MADE EASY

GATE 2026

Civil Engineering-2

Afternoon Session

Detailed Solutions

Exam held on 14-02-2026

MADE EASY Corporate Office:

44-A/1, Kalu Sarai, Near Hauz Khas Metro Station, New Delhi-110016

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SECTION - A GENERAL APTITUDE

Q.1 'The team ______ more than 300 runs in 20 overs ___________ rains. However, some players needed to improve their batting skills.'
Choose the option with the correct sequence of words to fill the blanks.
(a) score; despite
(b) scoring; instead of
(c) scored; despite
(d) scoring; in spite of

Ans. **(c)**
Scored, Despite

End of Solution

Q.2 If a positive real x satisfies the following equation

$$\log_2 x + \log_{\sqrt{2}} x = 48$$

then the value of x is _____.
(a) 2^{16}
(b) 4^{16}
(c) 2^{14}
(d) 4^{14}

Ans. **(a)**

$$\log_2 x + \log_{\sqrt{2}} x = 48$$

$$\log_2 x + \frac{\log_2 x}{\log_2 \sqrt{2}} = 48$$

$$\log_2 x + \frac{\log_2 x}{\log_2^{\sqrt{2}}} = 48 \qquad \left[\log_b a + \frac{\log_k a}{\log_k b}\right]$$

$$\log_2 x + \frac{\log_2 x}{\frac{1}{2}} = 48$$

$$\log_2 x + 2\log_2 x = 48$$

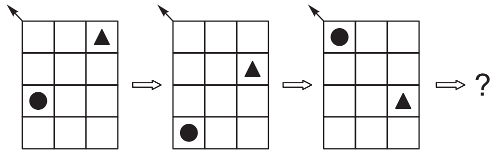
$$3\log_2 x = 48$$

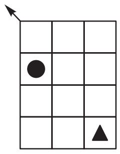
$$\log_2 x = 16$$

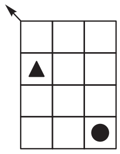
$$x = 2^{16}$$

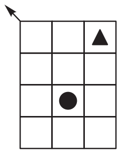
End of Solution

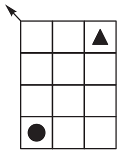
Q.3 The next figure (indicated by '?') in the sequence is



(a) 

(b) 

(c) 

(d) 

Ans. (a)

- **Moving down**

△ **Moving down**

End of Solution

Q.4 'All the mangoes in the basket are good.'
If the above statement is false, then which one of the following statements is necessarily true?
(a) All the mangoes in the basket are not good.
(b) No mango in the basket is good.
(c) In the basket, some of the mangoes are good and some are not good.
(d) There exists at least one mango in the basket that is not good.

Ans. (d)

End of Solution

Q.5 Consider the following statements about four numbers:
(S1) The average of the four numbers is 25
(S2) Each number is at most 40
(S3) Each number is at least 20
Choose the option that is necessarily correct.
(a) (S1) and (S2) together imply (S3)
(B) (S2) and (S3) together imply (S1)
(c) (S1) and (S3) together imply (S2)
(d) (S1) implies (S3)

Ans. (c)

End of Solution

Q.6 'People are crowding around _____ pit into which _____ elephant has fallen. I have never seen an elephant looking more bewildered _____ miserable. Here it is in a most undignified position, thrust into a pit and made to look up _____ a vast, curiosity-stricken crowd.'

Choose the option with the correct sequence of words to fill the blanks.

(a) an; a; at; and
(b) a; an; and; at
(c) and; a; an; at
(d) at; a; an; and

Ans. **(b)**

an elephant

End of Solution

Q.7 The table lists the unit selling price of five products P, Q, R, S, and T. On a particular day, 250 items were sold with the average selling price of Rs. 60. The following observations were made:

(i) The quantity of S sold was twice that of T.
(ii) The quantity of R sold was thrice that of T.
(iii) The quantity of Q sold was four times that of T.

Product	P	Q	R	S	T
Unit selling price (Rs.)	100	50	40	60	60

What is the quantity of product P sold on that day?

(a) 40
(b) 50
(c) 60
(d) 70

Ans. **(b)**

End of Solution

Q.8 Consider a string P of length l that is laid out as a straight-line segment. Another string K is laid out as a semicircular arc with string P as its diameter, as represented in Figure (i). When both the strings are shortened by a length x they can be re-arranged such that the shortened string K forms a full circle with the shortened string P as its diameter, as represented in Figure (ii). The value of x/l is _____

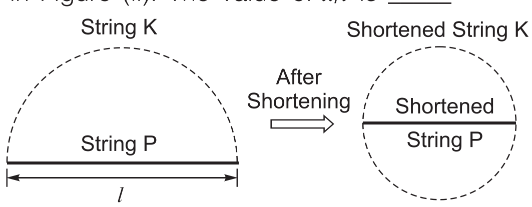


Figure (i) Figure (ii)

(a) π
(b) $\frac{\pi-1}{2\pi}$
(c) $\frac{\pi}{2(\pi-1)}$
(d) $\frac{\pi}{\pi-1}$

Ans. **(c)**

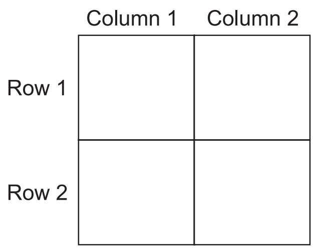
End of Solution

Q.9 The Roman senator Meritorius, his brother, his son, and his daughter have varying oratory skill levels. They are seated in rows and columns as shown in the figure with exactly one person sitting in each box. It is known that

(i) Meritorius' daughter and his brother are seated in the same column.
(ii) His son is seated diagonally across the sibling of the worst orator.
(iii) The best and worst orators are seated in the same row.

Who is the best orator?

Seating Arrangement

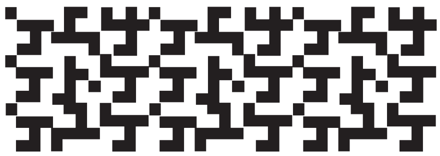


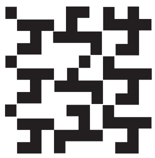
(a) Meritorius
(b) Meritorius' brother
(c) Meritorius' son
(d) Meritorius' daughter

Ans. **(b)**

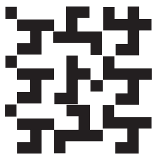
End of Solution

Q.10 Which one of the patterns labelled *P*, *Q*, *R*, and *S* is used to generate the following figure?

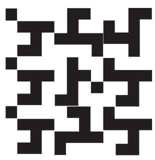




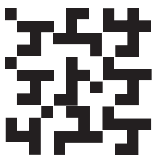
P



Q



R



S

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

Ans. **(b)**

End of Solution

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SECTION - B TECHNICAL

Q.11 Matrix A has the eigenvalues 1, 2, and 3. The Trace of A^2 is

(a) 6 (b) 14

(c) 20 (d) 8

Ans. **(b)**

Eigen values of matrix A are 1, 2, 3

Eigen values of matrix A^2 = $(1)^2, (2)^2, (3)^2$

$= 1, 4, 9$

$Tr(A^2) = 1 + 4 + 9$

$= 14$

End of Solution

Q.12 A fifth-degree polynomial in x is defined for $x > 0$. All coefficients of the polynomial are positive. The first derivative of the polynomial is obtained numerically at a point by using the first-order forward as well as the first-order backward difference methods. Identical step lengths are used for both the methods.

Following statements are made.

(I) Forward difference method underestimates the true derivative.

(II) Backward difference method overestimates the true derivative.

Which one of the following options is CORRECT?

(a) Both statements (I) and (II) are FALSE.

(b) Both statements (I) and (II) are TRUE.

(c) Statement (I) is TRUE and statement (II) is FALSE.

(d) Statement (I) is FALSE and statement (II) is TRUE.

Ans. **(a)**

End of Solution

Q.13 Periodic function $f(x)$ is given below.

$$f(x) = \begin{cases} -1, & \text{when } -\pi < x < 0 \\ 1, & \text{when } 0 < x < \pi \end{cases}; \quad f(x + 2\pi) = f(x)$$

The CORRECT option representing the Fourier series expansion of $f(x)$ is:

(a) $f(x) = \frac{4}{\pi}\left[\sin x + \frac{\sin 3x}{3} + \frac{\sin 5x}{5} + ...\right]$

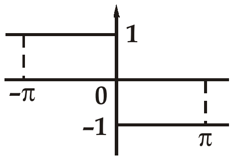
(b) $f(x) = -\frac{4}{\pi}\left[\sin x + \frac{\sin 3x}{3} + \frac{\sin 5x}{5} + ...\right]$

(c) $f(x)=1+\frac{4}{\pi}\left[\sin x+\frac{\sin 3x}{3}+\frac{\sin 5x}{5}+.....\right]$

(d) $f(x)=1-\frac{4}{\pi}\left[\sin x+\frac{\sin 3x}{3}+\frac{\sin 5x}{5}+.....\right]$

Ans. (a)

$$f(x) = \begin{cases} -1, & \pi < x < 0 \\ 1, & 0 < x < -\pi \end{cases}$$



$f(x)$ = Odd function

Since $f(x)$ is odd function

So $a_0 = 0$ and $a_n = 0$

$$b_n = \frac{1}{\pi}\int_{-n}^{\pi} f(x)\cdot\sin(nx)dx$$

$\Rightarrow$ $$b_n = \frac{2}{\pi}\int_0^{\pi} 1\times\sin(nx)dx$$

$\Rightarrow$ $$b_n = \frac{2}{\pi}\int_0^{\pi} \sin(nx)dx$$

$\Rightarrow$ $$b_n = \frac{2}{\pi}\left[\frac{-\cos nx}{n}\right]_0^{\pi}$$

$\Rightarrow$ $$b_n = \frac{-2}{n\pi}[\cos n\pi - \cos 0]$$

$\Rightarrow$ $$b_n = \frac{-2}{n\pi}\left[(-1)^n - 1\right]$$

$\Rightarrow$ $$b_n = \begin{cases} 0 & \text{if} & n = \text{even} \\ +\frac{4}{n\pi} & \text{if} & n = \text{odd} \end{cases}$$

$$f(x) = \sum_{n=1}^{\infty} b_n \sin(nx)$$

$\Rightarrow$ $$f(x) = \frac{4}{\pi}\sin x + \frac{4}{3\pi}\sin 3x + \frac{4}{5\pi}\sin 5x + ...$$

$$\Rightarrow \qquad f(x) = \frac{4}{\pi}\left[\sin x + \frac{\sin 3x}{3} + \frac{\sin 5x}{5} + \ldots\right]$$

End of Solution

Q.14 A rectangular singly reinforced concrete beam has a width of 300 mm and an effective depth of 550 mm. The grades of steel and concrete are Fe500 and M25, respectively. The area of steel in tension is 1963 mm^2. The depth of neutral axis is 302 mm. The ratio of the limiting depth of the neutral axis ($x_{u,\ max}$) to the effective depth (d) of the beam is 0.456.

The most probable mode of failure of the beam is

(a) compression failure
(b) bond failure
(c) shear failure
(d) ductile failure

Ans. **(a)**

Given: $x_{u,\ lim} = 0.456d, \quad f_{ck} = 25 \text{ N/mm}^2, \ d = 550 \text{ mm}$

$x_u = 302$ mm

Limiting depth of NA,

$$x_{u,\ lim} = 0.456 \times 550$$
$$= 250.8 \text{ mm} < 302 \text{ mm}$$

$\therefore \quad x_u > x_{u,\ lim}$ (over reinforced section)

So, compression failure will occurs.

End of Solution

Q.15 As per IS:800-2007, design of a cantilever steel beam section for its moment capacity requires fulfilment of an upper bound, expressed as:

$$M_d \le 1.5 Z_e \frac{f_y}{\gamma_{m0}}$$

The reason for such upper bound is to

(a) control deflection
(b) restrain lateral-torsional buckling
(c) avoid plastic deformation under working load
(d) avoid yielding at ultimate load

Ans. **(c)**

Design moment capacity, $M_d \le 1.5\ Z_e\left(\frac{f_y}{\gamma_{mo}}\right)$ for cantilever beam to avoid plastic deformation under working loads.

End of Solution

Q.16 A plane strain problem (in *X-Y* plane) must satisfy the condition:

(a) $\sigma_{zz} = 0$

(b) $\in_{zz} = \in_{xz} = \in_{zy} = 0$

(c) $\sigma_{xx} \neq \sigma_{xy} = \sigma_{xz} = 0$

(d) $\in_{xx} \neq \in_{yy} = \in_{xy} = 0$

Ans. (b)

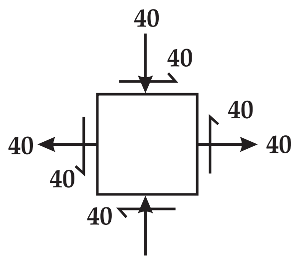
$$\text{Given strain matrix} = \begin{bmatrix} \in_{xx} & \frac{\gamma_{xy}}{2} & \frac{\gamma_{xz}}{2} \\ \frac{\gamma_{yx}}{2} & \in_{yy} & \frac{\gamma_{yz}}{2} \\ \frac{\gamma_{zx}}{2} & \frac{\gamma_{zy}}{2} & \in_{zz} \end{bmatrix}$$

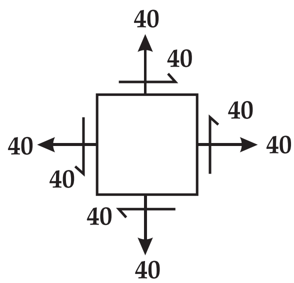
For plain strain condition,

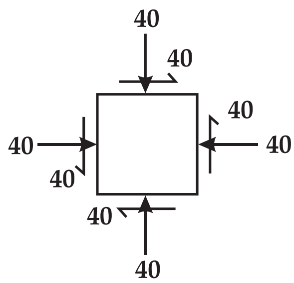
$$\in_{zz} = 0$$
$$\gamma_{zy} = \gamma_{yz} = 0$$
$$\gamma_{xz} = \gamma_{zx} = 0$$

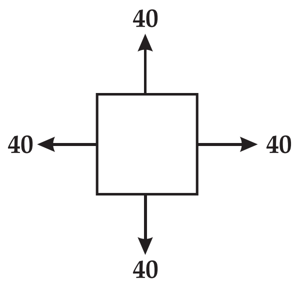
End of Solution

Q.17 Which one of the following stress conditions represents the state of pure shear stress?

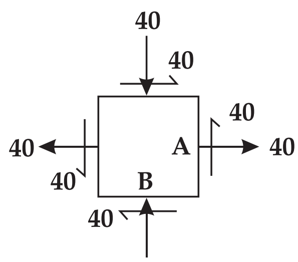
(a)


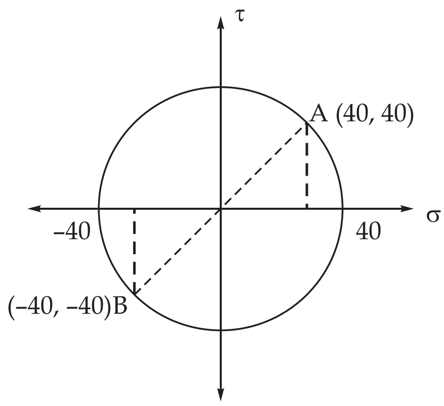
(b)


(c)


(d)


Ans. (a)

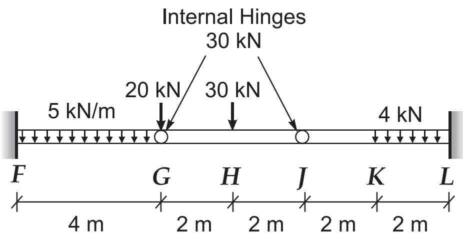




(Pure shear)

End of Solution

Q.18 The horizontal beam shown in the figure has fixed supports at *F* and *L*. Internal hinges are provided at locations *G* and *J*. The beam supports vertically downward concentrated loads as well as uniformly distributed loads, as shown in the figure.



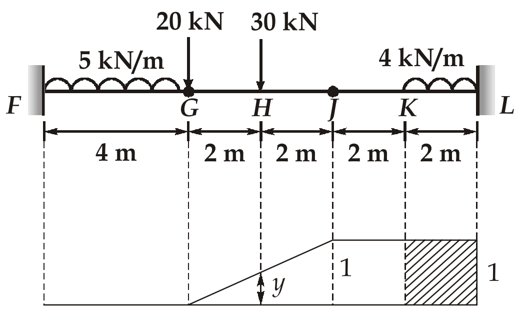
(Figure not to scale)

The upward vertical reaction (in kN) at the support *L* is

(a) 23 (b) 33

(c) 43 (d) 58

Ans. (a)



(ILD of V_L)

From ILD, $\frac{y}{2} = \frac{1}{4}$

$\Rightarrow$ $y = 0.5$

Vertical reaction at support L,

$$V_L = 30 \times 0.5 + 4\,(2 \times 1)$$

$\Rightarrow$ $V_L = 23$ kN

End of Solution

Q.19 The Culturable Command Area (CCA) for a canal is 10000 hectares. The base period for a crop in the CCA is 140 days. Watering depth for the crop is 40 cm. The outlet discharge (in m^3/s) lies between

(a) 3 and 4 (b) 13 and 14

(c) 23 and 24 (d) 33 and 34

Ans. **(a)**

Given: CCA, $A = 10000$ ha

Base period, $B = 140$ days

Depth of watering, $\Delta = 40$ cm

$\because$ $$D = \frac{8.64\,B}{\Delta}$$

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

$\Rightarrow$ $$\frac{10{,}000}{Q} = \frac{8.64 \times 140}{0.4}$$

$\Rightarrow$ $Q = 3.31$ m^3/sec (It is lies between 3 and 4)

End of Solution

Q.20 Following statements are made with respect to the mass curve of rainfall:

(I) Slope at a point on the curve can be positive.

(II) Slope at a point on the curve can be zero.

Which one of the following options is CORRECT?

(a) Both statements (I) and (II) are TRUE.

(b) Both statements (I) and (II) are FALSE.

(c) Statement (I) is TRUE and statement (II) is FALSE.

(d) Statement (I) is FALSE and statement (II) is TRUE.

Ans. **(a)**

Statement (I): A mass curve of rainfall is a plot of cumulative precipitation (y-axis) against time (x-axis). The slope of this curve represents the intensity of rainfall. Since intensity is positive during a rainfall event, the slope can be positive.

Statement (II): If there is a break in the storm or a period with no rain, the cumulative rainfall remains constant. During this interval, the curve becomes a horizontal line, meaning the slope is zero.

End of Solution

Q.21 Based on the Casagrande's plasticity chart, plasticity index (in %) of inorganic clays having a liquid limit of 40 %, ranges between

(a) 18.0 and 28.8
(b) 14.6 and 28.8
(c) 14.6 and 23.4
(d) 18.0 and 43.8

Ans. **(b)**

Given : Liquid limit w_L = 40%

The plasticity index (I_P) must be greater than or equal to the value calculated by the A-line

$$(I_P) = 0.73\,(w_L - 20)$$
$$= 0.73\,(40 - 20) = 14.6\%$$

The U-line represents the upper limit for all known soils.

$$(I_P)_{\text{U-line}} = 0.9\,(w_L - 8)$$
$$= 0.9\,(40 - 8) = 28.8\%$$

End of Solution

Q.22 Information related to foundation design is provided in table below.

Column 1	Column 2
(I) Converse-Labarre formula	(P) Pile capacity from dynamic formula
(II) Hiley formula	(Q) Pile group efficiency
(III) Newmark's influence chart	(R) Bearing capacity factor of saturated clay
(IV) Skempton's equation	(S) Increase in vertical stress below footing

Option giving the CORRECT match between Column 1 and Column 2 is:

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

Ans. **(a)**

End of Solution

Q.23 An incident occurred on one side of a median on a four-lane dual carriageway road section. This incident disrupted the traffic movement in one direction. Traffic police diverted the traffic from disrupted side to the other side through an opening in a median. The desired sight distance on the four-lane dual carriageway was kept as 360 m under normal conditions. The Stopping Sight Distance (SSD, in m), which should be available on the operating road section after the incident, is

(a) 360
(b) 240
(c) 180
(d) 720

Ans. **(a)**

End of Solution

Q.24 Which one of the following statements is TRUE?

(a) Cant deficiency is related to train moving faster, and Cant excess is related to train moving slower.
(b) Cant deficiency is related to train moving slower, and Cant excess is related to train moving faster.
(c) Cant deficiency is related to train moving on the main line, and Cant excess is related to train moving on the branch line.
(d) Cant deficiency is related to train moving on the branch line, and Cant excess is related to train moving on the main line.

Ans. **(a)**

To understand why this is the case, we look at the relationship between equilibrium speed (the speed for which the track is actually banked) and the actual speed of the train.

- **Cant Deficiency (Fast Trains):** When a train travels faster than the equilibrium speed, the centrifugal force is greater than what the track banking (cant) can counteract. The train "needs" more banking than is provided. This shortage is called Cant Deficiency.
- **Cant Excess (Slow Trains):** When a train travels slower than the equilibrium speed (such as a freight train on a track designed for high-speed expresses), the banking is steeper than necessary for that speed. The train "has" more banking than it needs, leading to more pressure on the inner rail. This surplus is called Cant Excess.

End of Solution

Q.25 The primary purpose of the Windrose diagram is for the design of

(a) length of a runway.
(b) orientation of a runway.
(c) width of a runway.
(d) gradient of a runway.

Ans. **(b)**

The primary purpose of a windrose diagram is to determine the most effective orientation for a runway at an airport. It is a graphical tool that displays the direction, intensity, and duration of winds at a specific location over a long period (typically 5-10 years). By analyzing this data, planners can align the runway with prevailing winds to ensure aircraft experience favorable headwinds during takeoff and landing, which increases safety by minimizing dangerous crosswinds.

End of Solution

Q.26 Which one of the following statements is TRUE with respect to levelling survey?

(a) A level surface at all points is normal to the direction of the force of gravity.
(b) Two level surfaces can cross each other.
(c) Ellipsoid is an irregular surface approximating the physical surface of the Earth.
(d) Geoid is a regular surface approximating the physical surface of the Earth.

Ans. **(a)**

End of Solution

Q.27 Column I presents common air pollutants, and column II presents treatment technologies commonly employed to control air pollutants.

	Air pollutant		Treatment technology
1	Dust (size 5-25 μm)	P	Cyclone separator
2	Carbon monoxide (CO)	Q	Wet lime-water scrubber
3	Sulfur dioxide (SO_2)	R	Electrostatic precipitator
4	Fly ash (size < 2.5 μm)	S	Catalytic converter

The option that CORRECTLY matches the air pollutant with its treatment technology is:

(a) 1 - P; 2 - S; 3 - Q; 4 - R
(b) 1 - P; 2 - R; 3 - S; 4 - Q
(c) 1 - R; 2 - Q; 3 - P; 4 - S
(d) 1 - R; 2 - Q; 3 - S; 4 - P

Ans. (a)

End of Solution

Q.28 One-third of the solid matter in a sludge containing 90% water is composed of fixed mineral solids with specific gravity 2.5, and two-third is composed of volatile solids with specific gravity 1.0. Specific gravity of all solids lies between

(a) 1.2 and 1.3
(b) 1.5 and 1.6
(c) 1.7 and 1.8
(d) 2.0 and 2.1

Ans. (a)

$$G_S = \frac{1}{\frac{(1/3)}{2.5} + \frac{(2/3)}{1}} = 1.25 \quad \text{(It is lies between 1.2 and 1.3)}$$

End of Solution

Q.29 The grown algae are useful in the operation of

(a) oxidation pond.
(b) slow sand filter.
(c) cyclone separator.
(d) septic tank.

Ans. (a)

An **oxidation pond** (also known as a stabilization pond) relies on a symbiotic relationship between bacteria and algae to treat wastewater.

- **Oxygen Production:** Through photosynthesis, algae release dissolved oxygen into the water.
- **Bacteria Support:** Aerobic bacteria use this oxygen to break down organic matter in the sewage.
- **Carbon Dioxide Cycle:** In return, the bacteria release carbon dioxide, which the algae use for further photosynthesis.

End of Solution

Q.30 A partial differential equation is given below.

$$\frac{\partial^2 u}{\partial x^2} - \frac{\partial^2 u}{\partial y^2} = 0$$

Possible solution(s) is/are:

(a) $(x + y)^5$

(b) $(x - 2y)^5$

(c) $\cos(x + y)$

(d) $\sin(x + 2y)$

Ans. (a, c)

Option (a) $N = (x + y)^5$

$$\frac{\partial u}{\partial x} = 5(x + y)^4$$

$$\frac{\partial^2 u}{\partial x^2} = 20(x + y)^3$$

$$\frac{\partial u}{\partial x} = 5(x + y)^4$$

$$\frac{\partial^2 u}{\partial x^2} = 20(x + y)^3$$

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$$

$$= 20(x + y)^3 - 20(x + y)^3$$

$$= 0$$

Option (c) $u = \cos(x + y)$

$$\frac{\partial u}{\partial x} = -\sin(x + y)$$

$$\frac{\partial^2 u}{\partial x^2} = -\cos(x + y)$$

$$\frac{\partial u}{\partial x} = -\sin(x + y)$$

$$\frac{\partial^2 u}{\partial x^2} = -\cos(x + y)$$

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$$

End of Solution

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Q.31 The eigenvalues of $[A]=\begin{bmatrix} 2 & -3.5 & 6 \\ 3.5 & 5 & 2 \\ 8 & 1 & 8.5 \end{bmatrix}$ are

$\lambda_1 = -1.547$. $\lambda_2 = 12.330$, and $\lambda_3 = 4.711$.

The absolute value of the determinant of matrix A is ______ (rounded off to two decimal places).

Ans. **(89 - 91)**

Given:

$$\lambda_1 = -1.547$$
$$\lambda_2 = 12.33$$
$$\lambda_3 = 4.711$$
$$\text{Det}(A) = \text{Product of Eigen values}$$
$$= \lambda_1\lambda_2\lambda_3$$
$$= (-1.547) \times 12.33 \times 4.711$$
$$= -89.86$$

Absolute value of Det(A) = $|-89.86| = 89.86$

End of Solution

Q.32 The probability (in %) that a storm having return period of 15 years may occur in the next 10 years is ______ (rounded off to two decimal places).

Ans. **(45 - 55)**

Given: Return period, $T = 15$ years

At least one

$$P(r \geq 1) = 1 - P(r = 0)$$
$$= 1 - q^n$$
$$= 1 - \left(\frac{14}{15}\right)^{10}$$
$$= 0.4984 = 49.84\%$$

End of Solution

Q.33 A fully saturated sandy soil deposit has water content 20 % and specific gravity 2.65. The critical hydraulic gradient for seepage through the soil to create the quicksand condition is ____________ (rounded off to two decimal places).

Ans. **(1.00 - 1.15)**

Given: Water content, $w = 20\%$ (Fully saturated soil)

Specific gravity, $G = 2.65$

Critical hydraulic gradient, $i_c = ?$

$$\because \quad i_c = \frac{G-1}{1+e}$$

$$\Rightarrow \quad i_c = \frac{G-1}{\left(1+\frac{Gw}{S}\right)} \qquad (\because \; es = Gw)$$

$$\Rightarrow \quad i_c = \frac{2.65-1}{\left(1+\frac{2.65\times0.20}{1}\right)}$$

$$\Rightarrow \quad i_c = 1.078$$

End of Solution

Q.34 A downgrade of 1 in 100 meets an upgrade of 1 in 125 on a road. If the rate of change of grade is 0.10 % per 30 m, the length (in m) of the vertical curve between the two grades is ______ (rounded off to the nearest integer).

Ans. **(540 - 540)**

Given: $n_1 = \frac{-1}{100}, \quad n_2 = +\frac{1}{125}$

$$N = \left|\frac{-1}{100} - \frac{1}{125}\right| = 0.018 = 1.8\%$$

Rate of change of gradient $= \frac{N}{L_v}$

$$\Rightarrow \quad \frac{0.1\%}{30} = \frac{1.8\%}{L_v}$$

$$L_v = 540 \text{ m}$$

End of Solution

Q.35 A tourist visiting a city holds a map prepared at a scale of 1:25000. The tourist measures the distance between place A and place B in the city as 12.0 cm on the map. Assuming both the places are connected by a straight road, the distance (in km) the tourist needs to walk from A to B is __________ (rounded off to the nearest integer).

Ans. **(3 - 3)**

Given: $RF = \frac{1}{25,000}$

1 cm on map = 25000 cm on ground
= 0.25 km on ground
12 cm on map = 12×0.25
= 3 km on ground.

End of Solution

Q.36 Let $f(x) = \begin{vmatrix} x^3 & \sin x & \cos x \\ 6 & -1 & 0 \\ p & p^2 & p^3 \end{vmatrix}$

where p is a constant.

The value of $\frac{d^3}{dx^3} f(x)$ at $x = 0$ is

(a) $6p^3$
(b) $p + p^2$
(c) $p + p^3$
(d) independent of p

Ans. (d)

$$f(x) = \begin{vmatrix} x^3 & \sin x & \cos x \\ 6 & -1 & 0 \\ p & p^3 & p^3 \end{vmatrix}$$

$$\frac{d}{dx} f(x) = \begin{vmatrix} 3x^3 & \cos x & -\sin x \\ 6 & -1 & 0 \\ p & p^3 & p^3 \end{vmatrix} + \begin{vmatrix} x^3 & \sin x & \cos x \\ 0 & 0 & 0 \\ p & p^3 & p^3 \end{vmatrix} + \begin{vmatrix} x^3 & \sin x & \cos x \\ 6 & -1 & 0 \\ 0 & 0 & 0 \end{vmatrix}$$

$$f'(x) = \begin{vmatrix} 3x^3 & \cos x & -\sin x \\ 6 & -1 & 0 \\ p & p^3 & p^3 \end{vmatrix}$$

Again differentiation,

$$f''(x) = \begin{vmatrix} 6x & -\sin x & -\cos x \\ 6 & -1 & 0 \\ p & p^3 & p^3 \end{vmatrix} + 0 + 0$$

Again differentiation,

$$f'''(x) = \begin{vmatrix} 6 & -\cos x & \sin x \\ 6 & -1 & 0 \\ p & p^3 & p^3 \end{vmatrix} + 0 + 0$$

$$f'''(x) = -6[-p^3 \cos x - p^2 \sin x] - 1(6p^3 - p \sin x)$$

$$f'''(x)_{\text{at } x=0} = -6(-p^3 - 0) - 1(6p^3 - 0)$$

$$= 6p^3 - 6p^3$$

$$= 0 \quad \text{(independent of } p\text{)}$$

End of Solution

Q.37 Vector field $\vec{V}$ is defined as

$$\vec{V} = 3x^2yz\,\hat{i} - 5xy\,\hat{j} + 6yz^2\hat{k}$$

The curl of $\vec{V}$ at point (2, –1, 1) is

(a) $6\hat{i} - 12\hat{j} - 7\hat{k}$

(b) $-12\hat{i} - 10\hat{j} - 12\hat{k}$

(c) – 34

(d) $\begin{bmatrix} -12 & 12 & -12 \\ 5 & -10 & 0 \\ 0 & 6 & -12 \end{bmatrix}$

Ans. (a)

$$\vec{V} = 3x^2yz - 5xy\hat{j} + 6yz^2\hat{k}$$

$$\text{curl}\left(\vec{V}\right) = \begin{vmatrix} i & j & k \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 3x^2yz & -5xy & 6yz^2 \end{vmatrix}$$

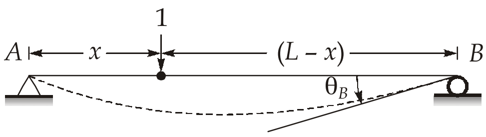
$$= i\left(6z^2 + 0\right) - j\left(0 - 3x^2y\right) + \hat{k}\left(-5y - 3x^2z\right)$$

$$\text{curl}\left(\vec{V}\right) = \left(6z^2\right)\hat{i} + \left(3x^2y\right)\hat{j} - \left(5y + 3x^2z\right)\hat{k}$$

$$\text{curl}\left(\vec{V}\right)_{\text{at}(2,-1,1)} = 6\hat{i} - 12\hat{j} - 7\hat{k}$$

End of Solution

Q.38 A simply supported, linearly elastic, homogeneous, prismatic beam of length L and flexural rigidity EI is shown in the figure.



The expression for the Influence Line Diagram (ILD) of the rotation $\theta_B(x)$ at the support B is

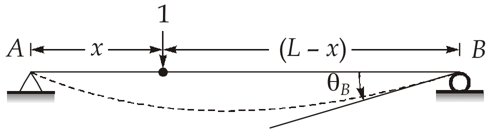
(a) $\frac{1}{6EI}\left(x^2 - L^2\right)$

(b) $\frac{1}{6EIL}\left(x^3 - L^2x\right)$

(c) $\frac{1}{3EI}\left(x^2 - Lx\right)$

(d) $\frac{1}{3EIL}\left(x^3 - L^2x\right)$

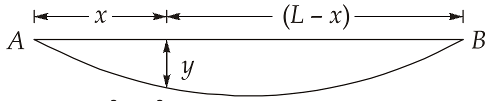
Ans. **(b)**



Slope at support B,

$$\theta_B = \frac{wa}{6EIL}\left(L^2 - a^2\right)$$

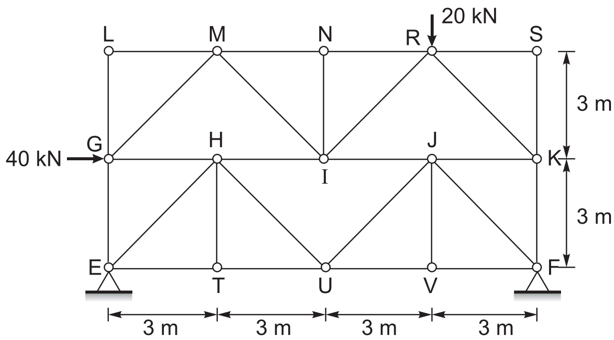
$$\theta_B = \frac{1 \times x}{6EIL}\left(L^2 - x^2\right) = \frac{x}{6EIL}\left(L^2 - x^2\right)$$



$$y = \frac{x}{6EIL}(L^2 - x^2) \qquad \text{(ILD for } \theta_B\text{)}$$

End of Solution

Q.39 The plane truss shown in the figure is hinge-supported at E and F. The truss is subjected to vertical downward force at R and horizontal force at G.



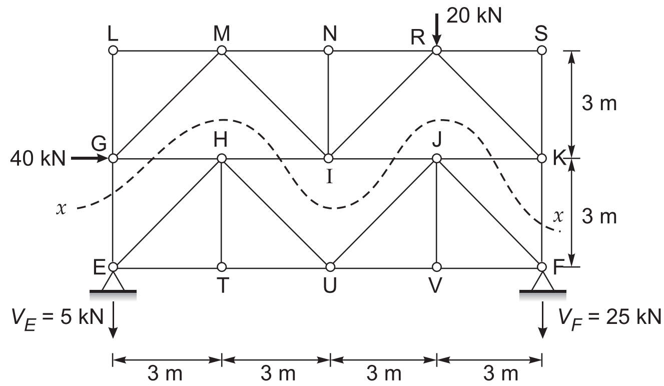
(Figure not to scale)

The force (in kN) along with its nature in member JF is

(a) $10\sqrt{2}$ compression (b) $10\sqrt{2}$ tension

(c) $25\sqrt{2}$ compression (d) $25\sqrt{2}$ tension

Ans. **(a)**



Support reactions:

Taking moment about F

$\Sigma M_F = 0$

$\Rightarrow \quad -V_E \times 12 + 40 \times 3 - 20 \times 3 = 0$

$$\Rightarrow \quad V_E = \frac{60}{12} = 5 \text{ kN } (\downarrow)$$

$V_F = 25$ kN($\uparrow$)

Cut of by (x) - (x) consider upper side of (x) - (x)

Taking moment about G

$\Sigma M_G = 0$

$\Rightarrow \quad 20 \times 9 - F_{KF} \times 12 = 0$

$$\Rightarrow \quad F_{KF} = \frac{180}{12} = 15 \text{ kN (compressive)}$$

From FBD of joint (F)

$\Sigma F_y = 0$

$\Rightarrow \quad 25 - 15 - F_{JF} \sin 45° = 0$

$\Rightarrow \quad F_{JF} = 10\sqrt{2}$ kN (compressive)

End of Solution

Q.40 Consider the following statements with respect to rigid pavements:

Statement-1: Bottom-up cracking (BUC) in rigid pavements is caused at the edge of the slab due to combined effect of single or tandem rear axle load and positive temperature differential.

Statement-2: Top-down fatigue cracking (TDC) in rigid pavements is caused due to repeated cycles of axle loads and negative temperature differential.

The CORRECT option is:

(a) Both statements are TRUE.

(b) Statement-1 is TRUE, but Statement-2 is FALSE.

(c) Statement-1 is FALSE, but Statement-2 is TRUE.

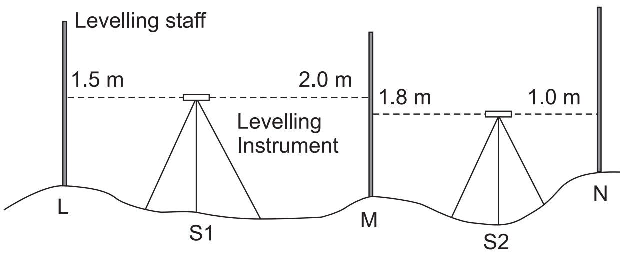
(d) Both statements are FALSE.

Ans. **(a)**

Bottom-up cracking occurs during the day (positive temperature differential) when the slab warps downward; edge loading then creates maximum tension at the bottom. Top-down cracking occurs at night (negative temperature differential) as the slab curls upward, causing maximum tension and cracking at the top surface.

End of Solution

Q.41 For the traverse given below, the benchmark is at ground point *L*. The Reduced Level (RL) of *L* is 150.000 m. The direction of the traverse is from *L* to *N*. The readings on levelling staff using the same levelling instrument kept at Stations S_1 and S_1 during the traversing are shown in the figure.



Column I	Column II
	(P) 3.300 m
(I) Sum of Back Sights	(Q) 2.500 m
(II) Sum of Fore Sights	(R) 150.300 m
(III) RL of Point N	(S) 3.000 m
	(T) 150.500 m

Matching the information given under Column 1 and Column 2, which one of the following options is CORRECT?

(a) (I) – (P); (II) – (S); (III) – (R)
(b) (I) – (P); (II) – (Q); (III) – (R)
(c) (I) – (S); (II) – (P); (III) – (T)
(d) (I) – (S); (II) – (Q); (III) – (T)

Ans. **(a)**

$$HI = BM + BS$$
$$= 150 + 1.5 = 151.5 \text{ m}$$
$$RL_N = 151.5 - 2 + 1.8 - 1 = 150.3 \text{ m}$$

Sum of Back sight, $\Sigma(BS) = 1.5 + 1.8 = 3.3$ m

Sum of fore sight, $\Sigma(FS) = 2 + 1 = 3$ m

End of Solution

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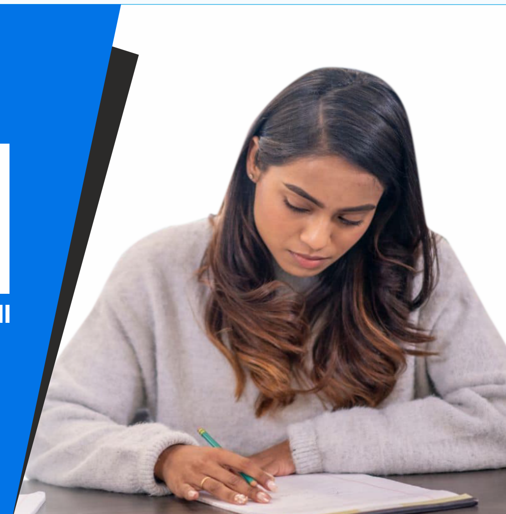

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Q.42 The 2.4 ml of raw sewage is diluted to 240 m*l*. The Dissolved Oxygen (DO) of the diluted sample at the beginning of Biochemical Oxygen Demand (BOD) test was 8 mg/*l* and it was 6 mg/*l* after 5-day incubation at 20°C.
The BOD5 (in mg/*l*) of the raw sewage is

(a) 200 (b) 100
(c) 250 (d) 150

Ans. (a)

Given:
$$DO_i = 8 \text{ mg}/l$$
$$DO_f = 6 \text{ mg}/l$$
$$(BOD)_{5,\,20°\text{C}} = (DO_i - DO_f) \times D.F.$$
$$= (8 - 6) \times \frac{240}{2.4}$$
$$= 200 \text{ mg}/l$$

End of Solution

Q.43 Types of flood routing and methods are given in the table below.

Column 1 Type of Flood Routing	Column 2 Method
(P) Hydrologic routing	(i) Muskingum method
(Q) Hydraulic routing	(ii) Modified Pul's method
(R) Reservoir routing	(iii) Method of Characteristics
(S) Channel routing	

Option(s) giving the CORRECT match(es) between Column 1 and Column 2 is/are:

(a) (P) – (i); (Q) – (iii); (R) – (ii) (b) (Q) – (i); (R) – (iii); (S) – (ii)
(c) (P) – (i); (R) – (ii); (S) – (i) (d) (P) – (ii): (Q) – (iii): (R) – (ii)

Ans. (a, c, d)

End of Solution

Q.44 A shallow footing is subjected to a vertical load. Within the elastic limit of the underlying soil, the TRUE statement(s) is/are:

(a) Vertical displacement below a rigid shallow footing is uniform in clay as well as sand.
(b) Vertical contact pressure below a rigid shallow footing is uniform in clay as well as sand.
(c) Vertical displacement below a flexible shallow footing is uniform in clay as well as sand.
(d) Vertical contact pressure below a flexible shallow footing is uniform in clay as well as sand.

Ans. (a, d)

Within the elastic limit, a rigid footing undergoes uniform settlement because it does not deform, which leads to non-uniform contact pressure distribution on soil. In contrast, a flexible footing deforms along with the soil, resulting in non-uniform vertical displacement but nearly uniform contact pressure.

End of Solution

Q.45 Which of the following statements is/are TRUE with respect to the type of stresses to be considered for the design of rigid pavements?

(a) Warping stress due to temperature differential between the top and bottom of the pavement slab as a result of daily variation in temperature
(b) Frictional stress due to the overall increase or decrease in temperature of the pavement slab as a result of seasonal variation in temperature
(c) Critical stress obtained as the maximum of the wheel load stress, the warping stress, and the frictional stress
(d) Critical stress obtained as the sum of wheel load stresses at edge, interior, and corner of the pavement slab

Ans. (a, b)

End of Solution

Q.46 Consider differential equation $\frac{dy}{dx} + xy = x$ with the condition as $y = 0$ at $x = 0$. The value of y at $x = 1.0$ is ______ (rounded off to two decimal places).

Ans. (0.38 - 0.42)

$$\frac{dy}{dx} + xy = x$$

$$P = x, \quad q = x$$

$$I.F. = e^{\int p dx} = e^{\int x dx}$$

$$\Rightarrow \quad I.F. = e^{x^2/2}$$

$$y.e^{x^2/2} = \int x.e^{x^2/2} dx + c$$

Put, $\frac{x^2}{2} = t$

$$x dx = dt$$

$$y.e^{x^2/2} = \int e^t dt$$

$$y.e^{x^2/2} = e^t + c$$

$$y.e^{x^2/2} = e^{x^2/2} + c$$

$y(0) = 0 \quad \Rightarrow \quad x = 0, \quad y = 0$

$$0 \times 1 = 1 + c$$

$$\Rightarrow \quad c = -1$$

At $x = 1$,

$$y(1)e^{1/2} = e^{1/2} - 1$$

$$y = 1 - \frac{1}{e^{1/2}} = 1 - \frac{1}{\sqrt{e}} = 1 - \frac{1}{1.6487} = 0.39346$$

End of Solution

Q.47 The age (in years) of a population is normally distributed with a mean of 36 and standard deviation of 12. The height (in cm) of the same population is also normally distributed with a mean of 160 and standard deviation of 10.

If the probability of age greater than 50 years is equal to the probability of height greater than h, the value of h (in cm) is ______ (rounded off to two decimal places).

Ans. **(170 - 173)**

x = age y = height

$\mu_x = 36$ $\mu_y = 160$

$\sigma_x = 12$ $\sigma_y = 10$

$$P(x > 50) = P(y > h)$$

$$P\left(\frac{x-\mu_x}{\sigma_x} > \frac{50-36}{12}\right) = P\left(\frac{y-\mu_y}{\sigma_y} > \frac{h-160}{10}\right)$$

$$P\left(z > \frac{14}{12}\right) = P\left(z > \frac{h-160}{10}\right)$$

$$\frac{14}{12} = \frac{h-160}{10}$$

$$140 = 12h - 160 \times 12$$

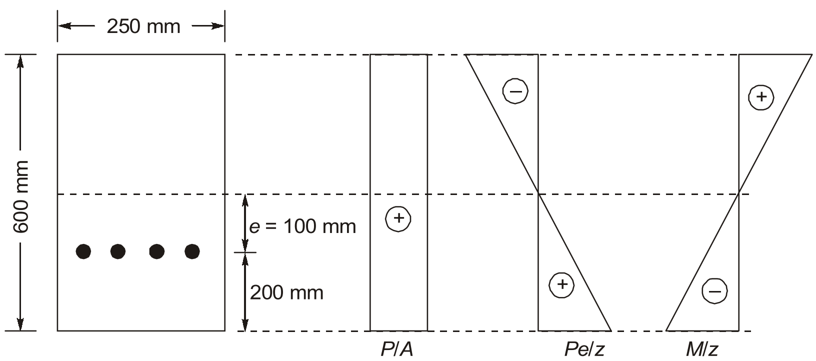
$$h = 171.66$$

End of Solution

Q.48 A 250 mm wide × 600 mm deep rectangular concrete beam is prestressed by means of 4 high-tensile tendons, each of 14 mm diameter. The centre of the tendons is 200 mm from the soffit of the beam. The effective stress in each tendon is 700 N/mm^2. The maximum bending moment (in kN-m), that can be applied to the section without causing tension at the soffit of the beam due to prestressing only, is ______ (rounded off to one decimal place).

Use π = 3.14.

Ans. **(85.5 - 87.6)**



$$\text{Eccentricity, } e = \frac{D}{2} - 200 = \frac{600}{2} - 200 = 100\text{mm}$$

$$P = 4 \times \frac{\pi}{4}(14)^2 \times \frac{700}{1000}$$

$$P = 431.026 \text{ kN}$$

For stress at bottom fibre = 0

$$\Rightarrow \quad \frac{P}{A} + \frac{Pe}{z} - \frac{M}{Z} = 0$$

$$\Rightarrow \quad \frac{M}{Z} = \frac{P}{A} + \frac{Pe}{Z}$$

$$\Rightarrow \quad M = P\left(e + \frac{Z}{A}\right) \qquad \left(\because z = \frac{BD^2}{6}\right)$$

$$\Rightarrow \quad M = P\left(e + \frac{D}{6}\right)$$

$$\Rightarrow \quad M = 431.026\left(100 + \frac{600}{6}\right)$$

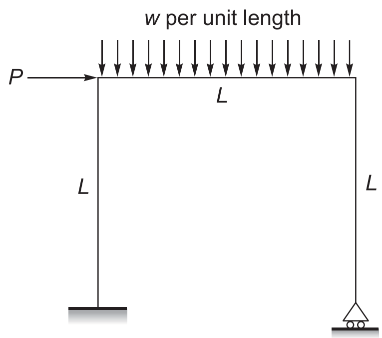
$$M = 86.205 \text{ kNm}$$

End of Solution

Q.49 A rigid-jointed portal frame, shown in the figure, consists of beam and columns of equal length L. The frame has a fixed support at one end and a roller support at the other end. The frame is subjected to a uniformly distributed load w and a lateral load Pas shown in the figure. The plastic moment capacity of the beam and column sections is M_p. Consider a combined beam-column mechanism for plastic collapse. By applying the virtual work equation corresponding to the combined plastic collapse mechanism, M_p is expressed as

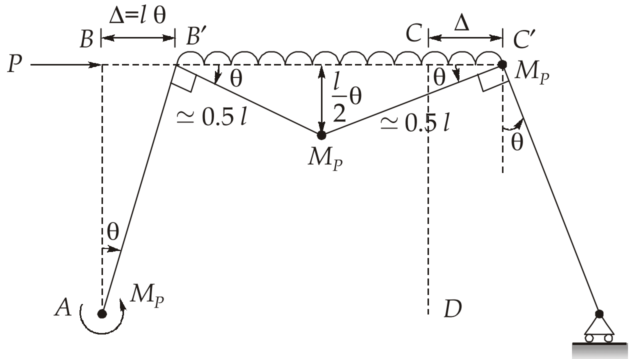
$$M_p = C_1PL + C_2WL^2$$

where C_1 and C_2 are constants.



The value of (C_1/C_2) is _______ (in integer).

Ans. **(4 - 4)**



(Combined mechanism)

Since $D_s = 1$

Number of plastic hinge required for complete collapse, $N = D_s + 1 = 2$

$\because$ External workdone = Internal workdone

$$\Rightarrow \quad P\Delta + w\left(\frac{1}{2}\times l\times\frac{l}{2}\theta\right) = M_p\theta + M_p(\theta + \theta)$$

$$\Rightarrow \quad M_P = \frac{Pl}{3}+\frac{wl^2}{12}$$

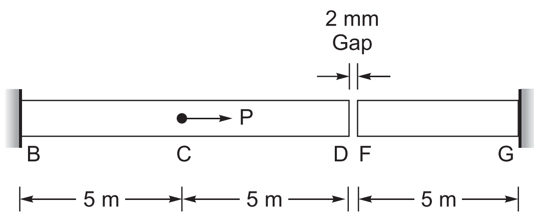
Given: $M_p = C_1Pl + C_2wl^2$

$$\therefore \quad C_1 = \frac{1}{3} \text{ and } C_2 = \frac{1}{12}$$

$$\text{ratio} = \frac{C_1}{C_2} = \frac{1}{3}\times 12 = 4$$

End of Solution

Q.50 Linearly elastic, homogeneous, uniform bars *BCD* and *FG* shown in the figure have fixed supports at *B* and *G*, respectively. For both the bars, axial rigidity is 20000 kN. A gap of 2 mm exists between *D* and *F* prior to application of any load (i.e. $P = 0$). Small deformation and infinitesimal strain assumptions are valid for the given bars.

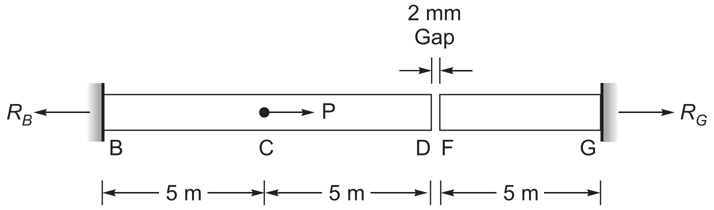


The magnitude of the horizontal reaction (in kN) at *B* after application of the axial force *P* of 20 kN at *C* is ______ (rounded off to the nearest integer).

Ans. **(16 - 16)**

$$\Delta_{BC} = \frac{Pl_{BC}}{AE}$$

$$\Delta_{BC} = \frac{20\times10^3\times5000}{20000\times10^3} = 5 \text{ mm} > (\text{gap} = 2 \text{ mm})$$



$$\Delta_{BC} + \Delta_{CD} + \Delta_{FG} = 2 \text{ mm}$$

$$\Rightarrow \frac{R_B l_{BC}}{AE} + \frac{(R_B - P)l_{CD}}{AE} + \frac{(-R_G)l_{FG}}{AE} = 2 \text{ mm}$$

$$\Rightarrow R_B \times 5000 + (R_B - 20)\times 5000 - R_G \times 5000 = 2 \times 20000$$

$$\Rightarrow R_B + (R_B - 20) - R_G = 8$$

$$\Rightarrow 2R_B - R_G = 28 \qquad ...(i)$$

$$\Sigma F_x = 0 \quad \Rightarrow \quad R_B + R_G = 20 \qquad ...(ii)$$

On solving equation (i) and (ii),

$$3R_B = 48$$

$$R_B = 16 \text{ kN } (\leftarrow)$$

$$R_G = 4 \text{ kN } (\leftarrow)$$

End of Solution

Q.51 A simply-supported rectangular reinforced concrete beam has a width 250 mm and an overall depth 600 mm. The effective span of the beam is 6.23 m. The beam carries a live load of 5 kN/m and super imposed dead load of 5 kN/m, in addition to its own weight. The unit weight of reinforced concrete is 25 kN/m^3. Consider the load factor of 1.5 for all stated loads.

The design bending moment (in kN-m) for the limit state of collapse is ______ (rounded off to two decimal places).

Ans. **(98.00 - 102.00)**

Given:

$$b = 250 \text{ mm}$$

$$D = 600 \text{ mm}$$

$$l_{eff} = 6.23 \text{ m}$$

$$w_{\text{live load}} = 5 \text{ kN/m}$$

$$w_{\text{super impose load}} = 5 \text{ kN/m}$$

$$\gamma_{\text{concrete}} = 25 \text{ kN/m}^3$$

$$\text{Dead load, } (w_{DL}) = 25 \times 0.6 \times 0.25 \times 1 = 3.75 \text{ kN/m}$$

$$\text{Total load, } (w_T) = 5 + 5 + 3.75 = 13.75 \text{ kN/m}$$

$$\text{Factored load, } (w_u) = 1.5 \times 13.75 = 25.625 \text{ kN/m}$$

Design bending moment

$$M_u = \frac{w_u l_{eff}^2}{8}$$

$$M_u = \frac{20.625 \times 6.23^2}{8} = 100.064 \text{ kNm}$$

End of Solution

Q.52 Width (in *m*) of a rectangular channel required to carry a discharge of 96 m^3/s at a critical depth of 9.8 m is _____ (rounded off to two decimal places).
Use acceleration due to gravity = 9.8 m/s^2

Ans. **(0.9 - 1.1)**

Given: Discharge, $Q = 96 \text{ m}^3/\text{sec}$

Critical depth, $y_c = 9.8$ m

Width, B = ?

$$\because \quad \frac{Q^2}{g} = \frac{A^3}{T}$$

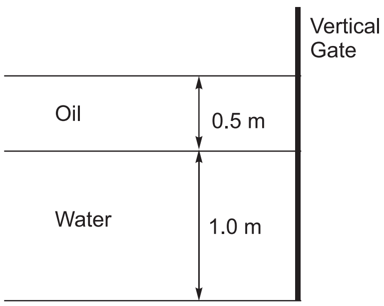
$$\Rightarrow \quad \frac{96^2}{9.81} = B_2 y_c^3$$

$$\Rightarrow \quad 939.45 = B^2 \times 9.8^3$$

$$B = 0.999 \text{ m} \simeq 1 \text{ m}$$

End of Solution

Q.53 The cross section of a 0.5 m wide vertical gate holding water and oil is shown in the figure. The unit weights of water and oil are 10 kN/m3 and 7.5 kN/m^3, respectively.



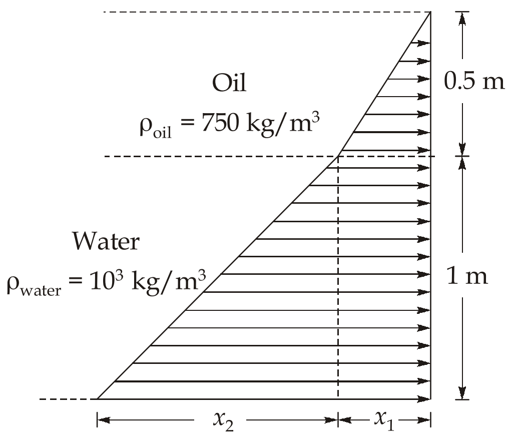
The horizontal hydrostatic force (in kN) acting on the vertical gate is _________ (rounded off to two decimal places).

Ans. **(4.75 - 5.00)**

Given: width of gate = 0.5 m

$$\rho_{water} = 10 \text{ kN/m}^3, \; \rho_{oil} = 7.5 \text{ kN/m}^3$$

Pressure diagram:



$$x_1 = \rho_{oil}\, gh = 750 \times 10 \times 0.5 = 3.75 \text{ kPa}$$
$$x_2 = \rho_{water}\, gh = 10^3 \times 10 \times 1 = 10 \text{ kPa}$$

Hydrostatic force on gate

$$F = \text{volume of pressure diagram}$$
$$\Rightarrow \quad F = (\text{Area})\ \text{width}$$
$$\Rightarrow \quad F = \left[\frac{1}{2}\times 3.75\times 0.5 + 3.75\times 1 + \frac{1}{2}\times 10\times 1\right]\times 0.5$$
$$\Rightarrow \quad F = 4.844 \text{ kN/m of width}$$

End of Solution

Q.54 A centrifugal pump is delivering water from an underground tank to an overhead reservoir against a static head of 35 m through a 2 km long, 250 mm diameter pipe. The head-discharge characteristic of the pump is given by

$$H = 140 - 9000Q^2$$

where H is the head (in m) generated by the pump and Q is the discharge (in m^3/s) of the pump.

Neglecting all minor losses, the head (in m) generated by the pump is (rounded off to the nearest integer).

Use: Darcy-Weisbach friction factor f = 0.04

Acceleration due to gravity = 9.81 m/s^2

π = 3.14

Ans. **(78 - 82)**

$$\because \quad H = H_{static} + H_f$$
$$H = H_{static} + \frac{8Q^2}{\pi^2 g}\left(\frac{fL}{D^5}\right)$$

Now,

$$\Rightarrow \quad 140 - 9000\,Q^2 = 35 + \frac{8Q^2}{\pi^2\times 9.81}\times\frac{0.04\times 2000}{(0.25)^5}$$

$\Rightarrow \quad 15768.792\, Q^2 = 105$

$\Rightarrow \quad Q = 0.0816 \text{ m}^3/\text{sec}$

Head generated by pump.

$$H = 140 - 9000\, Q^2$$

$$\Rightarrow \quad H = 140 - 9000 \times 0.0816^2$$

$$H = 80.07 \text{ m}$$

End of Solution

Q.55 The flow depth for a discharge of 10 m^3/s in a wide rectangular channel is 2.0 m. Assume that the flow is uniform.
If the discharge is doubled, the flow depth (in m) in this channel is ________ (rounded off to two decimal places).

Ans. **(3.00 - 3.05)**

Given: $Q_1 = 10 \text{ m}^3/\text{sec}, \quad y_1 = 2 \text{ m}$

$Q_2 = 2\, Q_1 \qquad y_2 = ?$

For wide rectangular channel, $R = y$

$$\because \quad Q = \frac{A}{n} R^{2/3} S^{1/2}$$

$$\Rightarrow \quad Q = \frac{By}{n} y^{2/3} S^{1/2}$$

$$\Rightarrow \quad Q \propto y^{5/3}$$

Now, $$\frac{Q_1}{Q_2} = \left(\frac{y_1}{y_2}\right)^{5/3}$$

$$\frac{10}{20} = \left(\frac{2}{y_2}\right)^{5/3}$$

$$y_2 = 3.03 \text{ m}$$

End of Solution

Q.56 For a clayey soil stratum, the time required for degree of consolidation from 25% to 50% is 30 days.
The total time (in days) required for 90% degree of consolidation of the same soil stratum is (rounded off to the nearest integer).

Ans. **(171 - 174)**

Given: $U_1 = 25\%$

$U_2 = 50\%$

$t_2 - t_1 = 30 \text{ days}$

$$\because \quad T_v = \frac{C_v t}{d^2}$$

$$\therefore \quad \frac{\pi}{4}(0.25)^2 = \frac{C_v t_1}{d^2}$$

and $$\frac{\pi}{4}(0.50) = \frac{C_v t_2}{d^2}$$

Now, $$\frac{\pi}{4}\left(0.5^2 - 0.25^2\right) = \frac{C_v}{d^2}(t_2 - t_1)$$

$\Rightarrow$ $$0.1473 = \frac{C_v}{d^2} \times 30$$

$\Rightarrow$ $$\frac{C_v}{d^2} = 4.9 \times 10^{-3}$$

Time required for 90% degrees of consolidation,

$$(T_r)_{90} = \frac{C_v t}{d^2}$$

$\Rightarrow$ $$0.848 = 4.9 \times 10^{-3} t$$

$\Rightarrow$ $$t = 173.06 \text{ days}$$

End of Solution

Q.57 The ultimate bearing capacity of a 1 m wide strip footing is 532.80 kPa, when it is embedded at 1 m depth in dry cohesionless soil. The soil has a unit weight of 18 kN/(m^3) The ultimate bearing capacity is 864 kPa when the depth of embedment becomes 2 m.

Neglecting the effect of the depth factor, the bearing capacity factor N_q is (rounded off to one decimal place).

Ans. **(18.2 - 18.6)**

$$\gamma = 18 \text{ kN/m}^3$$

Ultimate bearing capacity,

$$(q_u)_{Df = 1\text{ m}} = 532.8 \text{ kPa}$$

$$(q_u)_{Df = 2\text{ m}} = 864 \text{ kPa}$$

As per Terzaghi's bearing capacity equation ultimate bearing capacity of footing is given by (For square footing)

$$q_u = 1.3\, CN_C + \gamma D_f N_q + 0.4\, B\gamma N_r$$

For $D_f = 1$ m,

$$532.8 = \gamma \times 1 \times N_q + 0.4\, B\gamma N_r \quad \text{...(i)}$$

For $D_f = 2$ m,

$$864 = \gamma \times 2 \times N_q + 0.4\, B\gamma N_r \quad \text{...(ii)}$$

From equation (i) and (ii)

$$864 - 532.8 = \gamma N_q$$

$\Rightarrow$ $$N_q = 18.40$$

End of Solution

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Q.58 A building is proposed in an area having thick deposit of silty clay. The water table is at the ground surface. The saturated unit weight of soil is 18 kN/(m^3) and unit weight of water is 10kN/(m^3) The maximum vertical load (P) on a column of the proposed building is 2000 kN.

Consider $\sigma_z \leq 0.1\ \sigma_v'$ for computation of the minimum depth of soil exploration.

σ_v' is the effective vertical overburden stress. σ_z is the increase in the vertical stress at depth below load P as per the Boussinesq's stress theory.

Based on above, the minimum depth (in m) of soil exploration required for the foundation design is (rounded off to two decimal places).

Ans. **(10 - 11.2)**

Given: $\gamma_{sat} = 18\ \text{kN/m}^3,\ Q = 2000\ \text{kN}$

From Boussinesq's equation. Stress below the point load at depth z is given by

$$\sigma_z = \frac{3}{2\pi}\left(\frac{Q}{z^2}\right)$$

$\because$ $\sigma_z = 10\%$ of $(\gamma' z)$

$\therefore$ $\frac{3}{2\pi} \times \frac{2000}{Z^2} = 0.1 \times (18 - 9.81)Z$

$\Rightarrow$ $Z^3 = 1165.97$

$\Rightarrow$ $Z = 10.525$ m below the ground level.

End of Solution

Q.59 A soil sample has following properties:

Natural water content = 30 %

Plasticity index = 40 %

Liquidity index = 50 %

The estimated plastic limit (in %) of the soil is ________ (rounded off to one decimal place).

Ans. **(10 - 10)**

Given: liquidity index, $I_L = 0.5$

Plasticity index, $I_p = 40\%$

Natural water content, $w_n = 30\%$

Plastic limit, $w_p = ?$

$\because$ $I_L = \frac{w_n - w_p}{I_p}$

$\Rightarrow$ $0.5 = \frac{30 - w_p}{40}$

$\Rightarrow$ $w_p = 10\%$

End of Solution

Q.60 For a given traffic stream, the speed-density relationship is given as:

$$v = v_0 \ln\left(\frac{k_j}{k}\right)$$

where v is the mean speed (in km/h), and k is the density (in veh/km). Considering v_0 as 45 km/h, and k_j as 200 veh/km, the maximum flow (in veh/h) for the given stream is __________ (rounded off to the nearest integer).

Ans. **(3300 - 3350)**

Given: u_0 = 45 kmph, K_j = 200 veh/km

Speed-density relationship

$$u = u_0 \log_e\left(\frac{K_j}{K}\right) \quad \text{...(i)}$$

For maximum flow,

$$\frac{dq}{dk} = 0$$

$$\Rightarrow \quad u_0\left[K \times \frac{1}{(K_j/k)} \times K_j\left(\frac{-1}{K^2}\right) + \log_e\left(\frac{K_j}{K}\right) \times 1\right] = 0$$

$$\Rightarrow \quad -1 + \log_e\left(\frac{K_j}{K}\right) = 0$$

$$\frac{K_j}{K} = e$$

$$K = \frac{1}{e}K_j$$

From equation (i)

Maximum capacity of road,

$$q_{max} = u_0\left(\frac{K_j}{e}\right)\log_e\left(\frac{K_j}{K_j/e}\right)$$

$$\Rightarrow \quad q_{max} = \frac{1}{e}u_0 K_j$$

$$\Rightarrow \quad q_{max} = \frac{1}{e} \times 45 \times 200$$

$$q_{max} = 3310.9 \text{ veh/hr}$$

$$\simeq 3311 \text{ veh/hr}$$

End of Solution

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Q.61 A vertical curve is formed by a descending gradient of 1 in 40 meeting an ascending gradient of 1 in 50. Consider the following:
Stopping Sight Distance (SSD) = 90 m
Height of headlight of a vehicle above the road surface = 0.75 m
Headlight beam angle with respect to the longitudinal axis of the vehicle = 1.2°
Based on the sight distance criteria, the design length (in m) of the vertical curve is __________ (rounded off to the nearest integer).

Ans. **(60 - 67)**

Given: $n_1 = \frac{-1}{40}, n_2 = \frac{1}{50}, h = 0.75 m, \beta = 1.2°$

Sight distance, $S = 90$ m

Assume: $L_v > HSD$

$$L_v = \frac{NS^2}{(2h + 2S\tan\beta)}$$

$$\Rightarrow \quad L_v = \frac{\frac{9}{200}(90)^2}{2\times0.75 + 2\times90\tan1.2°}$$

$\Rightarrow \quad L_v = 69.159 \text{ m} < HSD$ (Assumption is wrong)

Assume: $L_v < HSD$

$$L_v = 2S - \frac{(2h + 2S\tan\beta)}{N}$$

$$\Rightarrow \quad L_v = 2 \times 90 - \frac{(2\times0.75 + 2\times90\tan1.2°)}{\left(\frac{9}{200}\right)}$$

$\Rightarrow \quad L_v = 62.878 \text{ m} < HSD$ (Assumption is right)

End of Solution

Q.62 Interior angles measured at the locations of a closed traverse ABCDA are given in table below.

Location	Interior angle
A	71° 1′ 40″
B	104° 54′ 23″
C	107° 54′ 10″
D	76° 20′ 42″

The total error in the measured angles (in degrees) is _____________ (rounded off to three decimal places).

Ans. **(0.180 - 0.184)**

Sum of interior angle = 360°10'55''

Correct sum = $(n - 2) \times 180°$

$= 2 \times 180°$ $\quad \because \; n = 4$

$= 360°$

Error $= M.V. - T.V.$

$= 360°10'55'' - 360° = 0°10'55' = 0.182°$

End of Solution

Q.63 The analysis of major cations and anions in a water sample collected from a city's water supply is given below. Ions present in minor concentrations are not given.

Anions	Cl^-	SO_4^{2-}	SO_3^-	SO_3^{2-}
Concentration (mM)	1.5	0.5	1.0	0.01
Cations	Na^+	Ca^{2+}	Mg^{2+}	K^+
Concentration (mM)	2	0.5	0.25	0.02

$HCl \rightleftharpoons H^+ + Cl^-$ pK = –3

$H_2SO_4^{2-} \rightleftharpoons 2H^+ + SO_4^{2-}$ pK = –3

$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ pK = 6.3

$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$ pK = 10.3

$HOCl \rightleftharpoons H^+ + OCl^-$ pK = 7.5

HOCl (in %) present in the total free chlorine in the water is _____ (rounded off to the nearest integer).

Ans. **(13 - 15)**

End of Solution

Q.64 Anaerobic bacteria are being utilized for the destruction of biodegradable organic content of wastewater measured in terms of Chemical Oxygen Demand (COD). The yield coefficient (Y) is 0.06 gram Volatile Suspended Solids (VSS) per gram of COD. Bacterial biomass forms the sludge during the process. The proximate chemical formula of anaerobic bacteria is $C_6H_7NO_2$.
The COD (in %) converted into bacterial biomass is ______ (rounded off to the nearest integer).

Ans. **(8 - 10)**

yield coefficient, (y) = 0.06 gm vss per gm of COD

$C_6H_7NO_2 + 6O_2 \rightarrow 6CO_2 + NH_3 + 2H_2O$

Molecular weight of $C_6H_7NO_2$

$= 6 \times 12 + 7 \times 1 + 14 + 2 \times 16$

$= 125$ gm/mol

Required (O_2) $= 6$ moles $= 6 \times 32 = 192$ gm/mol

$$\text{Required (COD)} = \frac{192}{125} = 1.536 \text{ gm COD/vss}$$

COD required to produce Biomass

$$= 0.06 \times 1.536 \text{ gm}$$
$$= 0.09216 \text{ gm}$$

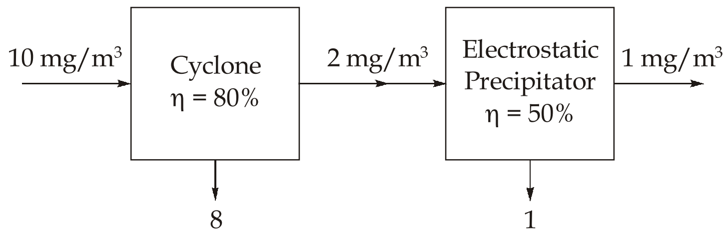
(COD) converted into Bacterial Biomass

$$= 0.09216 \times 100$$
$$= 9.216\% \simeq 9\% \text{ (nearest integer)}$$

End of Solution

Q.65 In an industry, a cyclone collector with 80 % efficiency is installed for air purification, followed by an electrostatic precipitator with 50 % efficiency. The concentration of particles entering the cyclone collector is 10 mg/m^3.
The concentration (in mg/m^3) of particles exiting the precipitator is __________ (rounded off to two decimal places).

Ans. (0.9 - 1.1)



Particle concentration in final outlet = 1 mg/m^3

End of Solution

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