) (in vph), throughout the cycle. Which one of the following statements is TRUE?
(a) \( v = 600 \) vph, and for this cycle, the average stopped delay per vehicle = 30 seconds.
(b) \( s = 1800 \) vph, and for this cycle, the average stopped delay per vehicle = 28.125 seconds.
(c) \( v = 600 \) vph, and for this cycle, the average stopped delay per vehicle = 45 seconds.
(d) \( s = 1200 \) vph, and for this cycle, the average stopped delay per vehicle = 28.125 seconds.
Ans. (a)

\[ v = \frac{10 \text{ veh}}{60 \text{ sec}} = \frac{1}{6} \text{ veh/sec} = 600 \text{ veh/hr} \]

\[ s = \frac{10}{30} \text{ veh/sec} = \frac{1}{3} \text{ veh/sec} = 1200 \text{ veh/hr} \]

Average stopped delay = \( \frac{0 + 60}{2} = 30 \text{ sec} \)

Q.47 The infinite sand slope shown in the figure is on the verge of sliding failure. The ground water table coincides with the ground surface. Unit weight of water \( \gamma_w = 9.81 \text{ kN/m}^3 \).

The value of the effective angle of internal friction (in degrees, up to one decimal place) of the sand is _________.

Ans. (34.3)

Infinite sand slope:
GWT coincides with the ground surface, therefore

\[ \text{F.O.S.} = \frac{\gamma}{\gamma_{\text{sat}}} \times \frac{\tan \psi'}{\tan \beta} \]

As slope is on the verge of sliding failure hence,

\[ \text{F.O.S.} = \frac{\gamma' \tan \psi'}{\gamma_{\text{sat}} \tan \beta} = 1 \]

\[(21 - 9.81) \tan \psi' = 21 \tan 20^\circ \]

\[ \psi' = 34.3^\circ \]
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Q. 48

Consider the equation \( \frac{du}{dt} = 3t^2 + 1 \) with \( u = 0 \) at \( t = 0 \). This is numerically solved by using the forward Euler method with a step size \( \Delta t = 2 \). The absolute error in the solution in the end of the first time step is ____________.

Ans. (8)

\[
\frac{du}{dt} = 3t^2 + 1
\]

\[
f(u, t) = 3t^2 + 1
\]

\[
u_0 = 0
\]

\[
t_0 = 0
\]

\[
\Delta t = 2
\]

By Euler’s method

\[
u_1 = u_0 + hf(u_0, t_0)
\]

\[
t_1 = t_0 + h
\]

\[
u_1 = u_0 + h(3t_0^2 + 1)
\]

\[
= 0 + h(3(0)^2 + 1)
\]

\[
= 0 + 2(3(0)^2 + 1)
\]

\[
= 0 + 2
\]

\[
= 2
\]

After first iteration \( u = 2 \) when \( t = 2 \)

\[
\frac{du}{dt} = 3t^2 + 1
\]

\[
du = (3t^2 + 1) \, dt
\]

\[
\int du = \int (3t^2 + 1) \, dt
\]

\[
u = \left[ \frac{3t^3}{3} + t \right]_0
\]

\[
= \frac{3(2)^3}{3} + 2
\]

\[
= 8 + 2
\]

\[
= 10
\]

Absolute error = Exact value – approx value

\[
= 10 – 2
\]

\[
= 8
\]

---

Q. 49

A particle of mass 2 kg is travelling at a velocity of 1.5 m/s. A force \( f(t) = 3t^2 \) (in N) is applied to it in the direction of motion for a duration of 2 seconds, where \( t \) denotes time in seconds. The velocity (in m/s, up to one decimal place) of the particle immediately after the removal of the force is ____________.
Ans. \( (5.5) \)

\[ m = 2 \text{ kg, } V_0 = 1.5 \text{ m/sec} \]

\[
\int_0^1 F(t)dt = m(V - V_0)
\]

\[
\int_0^2 3t^2 dt = 2(V - 1.5)
\]

\[
\left[ t^3 \right]_0^2 = 2(V - 1.5)
\]

\[ \Rightarrow \quad (8 - 0) = 2(V - 1.5) \]

\[ V = 5.5 \text{ m/s} \]

Q.50 A 1 m wide rectangular channel has a bed slope of 0.0016 and the Manning's roughness coefficient is 0.04. Uniform flow takes place in the channel at a flow depth of 0.5 m. At a particular section, gradually varied flow (GVF) is observed and the flow depth is measured as 0.6 m. The GVF profile at that section is classified as

(a) \( S_1 \)  
(b) \( S_2 \) 
(c) \( M_1 \)  
(d) \( M_2 \)

Ans. \( (c) \)

\[ Q = \frac{1}{n} \times A \times R^{2/3} \times S^{1/2} \]

\[ A = 1 \times 0.5 = 0.5 \text{ m}^2 \]

\[ P = 1 + (0.5 \times 2) = 2 \text{m} \]

\[ Q = \frac{1}{0.04} \times 0.5 \times \left( \frac{0.5}{2} \right)^{2/3} \times (0.0016)^{1/2} \]

\[ = 0.1984 \text{ m}^3/\text{s} \]

\[ q = \frac{Q}{1} = 0.1984 \text{ m}^3/\text{s/m} \]

For rectangular channel

\[ y_e = \left( \frac{q^2}{g} \right)^{1/3} = \left( \frac{0.1984^2}{9.81} \right)^{1/3} = 0.159 \text{ m} \]

Since, \( y_n > y_e \) (Thus it is Mild Slope)
Q.51 Consider the stepped bar made with a linear elastic material and subjected to an axial load of 1 kN, as shown in the figure.

Segments 1 and 2 have cross-sectional area of 100 mm$^2$ and 60 mm$^2$. Young’s modulus of $2 \times 10^5$ MPa and $3 \times 10^5$ MPa, and length of 400 mm and 900 mm, respectively. The strain energy (in N-mm up to one decimal place) in the bar due to the axial load is ________.

Ans. (35)
\[ A_1 = 100 \text{ mm}^2, \ E_1 = 2 \times 10^8 \text{ MPa} \]
\[ A_2 = 60 \text{ mm}^2, \ E_2 = 3 \times 10^8 \text{ MPa} \]

\[ \Delta_{AC} = \Delta_{AB} + \Delta_{BC} \]

\[ \Delta_{AC} = \frac{1 \times 10^8 \times 400}{100 \times 2 \times 10^8} + \frac{1 \times 10^8 \times 900}{60 \times 3 \times 10^8} \]

\[ = 0.02 + 0.05 = 0.07 \text{ mm} \]

\[ U = \frac{1}{2} \times P \times \Delta = \frac{1}{2} \times 1 \times 1000 \times 0.07 = 35 \text{ N-mm} \]

Q.52 A planar truss tower structure is shown in the figure.

Consider the following statements about the external and internal determinacies of the truss.

P. Externally Determinate
Q. External Static Indeterminacy = 1
R. External Static Indeterminacy = 2
S. Internally Determinate
T. Internal Static Indeterminacy = 1
U. Internal Static Indeterminacy = 2

Which one of the following options is correct?
(a) P-False; Q-True; R-False; S-False; T-False; U-True
(b) P-False; Q-True; R-False; S-False; T-True; U-False
(c) P-False; Q-False; R-True; S-False; T-False; U-True
(d) P-True; Q-True; R-False; S-True; T-False; U-True

Ans. (a)

\[ D_{se} = r - s = 4 - 3 = 1 \text{ degree} \]
\[ D_{se} = m - (2/ - 3) = 15 - (2 \times 8 - 3) = 2 \text{ degrees} \]
Q.53  The equivalent sound power level (in dB) of the four sources with the noise levels of 60 dB, 69 dB, 70 dB and 79 dB is 

\[ L_{eq} = 10 \log_{10} \left( \frac{1}{N} \sum_{i=1}^{N} 10^{L_i/10} \right) \]

\[ = 10 \log_{10} \left( \frac{1}{4} \left( 10^{60/10} + 10^{69/10} + 10^{70/10} + 10^{79/10} \right) \right) = 73.9 \text{ dB} \]

**Ans.** (73.9)

---

Q.54  Consider the beam ABCD shown in the figure

```
A          B          C          D
\[ \text{Internal hinge} \]
```

AB = BC = 4 m
CD = 10 m

For a moving concentrated load of 50 kN on the beam, the magnitude of the maximum bending moment (in kN-m) obtained at the support C will be equal to ________.

**Ans.** (200)

B.M. at C = 50 x 4 = 200 kNm

```
A        B        C        D
```

ILD for BM at C

```
A 4 m 4 m D
\[ \theta_c = 1 \]
```

---

Q.55  A column is subjected to a load through a bracket as shown in the figure

```
10 cm
10 cm
90°
```

\[ P = 10 \text{ kN} \]

The resultant force (in kN, up to one decimal place) in the bolt 1 is _____.
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3. Standards and Quality practices in production, construction, maintenance and services.
7. Information and Communication Technologies (ICT) based tools and their applications in Engineering such as networking, e-governance and technology based education.
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<th>Venue</th>
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<tr>
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<td>25th Feb, 2017</td>
</tr>
<tr>
<td>Delhi</td>
<td>Regular</td>
<td>20th Feb, 2017</td>
</tr>
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</table>

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Ans. (6.0)

\[ F_1 = \frac{P}{n} = \frac{10}{4} = 2.5 \text{ kN} \]

\[ F_2 = \frac{P \Sigma f_i}{\Sigma f_i^2} = \frac{10 \times 15}{4 \times 5^2} \times 5 = 7.5 \text{ kN} \]

\[ F_R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2 \cos \theta} \]

\[ = \sqrt{2.5^2 + 7.5^2 + 2 \times 2.5 \times 7.5 \times \cos 135^\circ} \]

\[ = 6 \text{ kN} \]

---

**GENERAL APTITUDE**

**Q.1**

The following sequence of numbers is arranged in increasing order: 1, x, x, x, y, y, y, 9, 16, 18. Given that the mean and median are equal, and are also equal to twice the mode, the value of y is

(a) 5  
(b) 6  
(c) 7  
(d) 8  

**Ans. (d)**

\[ 1, x, x, x, y, y, y, 9, 16, 18 \]

\[ \text{Mean} = \frac{1 + 3x + 2y + 9 + 16 + 18}{9} = \frac{3x + 2y + 44}{9}\quad \text{...(i)} \]

Median \( \Rightarrow \) As number of terms are odd i.e. 9, so median will be middle i.e. y.  
Mode \( \Rightarrow \) Number showing maximum frequency of repetition. So mode is x.  
Given \( \Rightarrow \) Mean = Median = 2 Mode  
\( \Rightarrow \)  
\[ y = 2x \quad \text{...(ii)} \]

From equation (i) and (ii), we get  
\[ x = 4, y = 8 \]

Value of y is 8

---

End of Solution
Q.2  The bacteria in milk are destroyed when it __________ heated to 80 degree Celsius.
   (a) would be  (b) will be  
   (c) is       (d) was

**Ans.**  (c)  
The bacteria in milk are destroyed when it is heated to 80° Celsius. Use of simple present tense is apt for indication factual statements / scientifically proven statements / universal truth.

Q.3  Consider the following sentences:
All benches are beds. No bed is a bulb. Some bulbs are lamps.
Which of the following can be inferred?
(i) Some beds are lamps.
(ii) Some lamps are beds.
   (a) Only (i)  (b) Only (ii)  
   (c) Both (i) and (ii)  (d) Neither (i) nor (ii)

**Ans.**  (d)  

![Diagram]

Since there is no direct relation given between **lamps** and **beds**. So, neither will be correct.

Q.4  If the radius of a right circular cone is increased by 50%, its volume increases by
   (a) 75%  (b) 100%  
   (c) 125%  (d) 237.5%  

**Ans.**  (c)  

\[
V = \frac{1}{3} \pi R^2 H \\
V' = \frac{1}{3} \pi (1.5R)^2 H \\
= \frac{1}{3} \pi 2.25 R^2 H = 2.25 V \\
\]

Hence increase 125% as \[\left(\frac{2.25V - V}{V}\right)\times100 = 125\%\]
Q.5 ______ with someone else’s email account is now a very serious offense.
(a) Involving (b) Assisting (c) Tampering (d) Incubating

Ans. (c) Tampering with someone else’s email account is a very serious offence. Tampering refers to interfering in a harmful or disruptive manner.

Q.6 Two machines M1 and M2 are able to execute any of four jobs, P, Q, R and S. The machines can perform one job on one object at a time. Jobs P, Q, R and S take 30 minutes, 20 minutes, 60 minutes and 15 minutes each respectively. There are 10 objects each requiring exactly 1 job. Job P is to be performed on 2 objects, Job Q on 3 objects, Job R on 1 object and Job S on 4 objects. What is the minimum time needed to complete all the jobs?
(a) 2 hours (b) 2.5 hours (c) 3 hours (d) 3.5 hours

Ans. (a)

\[
\begin{align*}
P & \quad 30 \text{ min} \times 2 = 60 \text{ min} \\
Q & \quad 20 \text{ min} \times 3 = 60 \text{ min} \\
R & \quad 60 \text{ min} \times 1 = 60 \text{ min} \\
S & \quad 15 \text{ min} \times 4 = 60 \text{ min} \\
M_1 & \quad \begin{array}{cc} P & Q \end{array} = 2 \text{ hrs} \\
M_2 & \quad \begin{array}{cc} R & S \end{array} = 2 \text{ hrs}
\end{align*}
\]

Q.7 The bar graph below shows the output of five carpenters over one month, each of whom made different items of furniture; chairs, tables and beds.
Consider the following statements:
(i) The number of beds made by carpenter C2 is exactly the same as the number of tables made by carpenter C3.
(ii) The total number of chairs made by all carpenters is less than the total number of tables.
Which one of the following is true?
(a) Only (i)  
(b) Only (ii) 
(c) Both (i) and (ii)  
(d) Neither (i) nor (ii)

Ans.  (c)
Clearly we can see from graph both (i) and (ii) are correct.

---

Q.8 Students applying for hostel rooms are allotted rooms in order of seniority. Students already staying in a room will move if they get a room in their preferred list. Preferences of lower ranked applicants are ignored during allocation.
Given the data below, which room will Ajit stay in?

<table>
<thead>
<tr>
<th>Names</th>
<th>Student Seniority</th>
<th>Current room</th>
<th>Room preference list</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amar</td>
<td>1</td>
<td>P</td>
<td>R, S, Q</td>
</tr>
<tr>
<td>Akbar</td>
<td>2</td>
<td>None</td>
<td>R, S</td>
</tr>
<tr>
<td>Antony</td>
<td>3</td>
<td>Q</td>
<td>P</td>
</tr>
<tr>
<td>Ajit</td>
<td>4</td>
<td>S</td>
<td>Q, P, R</td>
</tr>
</tbody>
</table>

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

Ans.  (b)

\[\text{Amar} \rightarrow R\]
\[\text{Akbar} \rightarrow S\]
\[\text{Antony} \rightarrow P\]
\[\text{Ajit} \rightarrow Q\]
As per their preferences given.

---

Q.9 The old concert hall was demolished because of fears that the foundation would be affected by the construction of the new metro line in the area. Modern technology for underground metro construction tried to mitigate the impact of pressurized air pockets created by the excavation of large amounts of soil. But even with these safeguards, it was feared that the soil below the concert hall would not be stable.
From this, one can infer that
(a) the foundations of old buildings create pressurized air pockets underground, which are different to handle during metro construction.
(b) metro construction has to be done carefully considering its impact on the foundations of existing buildings.
(c) Old buildings in an area form an impossible hurdle to metro construction in that area.
(d) Pressurized air can be used to excavate large amount of soil from underground areas.

**Ans. (b)**

---

**Q.10** The last digit of \((2171)^7 + (2172)^9 + (2173)^{11} + (2174)^{13}\) is

(a) 2  
(b) 4  
(c) 6  
(d) 8

**Ans. (b)**

\[
(2171)^7 + (2172)^9 + (2173)^{11} + (2174)^{13}
\]

Unit digit \((1)^{\text{any}} + (2)^{4n+1} + (3)^{4n+3} + (4)^{2n+1}\)

\[
1 + 2 + 7 + 4 = 14
\]