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

SECTION - A GENERAL APTITUDE

Q.1 Visualize a cube that is held with one of the four body diagonals aligned to the vertical axis. Rotate the cube about this axis such that its view remains unchanged. The magnitude of the minimum angle of rotation is

(a) 120° (b) 90°
(c) 180° (d) 60°

Ans. (a)

End of Solution

Q.2 **Statements:**

1. All heroes are winners.
2. All winners are lucky people.

Inferences:

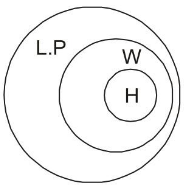
I. All lucky people are heroes.
II. Some lucky people are heroes.
III. Some winners are heroes.

Which of the above inferences can be logically deduced from statements 1 and 2?

(a) Only I and II (b) Only I and III
(c) Only II and III (d) Only III

Ans. (c)

Conclusion 1 ×
Conclusion 2 ✓
Conclusion 3 ✓



End of Solution

Q.3 A student was supposed to **multiply** a positive real number p with another positive real number q, Instead, the student **divided** p by q. If the percentage error in the student's answer is 80%, the value of q is

(a) 2 (b) $\sqrt{5}$
(c) 5 (d) $\sqrt{2}$

Ans. (b)

$$\frac{R\times q-\frac{R}{q}}{R\times q}=\frac{80}{100}=\frac{4}{5}$$

$$\frac{Rq-\frac{R}{q}}{Rq}=\frac{4}{5}$$

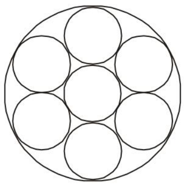
$$1-\frac{1}{q^2} = \frac{4}{5}$$

$$\frac{1}{q^2} = \frac{1}{5}$$

$$q = \sqrt{5}$$

End of Solution

Q.4 Seven identical cylindrical chalk-sticks are fitted tightly in a cylindrical container. The figure below shows the arrangement of the chalk-sticks inside the cylinder.



The length of the container is equal to the length of the chalk-sticks. The ratio of the occupied space to the empty space of the container is

(a) 9/2 (b) 5/2

(c) 3 (d) 7/2

Ans. (d)

Volume of outer cylinder = $\pi R^2 h$

Volume of smaller cylinder = $\pi r^2 h$

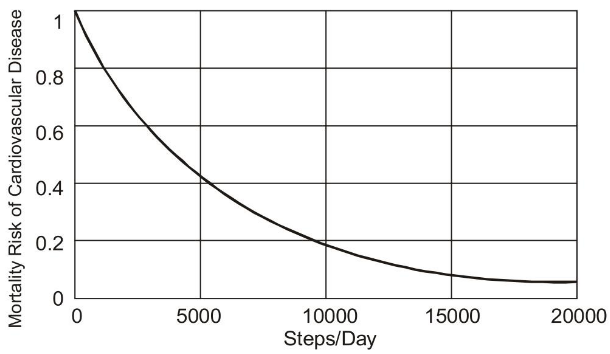
$R = 3r$

Ratio of occupied space to empty space

$$= \frac{7\times\pi r^2 h}{9\pi r^2 h - 7\times\pi r^2 h} = \frac{7}{2}$$

End of Solution

Q.5 The plot below shows the relationship between the mortality risk of cardiovascular disease and the number of steps a person walks per day. Based on the data, which one of the following options is true?



(a) For any 5000 increment in steps/day the largest risk reduction occurs on going from 15000 to 20000.

(b) The risk reduction on increasing the steps/day from 0 to 5000 is less than the risk reduction on increasing the steps/day from 15000 to 20000.

(c) The risk reduction on increasing the steps/day from 0 to 10000 is less than the risk reduction on increasing the steps/day from 10000 to 20000.

(d) For any 5000 increment in steps/day the largest risk reduction occurs on going from 0 to 5000.

Ans. (d)

End of Solution

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

Yoko Roi stands __(i)__ as an author for standing __(ii)__ as an honorary fellow, after she stood __(iii)__ her writings that stand __(iv)__ the freedom of speech.

(a) (i) down	(ii) out	(iii) by	(iv) in
(b) (i) down	(ii) out	(iii) for	(iv) in
(c) (i) out	(ii) down	(iii) in	(iv) for
(d) (i) out	(ii) down	(iii) by	(iv) for

Ans. (d)

End of Solution

Q.7 If the sum of the first 20 consecutive positive odd numbers is divided by 20^2, the result is

(a) 1 (b) 20

(c) 1/2 (d) 2

Ans. (a)

The sum of first n odd natural number = n^2

$$\therefore \quad \text{Result is} \quad \frac{20^2}{20^2} = 1$$

End of Solution

Q.8 The ratio of the number of girls to boys in class VIII is the same as the ratio of the number of boys to girls in class IX. The total number of students (boys and girls) in classes VIII and IX is 450 and 360, respectively. If the number of girls in classes VIII and IX is the same, then the number of girls in each class is

(a) 200 (b) 175

(c) 250 (d) 150

Ans. (a)

	Class VIII	Class IX
Total students	450	360
Number of girls	G	G
Number of boys	450 – G	360 – G

According to question,

$$\frac{G}{450-G} = \frac{360-G}{G}$$

$$G^2 = 360 \times 450 - 450\ G - 360\ G + G^2$$

$$810\ G = 360 - 450$$

$$G = \frac{360 \times 450}{810} = 200$$

End of Solution

Q.9 Five cubes of identical size and another smaller cube are assembled as shown in Figure *A*. If viewed from direction *X*, the planar image of the assembly appears as Figure *B*.

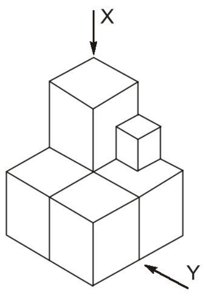


Figure A

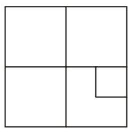
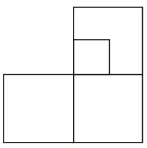
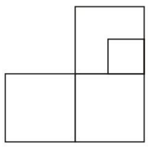
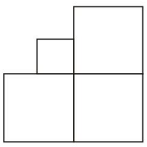
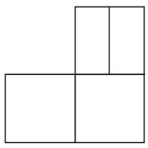


Figure B

(a) 

(b) 

(c) 

(d) 

Ans. **(b)**

End of Solution

Q.10 If '$\rightarrow$' denotes increasing order of intensity, then the meaning of the words [drizzle $\rightarrow$ rain $\rightarrow$ downpour] is analogous to [________ $\rightarrow$ quarrel $\rightarrow$ feud]. Which one of the given options is appropriate to fill the blank?

(a) bog
(b) dither
(c) bicker
(d) dodge

Ans. **(c)**

Bicker $\rightarrow$ To argue about un-important thing or issue

Quarrel $\rightarrow$ Angry, argument or diagreement

Feud $\rightarrow$ Angry or serious argument between two people that continues for long period of time.

■■■■

SECTION - B TECHNICAL

Q.1 The second derivative of a function f is computed using the fourth-order Central Divided Difference method with a step length h.

The CORRECT expression for the second derivative is

(a) $\frac{1}{12h^2}\left[f_{i+2} + 16f_{i+1} - 30f_i + 16f_{i-1} - f_{i-2}\right]$

(b) $\frac{1}{12h^2}\left[-f_{i+2} - 16f_{i+1} + 30f_i - 16f_{i-1} - f_{i-2}\right]$

(c) $\frac{1}{12h^2}\left[-f_{i+2} + 16f_{i+1} - 30f_i + 16f_{i-1} + f_{i-2}\right]$

(d) $\frac{1}{12h^2}\left[-f_{i+2} + 16f_{i+1} - 30f_i + 16f_{i-1} - f_{i-2}\right]$

Ans. **(d)**

Standard formula for finding 2nd derivative using 4th order divided difference formula is an follows;

$$f''(x) = \frac{1}{12h^2}\left[-f_{i+2} + 16f_{i+1} - 30f_i + 16f_{i-1} - f_{i-2}\right]$$

On comparision the given options with above result, the correction option is (d).

End of Solution

Q.2 For a reconnaissance survey, it is necessary to obtain vertical aerial photographs of a terrain at an average scale of 1:13000 using a camera. If the permissible flying height is assumed as 3000 m above a datum and the average terrain elevation is 1050 m above the datum, the required focal length (in mm) of the camera is

(a) 150
(b) 200
(c) 125
(d) 100

Ans. **(a)**

$$\text{Scale} = \frac{1}{13000} = \frac{f}{H - h_{avg}} \quad \text{where } f \text{ is focal length}$$

$$\Rightarrow \quad \frac{1}{13000} = \frac{f}{3000 - 1050}$$

$$f = 0.15 \text{ m} = 150 \text{ mm}$$

End of Solution

Q.3 Which one of the following saturated fine-grained soils can attain a negative Skempton's pore pressure coefficient (A)?

(a) Over-consolidated clays
(b) Lightly-consolidated clays
(c) Quick clays
(d) Normally-consolidated clays

Ans. (a)

End of Solution

Q.4 Various stresses in jointed plain concrete pavement with slab size of 3.5 m × 4.5 m are denoted as follows:

Wheel load stress at interior = S_{wl}^{i}

Wheel load stress at edge = S_{wl}^{e}

Wheel load stress at corner = S_{wl}^{c}

Warping stress at interior = S_t^{i}

Warping stress at edge = S_t^{e}

Warping stress at corner = S_t^{c}

Frictional stress between slab and supporting layer = S_f

The critical stress combination in the concrete slab during a summer midnight is

(a) $S_{wl}^{c} + S_t^{c} + S_f$
(b) $S_{wl}^{c} + S_t^{c}$
(c) $S_{wl}^{e} + S_t^{e} - S_f$
(d) $S_{wl}^{e} + S_t^{e} + S_f$

Ans. (b)

During summer at night, maximum stress combination occur due to load and warping stresses at corner.

End of Solution

Q.5 The function $f(x) = x^3 - 27x + 4,\ 1 \le x \le 6$ has

(a) Minima point
(b) Maxima point
(c) Saddle point
(d) Inflection point

Ans. (a)

$$f(x) = x^3 - 27x + 4$$
$$f'(x) = 3x^2 - 27$$
$$f'(x) = 0$$
$$\Rightarrow \quad 3x^2 - 27 = 0$$
$$3x^2 = 27$$
$$x^2 = 9$$
$$x = \pm 3$$
$$f''(x) = 6x$$

$$f''(x)\big|_{x=3} = 6 \times 3 = 18 > 0$$

$$f''(x) > 0$$

At x = 3, there will point of minima.

Hence option (a) is answer.

End of Solution

Q.6 To finalize the direction of a survey, four surveyors set up a theodolite at a station P and performed all the temporary adjustments. From the station P, each of the surveyors observed the bearing to a tower located at station Q with the same instrument without shifting it. The bearings observed by the surveyors are 30° 30′ 00′, 30° 29′ 40″, 30° 30′ 20″ and 30° 31′ 20″. Assuming that each measurement is taken with equal precision, the most probable value of the bearing is

(a) 30° 29′ 40″
(b) 30° 30′ 20″
(c) 30° 31′ 20″
(d) 30° 30′ 00″

Ans. (b)

Most probable value $= \dfrac{30°30'00'' + 30°29'40'' + 30°30'20'' + 30°31'20''}{4}$

$= 30° 30' 20''$

End of Solution

Q.7 Consider the following data for a project of 300 days duration.

Budgeted Cost of Work Scheduled (BCWS) = Rs. 200

Budgeted Cost of Work Performed (BCWP) = Rs. 150

Actual Cost of Work Performed (ACWP) = Rs. 190

The 'schedule variance' for the project is

(a) (–)50 days
(b) (–)Rs 50
(c) (+)50 days
(d) (+)Rs 50

Ans. (b)

Schedule Variance is given by,

$$SV = BCWP - BCWS$$

here, BCWP = Rs. 150

BCWS = Rs. 200

$\therefore$ SV = 150 – 200

= (–) Rs. 50

A negative variance indicates a behind-schedule condition.

End of Solution

Q.8 What is the CORRECT match between the survey instruments/parts of instruments shown in the table and the operations carried out with them?

Instruments/Parts of instruments	Operations
P - Bubble tube	i - Tacheometry
Q - Plumb bob	ii - Minor movements
R - Tangent screw	iii - Centering
S - Stadia cross-wire	iv - Levelling

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

Ans. (a)

End of Solution

Q.9 Which one of the following products is NOT obtained in anaerobic decomposition of glucose?

(a) H_2O
(b) CH_4
(c) H_2S
(d) CO_2

Ans. (c)

End of Solution

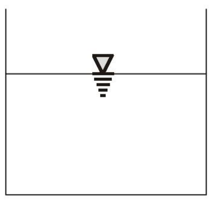
Q.10 A 2 m wide rectangular channel is carrying a discharge of 30 m^3/s at a bed slope of 1 in 300. Assuming the energy correction factor as 1.1 and acceleration due to gravity as 10 m/s^2, the critical depth of flow (in meters) is ________ (rounded off to 2 decimal places).

Ans. (2.91) (2.88 to 2.94)

Discharge, $Q = 30\ m^3/s$

$g = 10\ m/s^2$

Width of channel, $B = 2$ m



Now, Discharge intensity, $q = \frac{Q}{B} = \frac{30}{2} = 15\ m^3/s/m$

Now critical energy, E_c is given as

$$E_c = y_c + \alpha \cdot \frac{v^2}{2g}$$

$$\Rightarrow \quad E_c = y_c + \alpha \cdot \frac{q^2}{2g \cdot y_c^2}$$

$$\Rightarrow \quad 1.5y_c = y_c + \alpha \cdot \frac{q^2}{2g \cdot y_c^2}$$

$$\Rightarrow \quad 0.5y_c = \alpha \cdot \frac{q^2}{2g \cdot y_c^2}$$

$$\Rightarrow \quad y_c^3 = \alpha \cdot \frac{q^2}{g}$$

$$\Rightarrow \quad y_c = \left(\frac{\alpha \cdot q^2}{g}\right)^{1/3}$$

$$\Rightarrow \quad y_c = \left(\frac{1.1 \times 15^2}{20}\right)^{1/3} = 2.914 \text{ m}$$

Alternatively,

At critical condition,

$$\frac{\alpha Q^2}{g} = \frac{A_c^3}{T_c}$$

Where, A_c = Critical area of flow = $(By_c) = 2y_c$

T_c = Critical top width = B = 2 m

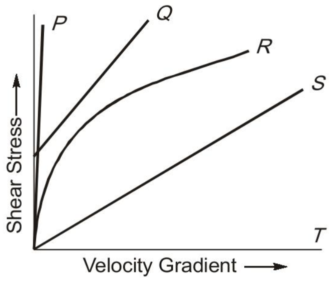
$$\Rightarrow \quad \frac{1.1 \times 30^2}{10} = \frac{(2y_c)^3}{2}$$

$$\Rightarrow \quad \frac{1.1 \times 30^2}{40} = y_c{}^3$$

$$\Rightarrow \quad y_c = 2.914 \text{ m}$$

End of Solution

Q.11 The following figure shows a plot between shear stress and velocity gradient for materials/fluids P.Q, R. S, and T.



Which one of the following options is CORRECT?

(a) P → Ideal Fluid; Q → Ideal Bingham plastic
R → Non-Newtomian fluid; T → Real solid

(b) P → Ideal Fluid; Q → Ideal Bingham plastic
R → Non-Newtonian fluid; S → Newtonian fluid

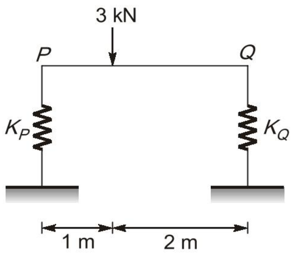
(c) P → Real solid; Q → Ideal Bingham plastic
S → Newtonian fluid; T → Ideal Fluid

(d) P → Real solid; Q → Newtonian fluid
R → Ideal Bingham plastic; T → Ideal Fluid

Ans. (c)

End of Solution

Q.12 A 3 m long, horizontal, rigid, uniform bean PQ has negligible mass. The beam is subjected to a 3kN concentrated vertically downward force at 1 m from P, as shown in the figure. The beam is resting on vertical linear springs at the ends P and Q. For the spring at the end P, the spring constant K_P = 100kN/m.



(Figure NOT to scale)

If the beam DOES NOT rotate under the application of the force and displaces only vertically, the value of the spring constant K_Q (in kN/m) for the spring at the end Q

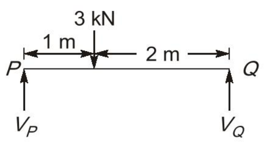
(a) 200 (b) 50

(c) 100 (d) 150

Ans. **(b)**

Let V_P and V_Q be forces in spring and stiffness of spring at Q is k_Q.

From equilibrium equations,



$$\Sigma F_y = 0$$

$$V_P + V_Q = 3$$

Also, $$\Sigma M_P = 0$$

$\Rightarrow$ $$V_Q \times 3 - 3 \times 1 = 0$$

$\Rightarrow$ $$V_Q = 1 \text{ kN and } V_P = 2 \text{ kN}$$

Now, $$\delta_P = \delta_Q$$

$\Rightarrow$ $$\frac{2}{100} = \frac{1}{k_Q}$$

$\Rightarrow$ $$k_Q = 50 \text{ kN/m}$$

End of Solution

Q.13 A simply supported, uniformly loaded, two-way slab panel is torsionally unrestrained. The effective span lengths along the short span (x) and long span (y) directions of the panel are lx and l_y, respectively. The design moments for the reinforcements along the x and y directions are M_{ux} and M_{uy}, respectively. By using Rankine-Grashoff method, the ratio M_{ux}/M_{uy} is proportional to

(a) $(ly/lx)^2$ (b) ly/lx

(c) lx/l_y (d) $(lx/ly)^2$

Ans. (a)

By Rankine Grashoff method,

$$Mu_x = \frac{r^4}{1+r^4}\, w_u \times \frac{L_x^2}{8}$$

$$Mu_y = \frac{1}{1+r^4}\, w_u \times \frac{L_y^2}{8}$$

Now, $$\frac{Mu_x}{Mu_y} = r^4 \cdot \frac{L_x^2}{L_y^2} = \left(\frac{L_y}{L_x}\right)^4 \times \left(\frac{L_x}{L_y}\right)^2 = \left(\frac{L_y}{L_x}\right)^2$$

End of Solution

Q.14 What is the CORRECT match between the air pollutants and treatment techniques given in the table?

Air pollutants	Treatment techniques
P - NO_2	i - Flaring
Q - SO_2	ii - Cyclonic seperator
R - CO	iii - Lime scrubbing
S - Particles	iv - NH_3 injection

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

Ans. (d)

End of Solution

Q.15 A partial differential equation

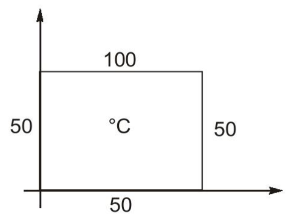
$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = 0$$

is defined for the two-dimensional field $T : T(x, y)$, inside a planar square domain of size 2 m × 2 m. Three boundary edges of the square domain are maintained at value $T = 50$, whereas the fourth boundary edge is maintained at $T = 100$.

The value of T at the center of the domain is

(a) 75.0
(b) 62.5
(c) 87.5
(d) 50.0

Ans. (b)

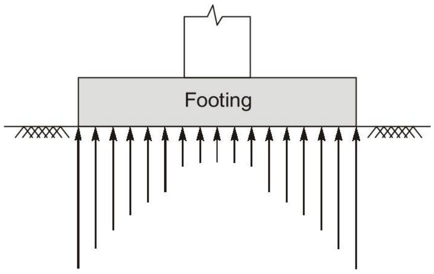


Temperature at centre = Average of temp at sides

$$= \frac{50+50+50+100}{4} = 62.5$$

End of Solution

Q.16 The contact pressure distribution shown in the figure belongs to a



(a) flexible footing resting on a cohesionless soil.
(b) rigid footing resting on a cohesive soil.
(c) flexible footing resting on a cohesive soil.
(d) rigid footing resting on a cohesionless soil.

Ans. **(b)**

End of Solution

Q.17 The statements P and Q are related to matrices A and B, which are conformable for both addition and multiplication.

$P : (A + B)^T = A^T + B_T$

$Q : (AB)^T = A^T B^T$

Which one of the following options is CORRECT?
(a) P is TRUE and Q is FALSE
(b) P is FALSE and Q is TRUE
(c) Both P and Q are FALSE
(d) Both P and Q are TRUE

Ans. **(a)**
P : it is obviously true because transpose is distributed over addition. i.e. $(A + B)^T = P^T + B^T$
Q : it is false because in matrix multiplication Transpose should follow Reversal law i.e. $(AB)^T = B^T A^T$.

End of Solution

Q.18 In general, the outer edge is raised above the inner edge in horizontal curves for
(a) Railways and Taxiways only
(b) Highways, Railways, and Taxiways
(c) Highways and Railways only
(d) Highways only

Ans. **(c)**
In highways and railways, the outer edge is raised above the inner edge in horizontal curve.

End of Solution

Q.19 Consider the statements P and Q.

P : In a Pure project organization, the project manager maintains complete authority and has maximum control over the project.

Q : A Matrix organization structure facilitates quick response to changes, conflicts, and project needs.

Which one of the following options is CORRECT?

(a) Both P and Q are TRUE

(b) P is TRUE and Q is FALSE

(c) P is FALSE and Q is TRUE

(d) Both P and Q are FALSE

Ans. **(a)**

P: In a pure project organisation, the project manager has the complete authority and control over the project.

Q: In a matrix organisation, employees have more than one boss and work on multiple teams. This leads to quick response to changes, conflicts and project needs.

End of Solution

Q.20 Consider two Ordinary Differential Equations (ODEs):

$$P : \frac{dy}{dx} = \frac{x^4 + 3x^2y^2 + 2y^4}{x^3y}$$

$$Q : \frac{dy}{dx} = \frac{-y^2}{x^2}$$

Which one of the following options is CORRECT?

(a) P is a non-homogeneous ODE and Q is an exact ODE.

(b) P is a nonhomogeneous ODE and Q is not an exact ODE.

(c) P is a homogeneous ODE and Q is not an exact ODE.

(d) P is a homogeneous ODE and Q is an exact ODE.

Ans. **(c)**

$$p : \frac{dy}{dx} = \frac{x^4 + 3x^2 + 2y^4}{x^3y} \text{ is homogeneous DE.}$$

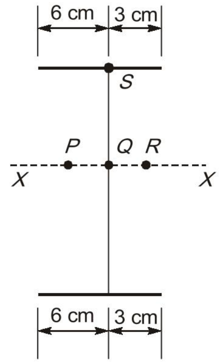
$$q : x^2dy + y^2dx = 0$$

$$\frac{\partial m}{\partial y} = 2y \neq \frac{\partial N}{\partial x} = 2x$$

$\Rightarrow$ q is not an exact DE.

End of Solution

Q.21 For a thin-walled section shown in the figure, points P, Q, and R are located on the major bending axis $X - X$ of the section. Point Q is located on the web whereas point S is located at the intersection of the web and the top flange of the section.



(Figure NOT to scale)

Qualitatively, the shear center of the section lies at

(a) *P* (b) *S*

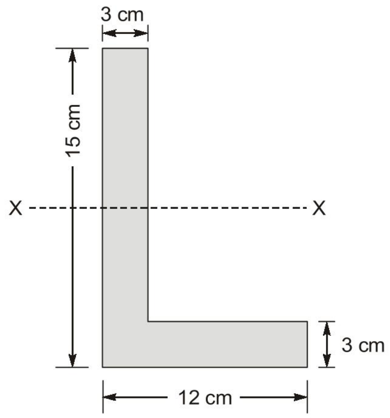
(c) *R* (d) *Q*

Ans. **(c)**

Position of shear centre will be at *R*.

End of Solution

Q.22 The steel angle section shown in the figure has elastic section modulus of 150.92 cm^3 about the horizontal $X - X$ axis, which passes through the centroid of the section.



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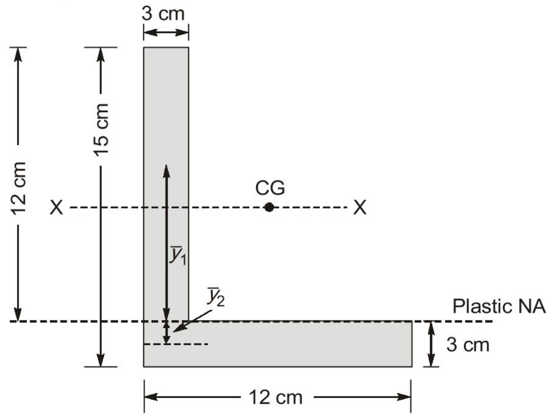
The shape factor of the section is __________ (rounded off to 2 decimal places).

Ans. **(1.79)(1.75 - 1.85)**



Gross area, Area = $b_e t$

= (15 + 12 − 3) × 3

= 72 cm^2

Location of plastic neutral axis

$$A_1 = A_2 = 36 \text{ cm}^2$$

where A_1 is the area above plastic N.A. and A_2 is the area below plastic N.A.

$$\therefore \quad Z_{Px} = \frac{A}{2}(\bar{y}_1 + \bar{y}_2) = \frac{72}{2}\left(6 + \frac{3}{2}\right)$$

$$= 270 \text{ cm}^3$$

$$\Rightarrow \quad \text{Shape factor, S.F.} = \frac{Z_P}{Z_e} = \frac{270}{150.92} = 1.79$$

End of Solution

Q.23 A reinforced concrete pile of 10 m length and 0.7 m diameter is embedded in a saturated pure clay with unit cohesion of 50 kPa. If the adhesion factor is 0.5, the net ultimate uplift pullout capacity (in kN) of the pile is _______ (rounded off to the nearest integer).

Ans. **(550)(545 - 555)**

Length of pile, L = 10 m, Diameter of pile, d = 0.7 m

Cohesion, C = 50 kPa

Adhesion factor, α = 0.5

Net ultimate uplift pullout capacity,

$$T = \alpha C \pi d L = 0.5 \times 50 \times \pi \times 0.7 \times 10 = 549.78 \text{ kN}$$

$$= 550 \text{ kN}$$

End of Solution

Q.24 The longitudinal sections of a runway have gradients as shown in the table.

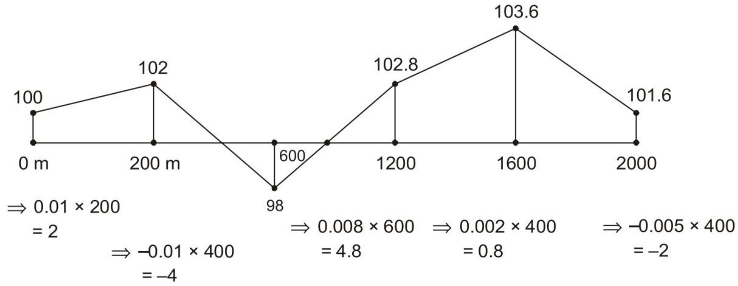
End to end for sections of runway (m)	Gradient (%)
0 to 200	+ 1.0
200 to 600	– 1.0
600 to 1200	+ 0.8
1200 to 1600	+ 0.2
1600 to 2000	– 0.5

Consider the reduced level (RL) at the starting point of the runway as 100 m.
The effective gradient of the runway is

(a) 0.28% (b) 0.18%

(c) 0.02% (d) 0.35%

Ans. **(a)**



$$\text{Gradient} = \frac{\text{Highest elevation} - \text{Lowest elevation}}{\text{Length}}$$

$$= \frac{103.6 - 98}{2000} \times 100 = 0.28\%$$

End of Solution

Q.25 The structural design method that DOES NOT take into account the safety factors on the design loads is

(a) limit state method. (b) ultimate load method.

(c) load factor method. (d) working stress method.

Ans. **(d)**

End of Solution

Q.26 A hypothetical multimedia filter, consisting of anthracite particles (specific gravity: 1.50), silica sand (specific gravity: 2.60), and ilmenite sand (specific gravity: 4.20), is to be designed for treating water/wastewater. After backwashing, the particles should settle forming three layers: coarse anthracite particles at the top of the bed, silica sand in the middle, and small ilmenite sand particles at the bottom of the bed.

Assume

(i) Slow discrete settling (Stoke's law is applicable)

(ii) All particles are spherical

(iii) Diameter of silica sand particles is 0.20 mm

The CORRECT option fulfilling the diameter requirements for this filter media is

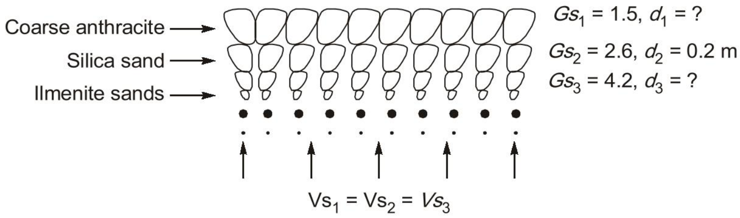
(a) diameter of anthracite particles is slightly less than 0.35 mm and diameter of ilmenite particles is slightly greater than 0.141 mm.

(b) diameter of anthracite particles is slightly greater than 0.35 mm and diameter of ilmenite particles is slightly less than 0.141 mm.

(c) diameter of anthracite particles is slightly greater than 0.64 mm and diameter of ilmenite particles is slightly less than 0.10 mm.

(d) diameter of anthracite particles is slightly less than 0.64 mm and diameter of ilmenite particles is slightly less than 0.10 mm.

Ans. (a)



$$\frac{1}{18\mu}(G_{s1}-1)\rho g d_1^2 = \frac{\rho g}{18\mu}(G_{S_2}-1)d_2^2 = \frac{\rho g}{18\mu}(G_{S_3}-1)d_3^2$$

$$\frac{\rho g}{18\mu}(G_S-1)d_1^2 = \frac{\rho g}{18\mu}(G_{S_2}-1)d_2^2 = \frac{\rho g}{18\mu}(G_{S_3}-1)d_3^2$$

$$(G_{S-1})d_1^2 = (G_{S2}-1).d_2^2$$

$$(1.5-1)d_1^2 = (2.6-1)\times(0.2)^2$$

$$d_1 = 0.357 \text{ m}$$

$$(G_{S2-1})d_2^2 = (G_{S3}-1).d_3^2$$

$$(2.6-1)\times(0.2)^2 = (4.2-1)d_3^2$$

$$d_3 = 0.141 \text{ mm}$$

The logic is that if we are creating 3 layers for better filtration and if we want those layers to be intact, even after backwashing, then we need to ensure that as the backwashing is stopped, each layer settles with the same velocity so that the stratification is maintained as it is.

End of Solution

Q.27 In a sample of 100 heart patients, each patient has 80% chance of having a heart attack without medicine *X*. It is clinically known that medicine *X* reduces the probability of having a heart attack by 50%. Medicine *X* is taken by 50 of these 100 patients. The probability that a randomly selected patient, out of the 100 patients, takes medicine *X* and has a heart attack is

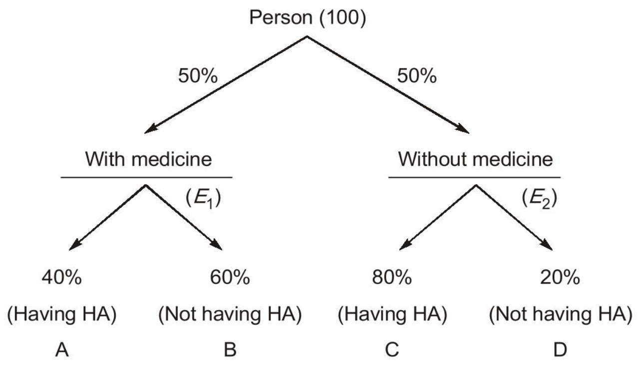
(a) 40%

(b) 60%

(c) 30%

(d) 20%

Ans. (d)



$$P\left(\frac{A}{E_1}\right) = 50\% \times 40\% = \frac{50}{100} \times \frac{40}{100} = \frac{20}{100} = 20\%$$

End of Solution

Q.28 A circular settling tank is to be designed for primary treatment of sewage at a flow rate of 10 million liters/day. Assume a detention period of 2.0 hours and surface loading rate of 40000 liters/ m²/ day. The height (in meters) of the water column in the tank is ________ (rounded off to 2 decimal places).

Ans. (3.33)(3.25 - 3.40)

Discharge, $Q = 10$ MLD

Discharge, $t_d = 2$ hr

Overflow rate, $V_0 = 40000$ litres/m²/day

Now, volume of tank, $V = Q \times t_d$

$$= 10 \times 10^6 \times \left(\frac{2}{24}\right) \times 10^{-3}$$

$$= 833.33 \text{ m}^3$$

Also, surface area of tank,

$$SA = \frac{Q}{V_0} = \frac{10 \times 10^6}{40000} = 250 \text{ m}^2\text{/day}$$

So, height of the tank $\frac{V}{SA} = \frac{833.33}{250} = 3.33$

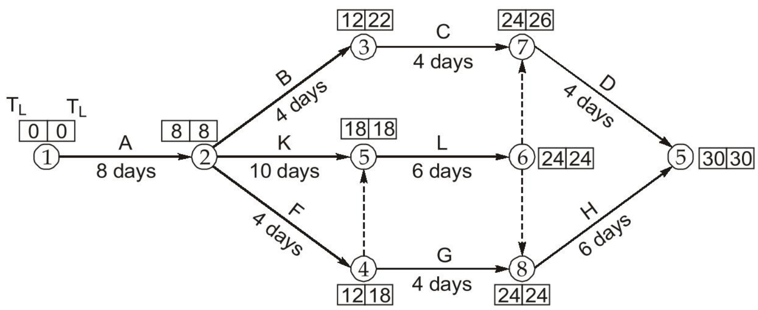
End of Solution

Q.29 The table shows the activities and their durations and dependencies in a project.

Activity	Duration (Days)	Depends on
A	8	-
B	4	A
C	4	B
D	4	C, L
F	4	A
G	4	F
H	6	G, L
K	10	A
L	6	F, K

The total duration (in days) of the project is ________ (in integer).

Ans. (30)(30 - 30)



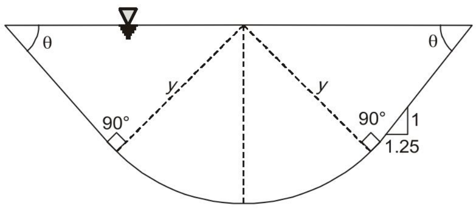
Critical path is along A – B – L – H and project duration is 30 days.

End of Solution

Q.30 A round-bottom triangular lined canal is to be laid at a slope of 1 in 1500, to carry a discharge of 25 m^3/s. The side slopes of the canal cross-section are to be kept at 1.25H : 1V. If Manning's roughness coefficient is 0.013, the flow depth (in meters) will be in the range of

(a) 1.94 to 1.97
(b) 2.39 to 2.42
(c) 2.24 to 2.27
(d) 2.61 to 2.64

Ans. (b)



From the figure, $\tan\theta = \dfrac{1}{1.25}$

$$\theta = 38.66° = 38.66° \times \frac{\pi}{180°} = 0.675 \text{ radians}$$

Also, $\cot\theta = 1.25$

Cross sectional area, $A = y^2 (\theta + \cot\theta)$

$= y^2 [0.675 + 1.25] = 1.925\, y^2$

Perimeter, $P = 2y (\theta + \cot\theta)$

Now, Hydraulic radius, $R = \frac{A}{P} = \frac{y^2(\theta + \cot\theta)}{2y(\theta + \cot\theta)} = \frac{y}{2}$

Now, Discharge, $Q = A \times \frac{1}{n} R^{2/3} S^{1/2}$

$$\Rightarrow \quad 25 = \left(1.925y^2\right) \times \frac{1}{0.013} \times \left(\frac{y}{2}\right)^{2/3} \times \left(\frac{1}{1500}\right)^{1/2}$$

$$\Rightarrow \quad y = 2.404 \text{ m}$$

End of Solution

Q.31 A vertical summit curve on a freight corridor is formed at the intersection of two gradients, +3.0% and -5.0%.

Assume the following:

Only large-sized trucks are allowed on this corridor

Design speed =80kmph

Eye height of truck drivers above the road surface =2.30" " m

Height of object above the road surface for which trucks need to stop =0.35" " m

Total reaction time of the truck drivers =2.0" " s

Coefficient of longitudinal friction of the road =0.36

Stopping sight distance gets compensated on the gradient

The design length of the summit curve (in meters) to accommodate the stopping sight distance is _______ (rounded off to 2 decimal places).

Ans. **(117.93)(117 - 120)**

$n_1 = +3\%$

$n_2 = -5\%$

$v = 80$ km/h

$h_1 = 2.30$ m

$h_2 = 0.35$ m

$t_r = 2$ sec.

$f = 0.36$

Deflection angle, $N = |n_1 - n_2| = 8\%$

Now stopping sight distance, S is given as

$$S = 0.278 V t_r + \frac{v^2}{254 f}$$

$$= 0.278 \times 80 \times 2 + \frac{80^2}{254 \times 0.36} = 114.47 \text{ m}$$

Now assume, length of summit curve (L_s) is greater than stopping sight distance.

$$L_s = \frac{NS^2}{2\left[\sqrt{h_1} + \sqrt{h_2}\right]^2} = \frac{0.08 \times (114.47)^2}{2\left[\sqrt{2.3} + \sqrt{0.35}\right]^2}$$

$$= 117.93 \text{ m} > 114.47$$

End of Solution

Q.32 A rectangular channel is 4.0 m wide and carries a discharge of 2.0 m^3/s with a depth of 0.4 m. The channel transitions to a maximum width contraction at a downstream location, without influencing the upstream flow conditions. The width (in meters) at the maximum contraction is ________ (rounded off to 2 decimal places).

Ans. (3.53)(3.30 - 3.70)

Width of channel, $B = 4$ m

Discharge, $Q = 2\ m^3/s$

Depth of flow, $y = 0.4$ m

Now,
$$E_1 = y_1 + \frac{V^2}{2y} = y_1 + \frac{Q^2}{2gA^2}$$

$$= 0.4 + \frac{(2)^2}{2 \times 9.81 \times (4 \times 0.4)^2} = 0.4796 \text{ m}$$

At maximum contraction

$$\Rightarrow \quad E_1 = E_{min} = 1.5 y_c$$

where y_c is depth at section of critical maximum contraction

$$0.4796 = 1.5\ y_c$$

$$y_c = 0.3197 \text{ m}$$

Now,
$$\left(\frac{q^2}{g}\right)^{1/3} = 0.3197$$

$$\Rightarrow \quad \left(\frac{q^2}{9.81}\right)^{1/3} = 0.3197$$

$$\Rightarrow \quad q = 0.566 \ m^3/s/m$$

Now,
$$\frac{Q}{B_{min}} = 0.566$$

where, B_{min} is width at maximum contraction section.

$$\Rightarrow \quad B_{min} = \frac{2}{0.566} = 3.533 \text{ m}$$

Alternatively,

$$B_{min} = \sqrt{\frac{27Q^2}{8gE_1^3}}$$

Where, $E_1 = 0.4796$ m

So, $B_{min} = \sqrt{\frac{27 \times 2^2}{8 \times 9.81 \times 0.4796^3}} = 3.53$ m

End of Solution

Q.33 A horizontal curve of radius 1080 m (with transition curves on either side) in a Broad Gauge railway track is designed and constructed for an equilibrium speed of 70kmph. However, a few years after construction, the Railway Authorities decided to run express trains on this track. The maximum allowable cant deficiency is 10 cm.

The maximum restricted speed (in kmph) of the express trains running on this track is __________ (rounded off to the nearest integer).

Ans. (113)(113 - 116)

$$R = 1080 \text{ m}$$
$$V_{avg} = 70 \text{ km/h}$$
$$C_D = 10 \text{ cm}$$
$$G = 1.75 \text{ m}$$

Now, $e_{theoretical} = e_{act.} + CD$

$$e_{theoretical} = \frac{GV^2}{127R} + CD$$

$$\frac{GV_{max}^2}{127R} = 0.1625$$

$$V_{max.} = 112.855 \text{ km/h}$$
$$V_{max.} = 113 \text{ km/h}$$

End of Solution

Q.34 A homogeneous, prismatic, linearly elastic steel bar fixed at both the ends has a slenderness ratio (l/r) of 105, where l is the bar length and r is the radius of gyration. The coefficient of thermal expansion of steel is 12×10^{-6}/° C. Consider the effective length of the steel bar as 0.5l and neglect the self-weight of the bar.

The differential increase in temperature (rounded off to the nearest integer) at which the bar buckles is

(a) 85 °C
(b) 250 °C
(c) 400 °C
(d) 298 °C

Ans. **(d)**

$$\frac{Pe}{A} = \alpha \Delta TE$$

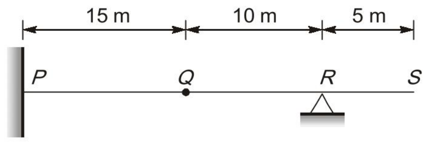
$$\frac{\pi^2 E}{\lambda^2} = \alpha \Delta TE$$

$$\Rightarrow \qquad \Delta T = \frac{\pi^2}{\alpha \cdot \lambda^2} = \frac{\pi^2}{\alpha \left[\frac{0.5L}{R}\right]^2} \qquad \left[\because \lambda = \frac{L}{R}\right]$$

$$= \frac{\pi^2}{12 \times 10^{-6} \times [0.5 \times 105]^2} = 298°C$$

End of Solution

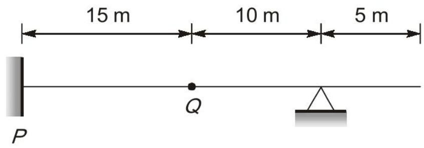
Q.35 The horizontal beam *PQRS* shown in the figure has a fixed support at point *P*, an internal hinge at point *Q*, and a pin support at point *R*. A concentrated vertically downward load (*V*) of 10 kN can act at any point over the entire length of the beam.



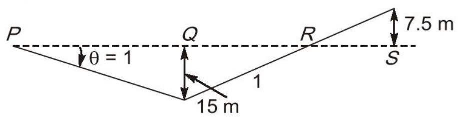
(Figure NOT to scale)

The maximum magnitude of the moment reaction (in kN.m) that can act at the support *P* due to *V* is ________ (in integer).

Ans. **(150)(150 - 150)**



ILD for moment at P,



$\therefore$ Maximum moment at P will be when load is at Q,

$$\Rightarrow \qquad (BM)_{max} = 10 \text{ kN} \times 15 \text{ m} = 150 \text{ kN-m}$$

End of Solution

Q.36 A drained triaxial test was conducted on a saturated sand specimen using a stress-path triaxial testing system. The specimen failed when the axial stress reached a value of 100kN/m^2 from an initial confining pressure of 300kN/m^2.

The angle of shearing plane (in degrees) with respect to horizontal is ________ (rounded off to the nearest integer).

Ans. **(49)(49 - 50)**

Given: σ_d = 100 kN/m^2, σ_3 = 300 kN/m^2

Now, $\sigma_1 = \sigma_3 \tan^2\alpha + 2c^o \tan\alpha$

$\Rightarrow$ $(\sigma_d + \sigma_3) = \sigma_3 \times \tan^2\alpha$ $\left[\therefore \alpha = 45° + \frac{\phi}{2}\right]$

$\Rightarrow$ $(100 + 300) = 300 \tan^2\alpha$

$\Rightarrow$ $400 = 300 \tan^2\alpha$

$$\tan^2\alpha = \frac{4}{3},$$

$$\tan\alpha = 1.1547 = \tan^{-1}(1.1547) = 49.10° \simeq 49°$$

NOTE: Gate has given its answer as 30.

End of Solution

Q.37 A 500 m long water distribution pipeline *P* with diameter 1.0 m, is used to convey 0.1m^3/*s* of flow. A new pipeline *Q*, with the same length and flow rate, is to replace *P*. The friction factors for *P* and *Q* are 0.04 and 0.01, respectively. The diameter of the pipeline *Q* (in meters) is (rounded off to 2 decimal places).

Ans. **(0.75)(0.70 - 0.80)**

Here, $h_{fP} = h_{fQ}$

$$\frac{8q^2}{\pi^2 g} \times \frac{0.04 \times L}{(1)^5} = \frac{8q^2}{\pi^2 g} \times \frac{0.01 \times L}{D^5}$$

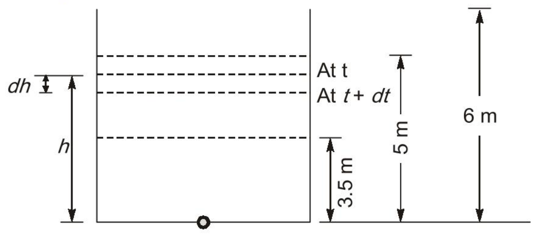
where *q* is discharge and *L* is length of pipeline.

$$D = \left(\frac{1}{4}\right)^{1/5} = 0.75 \text{ m}$$

End of Solution

Q.38 A 2 m × 1.5 m tank of 6 m height is provided with a 100 mm diameter orifice at the center of its base. The orifice is plugged and the tank is filled up to 5 m height. Consider the average value of discharge coefficient as 0.6 and acceleration due to gravity (*g*) as 10 m/s^2. After unplugging the orifice, the time (in seconds) taken for the water level to drop from 5 m to 3.5 m under free discharge condition is ___________ (rounded off to 2 decimal places).

Ans. **(103.98)(102 - 106)**



Coefficient of discharge, C_d = 0.6

Acceleration due to gravity, g = 10 m/s^2

$$\text{Area, } A = (2 \times 1.5)\ \text{m}^2 = 3\ \text{m}^2$$

Let, in dt time, the water level decreases by 'dh'.

$$-Adh = C_d \times a \times \sqrt{2gh} \cdot dt$$

$$\frac{-A}{aC_d\sqrt{2g}} \cdot \frac{dh}{\sqrt{h}} = \text{dt}$$

Integrating it,

$$\frac{-A}{aC_d\sqrt{2g}} \int_{H_1}^{H_2} \frac{dh}{\sqrt{h}} = \int_0^T dt$$

$$\frac{A}{aC_d\sqrt{2g}} \int_{H_2}^{H_1} \frac{dh}{\sqrt{h}} = T$$

$$\frac{A}{C_d a\sqrt{2g}} \times \left[2\sqrt{H}\right]_{H_2}^{H_1} = T$$

$$T = \frac{2A}{C_d a\sqrt{2g}}(\sqrt{H_1} - \sqrt{H_2})$$

$$= \frac{2 \times (2 \times 1.5)}{0.6 \times \frac{\pi}{4} \times 0.1^2 \times \sqrt{2(10)}} \times \left(\sqrt{5} - \sqrt{3.5}\right)$$

$$= 103.98 \text{ sec}$$

End of Solution

Q.39 A critical activity in a project is estimated to take 15 days to complete at a cost of Rs. 30,000. The activity can be expedited to complete in 12 days by spending a total amount of Rs. 54,000. Consider the statements *P* and *Q*.

P : It is economically advisable to complete the activity early by crashing, if the indirect cost of the project is Rs. 8,500 per day.

Q : It is economically advisable to complete the activity early by crashing, if the indirect cost of the project is Rs. 10.000 per day.

Which one of the following options is CORRECT?

(a) Both *P* and *Q* are TRUE

(b) *P* is TRUE and *Q* is FALSE

(c) *P* is FALSE and *Q* is TRUE

(d) Both *P* and *Q* are FALSE

Ans. **(a)**

End of Solution

Q.40 In the context of pavement material characterization, the CORRECT statement(s) is/are

(a) The toughness and hardness of road aggregates are determined by Los Angeles abrasion test and aggregate impact test, respectively.

(b) The load penetration curve of CBR test may need origin correction due to the non-vertical penetrating plunger of the loading machine.

(c) In compacted bituminous mix, Voids in the Mineral Aggregate (VMA) is equal to the sum of total volume of air voids (V_v) and total volume of bitumen (V_b).

(d) Grading of normal (unmodified) bitumen binders is done based on viscosity test results.

Ans. (b, c, d)

End of Solution

Q.41 Consider the statements *P*, *Q*, and *R*.

P : Compacted fine-grained soils with flocculated structure have isotropic permeability.

Q : Phreatic surface/line is the line along which the pore water pressure is always maximum.

R : The piping phenomenon occurring below the dam foundation is typically known as blowout piping.

Which of the following option(s) is/are CORRECT?

(a) *P* is FALSE and *Q* is TRUE

(b) Both *Q* and *R* are FALSE

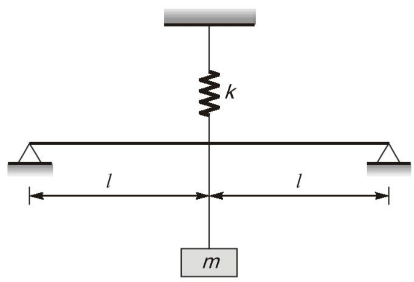
(c) Both *P* and *R* are TRUE

(d) *P* is TRUE and *R* is FALSE

Ans. (b, d)

End of Solution

Q.42 A linearly elastic beam of length $2l$ with flexural rigidity EI has negligible mass. A massless spring with a spring constant k and a rigid block of mass m are attached to the beam as shown in the figure.



The natural frequency of this system is

(a) $\sqrt{\dfrac{6EIk}{(kl^3+6EI)m}}$ (b) $\sqrt{\dfrac{48EIk}{(kl^3+48EI)m}}$

(c) $\sqrt{\dfrac{kl^3+48EI}{ml^3}}$ (d) $\sqrt{\dfrac{kl^3+6EI}{ml^3}}$

Ans. **(d)**

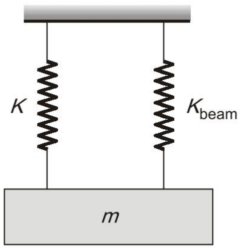
Here, weight (mg) is shared by the beam and top spring and the deflection in beam and top spring will be same.

∴ Beam and top spring will be in parallel.

Beam stiffness:

$$K_{beam} = \frac{48EI}{(2l)^3} = \frac{6EI}{l^3}$$

Equivalent stiffness:



$$K_{eq} = K + K_{beam}$$

$$= K + \frac{6EI}{l^3}$$

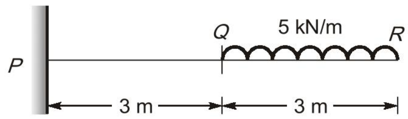
∴ Natural frequency,

$$w_n = \sqrt{\frac{K_{eq}}{m}} = \sqrt{\frac{K + \frac{6EI}{l^3}}{m}}$$

$$= \sqrt{\frac{Kl^3 + 6EI}{ml^3}} \text{ rad/s}$$

End of Solution

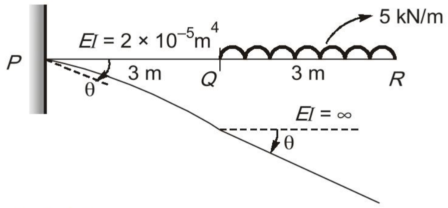
Q.43 For the 6 m long horizontal cantilever beam *PQR* shown in the figure, *Q* is the midpoint. Segment *PQ* of the beam has flexural rigidity $EI = 2 \times 10^5$ kN.m^2 whereas the segment *QR* has infinite flexural rigidity. Segment *QR* is subjected to uniformly distributed, vertically downward load of 5kN/m.



(Figure NOT to scale)

The magnitude of the vertical displacement (in mm) at point *Q* is ____________ (rounded off to 3 decimal places).

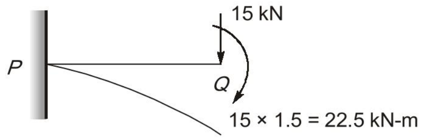
Ans. (1.181)(1.176 - 1.186)



∴ QR will remain straight

[Transferring UDL to point load and moment at *Q*]

From principle of superposition,



Deflection at *Q*, $\delta_Q = \frac{PL^3}{3EI} + \frac{ML^2}{2EI} = \frac{15 \times 3^3}{3 \times 2 \times 10^5} + \frac{22.5 \times 3^2}{2 \times 2 \times 10^5} = 1.181 \text{ mm}$

End of Solution

Q.44 Consider the statements *P* and *Q* related to the analysis/design of retaining walls.

P : When a rough retaining wall moves toward the backfill, the wall friction force/resistance mobilizes in upward direction along the wall.

Q : Most of the earth pressure theories calculate the earth pressure due to surcharge by neglecting the actual distribution of stresses due to surcharge.

Which one of the following options is CORRECT?

(a) *P* is FALSE and *Q* is TRUE

(b) Both *P* and *Q* are TRUE

(c) *P* is TRUE and *Q* is FALSE

(d) Both *P* and *Q* are FALSE

Ans. (b)

End of Solution

Q.45 Consider two matrices $A = \begin{bmatrix} 2 & 1 & 4 \\ 1 & 0 & 3 \end{bmatrix}$ and $B = \begin{bmatrix} -1 & 0 \\ 2 & 3 \\ 1 & 4 \end{bmatrix}$

The determinant of the matrix ***AB*** is ___________ (in integer).

Ans. (10)(10 - 10)

$$A = \begin{bmatrix} 2 & 1 & 4 \\ 1 & 0 & 3 \end{bmatrix}_{2\times3}, \quad B = \begin{bmatrix} -1 & 0 \\ 2 & 3 \\ 2 & 4 \end{bmatrix}_{3\times2}$$

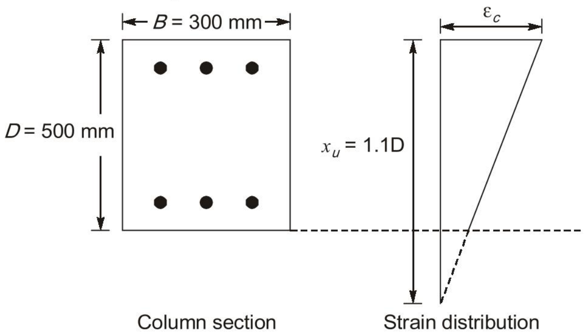
Then, $AB = \begin{bmatrix} 4 & 19 \\ 2 & 12 \end{bmatrix}$

So, $|AB| = (4)(12) - (2)(19)$

$= 48 - 38 = 10$

End of Solution

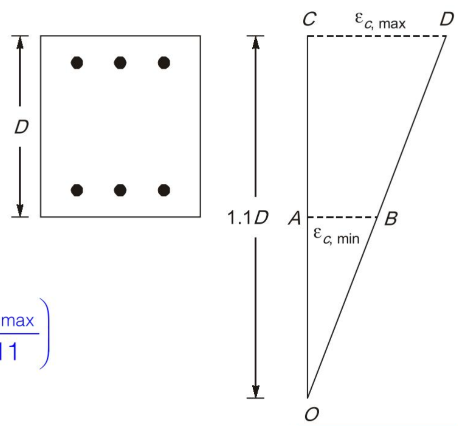
Q.46 A concrete column section of size 300 mm × 500 mm as shown in the figure is subjected to both axial compression and bending along the major axis. The depth of the neutral axis (x_u) is 1.1 times the depth of the column, as shown.



(Figure NOT to scale)

The maximum compressive strain (ε_c) at highly compressive extreme fiber in concrete, where there is no tension in the section, is ________ × 10^{-3} (rounded off to 2 decimal places).

Ans. **(3.27)(3.20 - 3.35)**



$\varepsilon_{c,\,max} = 0.0035 - 0.75\,\varepsilon_{c,\,min}$

From similar Δ, ΔOAB and ΔOCD,

$$\frac{\varepsilon_{c,min}}{0.1D} = \frac{\varepsilon_{c,max}}{1.1D}$$

$$\Rightarrow \quad \varepsilon_{c,\,min} = \frac{\varepsilon_{c,max}}{11}$$

$$\Rightarrow \quad \varepsilon_{c,\,max} = 0.0035 - 0.75\left(\frac{\varepsilon_{c,max}}{11}\right)$$

$$\Rightarrow \quad \varepsilon_{c,\,max} = 3.27 \times 10^{-3}$$

End of Solution

Q.47 Three vectors $\vec{p}, \vec{q}$, and $\vec{r}$ are given as

$$\vec{p} = \hat{i} + \hat{j} + \hat{k}$$

$$\vec{q} = \hat{i} + 2\hat{j} + 3\hat{k}$$

$$\vec{r} = 2\hat{i} + 3\hat{j} + 4\hat{k}$$

Which of the following is/are CORRECT?

(a) $\vec{p} \times (\vec{q} \times \vec{r}) = (\vec{p} \times \vec{q}) \times \vec{r}$

(b) $\vec{r} \cdot (\vec{p} \times \vec{q}) = (\vec{q} \times \vec{p}) \cdot \vec{r}$

(c) $\vec{p} \times (\vec{q} \times \vec{r}) + \vec{q} \times (\vec{r} \times \vec{p}) + \vec{r} \times (\vec{p} \times \vec{q}) = \vec{0}$

(d) $\vec{p} \times (\vec{q} \times \vec{r}) = (\vec{p} \cdot \vec{r})\vec{q} - (\vec{p} \cdot \vec{q})\vec{r}$

Ans. **(c, d)**

End of Solution

Q.48 Differential levelling is carried out from point *P*(BM:+200.000 m) to point *R*. The readings taken are given in the table.

Points	Staff readings (m)		Remarks
	Back Sight	Fore Sight	
P	(–) 2.050		BM: +200.000 m
Q	1.050	0.950	*Q* is a change point
R		(-)1.655	

Reduced Level (in meters) of the point *R* is ________ (rounded off to 3 decimal places).

Ans. **(199.705)(199.704 - 199.706)**

$$\Sigma BS - \Sigma FS = \text{Last RL} - \text{First RL}$$

$$(1.05 - 2.05) - (0.95 - 1.655) = (RL)_R - 200$$

$$RL_R = 199.705 \text{ m}$$

End of Solution

Q.49 A homogeneous earth dam has a maximum water head difference of 15 m between the upstream and downstream sides. A flownet was drawn with the number of potential drops as 10 and the average length of the element as 3 m. Specific gravity of the soil is 2.65. For a factor of safety of 2.0 against piping failure, void ratio of the soil is (rounded off to 2 decimal places).

Ans. **(0.65)(0.63 - 0.67)**

Total head loss, $h_L = 15$ m

Number of equipotential drops, $N_d = 10$

Average length, L = 3 m

Specific gravity, $G = 2.65$

Factor of safety, FOS = 2

Hydraulic gradient, $i = \frac{h_L}{L} = \frac{\frac{15}{10}}{3} = 0.5$

Now, $\text{FOS} = \frac{i_C}{i}$, where i_C is critical hydraulic gradient

$\Rightarrow$ $2 = \frac{i_C}{0.5}$

$\Rightarrow$ $i_C = 1$

$$\Rightarrow \quad i_C = \frac{G-1}{1+e}$$

$$\Rightarrow \quad 1 = \frac{2.65-1}{1+e}$$

$$\Rightarrow \quad e = 0.65$$

End of Solution

Q.50 The consolidated data of a spot speed study for a certain stretch of a highway is given in the table.

Speed range (kmph)	Number of observations
0-10	7
10-20	31
20-30	76
30-40	129
40-50	104
50-60	78
60-70	29
70-80	24
80-90	13
90-100	9

The “upper speed limit” (in kmph) for the traffic sign is

(a) 50 (b) 55

(c) 70 (d) 65

Ans. **(b)**

Speed range (kmph)	Number of observations	Cumulative number of Vehicles	Cumulative %age Passed
0 - 10	7	7	1.4%
10 - 20	31	38	7.6%
20 - 30	76	114	22.8%
30 - 40	129	243	48.6%
40 - 50	104	347	69.4%
50 - 60	78	425	85%
60 - 70	29	454	90.8%
70 - 80	24	478	95.6%
80 - 90	13	491	98.2%
90 - 100	9	500	100%
	$\Sigma N = 500$		

Upper speed limit is corresponding to 85% of cumulative vehicles passed.

$$\therefore \quad \text{Upper speed limit} = \frac{50+60}{2} = 55 \text{ kmph}$$

End of Solution

Q.51 The expression for computing the effective interest rate (i_{eff}) using continuous compounding for a nominal interest rate of 5% is

$$i_{eff} = \lim_{m\to\infty}\left(1+\frac{0.05}{m}\right)^m - 1$$

The effective interest rate (in percentage) is ________ (rounded off to 2 decimal places).

Ans. (5.13)(5.11 - 5.15)

$$i_{\text{eff}} = \lim_{m\to\infty}\left(1+\frac{0.05}{m}\right)^m - 1$$

$$y = e^{\lim\limits_{x\to\infty} mx\left[1+\frac{0.05}{m}-1\right]^m} ;\ 1^\infty \text{ form}$$

$$y = e^{\lim\limits_{x\to\infty} mx\left[1+\frac{0.05}{m}-1\right]}$$

$$y = e^{\lim\limits_{x\to\infty} mx\left[1+\frac{0.005}{m}-1\right]}$$

$$y = e^{\lim\limits_{x\to\infty} 0.05}$$

Finally,

$$y = e^{0.05} - 1$$

$$y = 0.05127 \simeq 5.13\%$$

End of Solution

Q.52 An organic waste is represented as $C_{240}\ O_{200}\ H_{180}N_5S$.
(Atomic weights: *S*-32, *H*-1, *C*-12, *O*-16, *N*-14).
Assume complete conversion of *S* to SO_2 while burning.
SO_2 generated (in grams) per kg of this waste is _______ (rounded off to 1 decimal place).

Ans. (10.1)(9.9 - 10.2)

Molecular weight of $C_{240}O_{200}H_{180}N_5$ S is given as :

$12 \times 240 + 16 \times 200 + 1 \times 180 + 14 \times 5 + 32 = 6362$ gm

$$SO_2 \text{ generated} \Rightarrow \frac{64}{6362}\times 1000 \text{ gm/kg}$$

$$= 10.059 \text{ gm/kg} \simeq 10.1 \text{ gm/kg}$$

End of Solution

Q.53 The in-situ percentage of voids of a sand deposit is 50%. The maximum and minimum densities of sand determined from the laboratory tests are 1.8 g/cm^3 and 1.3 g/cm^3, respectively, Assume the specific gravity of sand as 2.7.

The relative density index of the in-situ sand is ________ (rounded off to 2 decimal places).

Ans. **(0.13)(0.12 - 0.14)**

Minimum dry density, γ_{dmin} = 1.3 g/cm^3

Maximum dry density, γ_{dmax} = 1.8 g/cm^3

Specific gravity of soil solids, G = 2.7

Porosity of soil, n = 0.5

$$\text{Void ratio, } e = \frac{n}{1-n} = \frac{0.5}{0.5} = 1$$

$$\text{In situ dry density, } \gamma_d = \frac{G\rho_w}{1+e} = \frac{2.7\times 1}{1+1} = 1.35 \text{ g/cm}^3$$

$$\text{Now, Relative density, RD} = \frac{\frac{1}{\gamma_{d\min}} - \frac{1}{\gamma_d}}{\frac{1}{\gamma_{d\min}} - \frac{1}{\gamma_{d\max}}} = \frac{\frac{1}{1.3} - \frac{1}{1.35}}{\frac{1}{1.3} - \frac{1}{1.8}} = 0.13$$

End of Solution

Q.54 A storm with a recorded precipitation of 11.0 cm, as shown in the table, produced a direct run-off of 6.0 cm.

Time from start (hours)	1	2	3	4	5	6	7	8
Recorded cumulative precipitation (cm)	0.5	1.5	3.1	5.5	7.3	8.9	10.2	11.0

The ϕ-index of this storm is ________ cm/hr (rounded off to 2 decimal places).

Ans. **(0.64)(0.64 - 0.65)**

Time from start (hr)	1	2	3	4	5	6	7	8
Accumulated precipitation (cm)	0.5	1.5	3.1	5.5	7.3	8.9	10.2	11.0
Incremental precipitation (cm)	0.5	1	1.6	2.4	1.8	1.6	1.3	0.8
Rainfall intensity (cm/hr)	0.5	1	1.6	2.4	1.6	1.6	1.3	0.8

Total infiltration, I = Total rainfall – Total runoff

= 11 – 6 = 5 cm

∴ W–index = $\frac{5}{8} = 0.625$ cm/hr

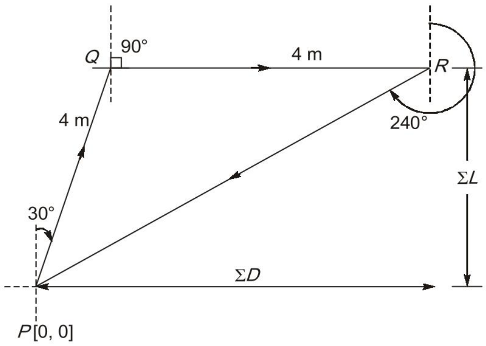
As the 1 hour rainfall is less than W-index.

So, ϕ-index = $\frac{5 - 0.5 \times 1}{(8-1)} = 0.6428$ cm/hr

End of Solution

Q.55 A child walks on a level surface from point P to point Q at a bearing of 30°, from point Q to point R at a bearing of 90° and then directly returns to the starting point P at a bearing of 240°. The straight-line paths PQ and QR are 4 m each. Assuming that all bearings are measured from the magnetic north in degrees, the straight-line path length RP (in meters) is (rounded off to the nearest integer).

Ans. **(7)(6 - 8)**



Horizontal distance of traverse from P to $R = \Sigma D$

$= PQ \sin 30° + QR \sin 90°$

$= 4 \times \frac{1}{2} + 4 \times 1$

$= 6$ m

Vertical distance of traverse from P to R = ΣL

$= PQ \cos 30° + QR \cos 90°$

$= 4 \times \frac{\sqrt{3}}{2} = 2\sqrt{3}$

⇒ $PR = \sqrt{(\Sigma L)^2 + (\Sigma D)^2}$

$= \sqrt{(6)^2 + (2\sqrt{3})^2} = \sqrt{48} = 6.928 \text{ m} \simeq 7 \text{ m}$

End of Solution

■■■■