GATE WALLAH

CIVIL ENGINEERING

EXAM HELD ON

4th FEBRUARY 2024

EVENING SESSION

DETAILED SOLUTION BY TEAM

Civil Engineering

[MCQ]

Q.1. 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.

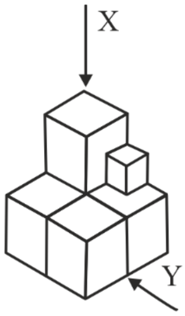


Figure A

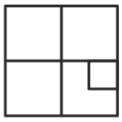
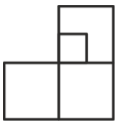
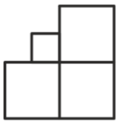
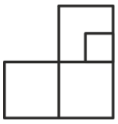


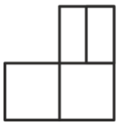
Figure B

If viewed from direction Y, the planar image of the assembly (Figure A) will appear as

(a) 

(b) 

(c) 

(d) 

Sol. **(c)**

[MCQ]

Q.2. In the sum of the first 20 consecutive positive odd numbers is divide by 20^2, the result is

(a) 1/2 (b) 2

(c) 20 (d) 1

Sol. **(d)**

$1 + 3 = 4 = 2^2$

$1 + 3 + 5 = 9 = 3^2$

(Which means sum of first odd integer = n^2)

$$\frac{1+3+5+\ldots}{20^2} = \frac{20^2}{20^2} = 1$$

[MCQ]

Q.3. 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) out (ii) down (iii) in (iv) for

(b) (i) out (ii) down (iii) by (iv) for

(c) (i) down (ii) out (iii) for (iv) in

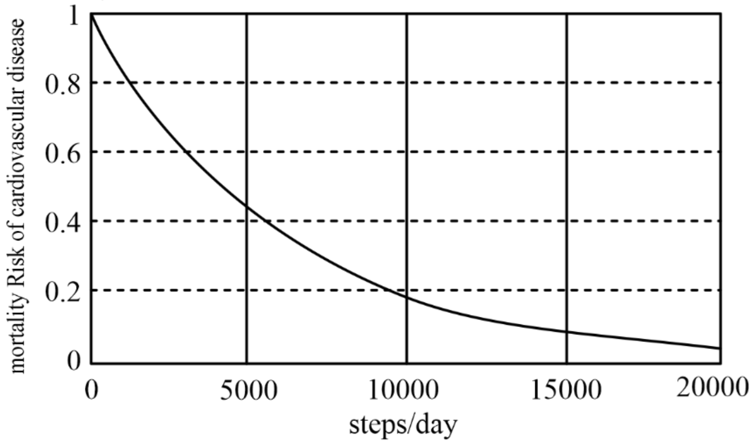
(d) (i) down (ii) out (iii) by (iv) in

Sol. **(b)**

Yoko Roi stands out as an author for standing down as an honorary fellow, after she stood by her writings that stand for the freedom of speech.

[MCQ]

Q.4. 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) 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.

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

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

(d) 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.

Sol. **(c)**

- The risk reduction 0 to 5000 = 1 – 0.4 = 0.6 (60%)

  The risk reduction 15000 to 200000 = 10%.

  Thus option (a) is wrong.

- For any 5000 increment in steps the largest risk reduction is between 0 to 5000. Thus option (b) is wrong.

- Option (c) correct.

- The risk reduction 0 to 10000 is 80% and 10000 to 20000 is 20%, thus option (d) wrong.

Civil Engineering

[NAT]

Q.5. 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) 150 (b) 200

(c) 175 (d) 250

Sol. **(b)**

$$\frac{G_8}{B_8} = \frac{B_9}{G_9}$$

$B_8 + G_8 = 450$

$B_9 + G_9 = 360$

$G_8 = G_9$

$$\Rightarrow \frac{G_8}{B_8} + 1 = \frac{B_9}{G_9} + 1$$

$$\Rightarrow \frac{G_8 + B_8}{B_8} = \frac{G_9 + B_9}{G_9}$$

$$\boxed{\Rightarrow B_8 = \frac{5}{4}.G_9}$$

$\Rightarrow B_8 + G_8 = 450.$

$$\Rightarrow \left(\frac{5}{4} + 1\right) G_8 = 450$$

$$\Rightarrow \frac{9}{4} G_8 = 450$$

$\Rightarrow G_8 = G_9 = 200$

[MCQ]

Q.6. 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) dodge

(c) dither (d) bicker

Sol. **(d)**

Drizzle $\rightarrow$ rain $\rightarrow$ downpour

Bicker $\rightarrow$ quarrel $\rightarrow$ fued

(1) Dodge (2) bicker

(3) bog $\rightarrow$ wet regular load (4) dither $\rightarrow$ confused to total any decision

Civil Engineering

[MCQ]

Q.7. Statements:

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

Inferences:

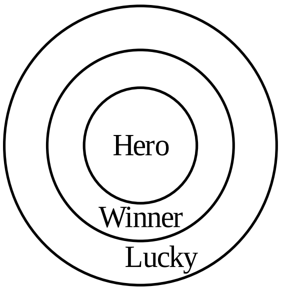
I. All lucky people are heroes.
II. Some lucky people are heroes.
III. Some winners are heroes.

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

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

Sol. **(b)**

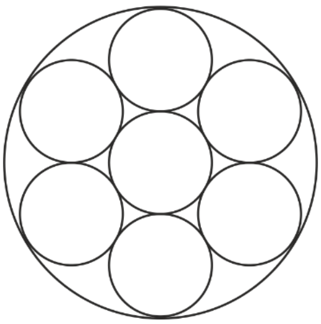
Venn-diagram:



Thus, only inferences II and III can be logically deuced from statement 1 and statement 2

[MCQ]

Q.8. Seven identical cylindrical chalk-sticks are fitted tightly in a cylindrical container The figure below shows the arrangement of tire chalk-sticks inside the cylinder.

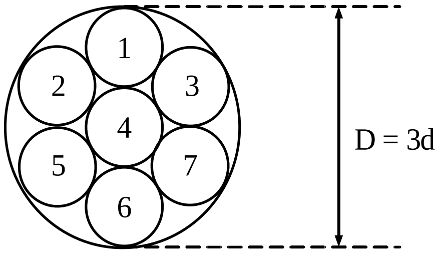


The length of the container is equal to the length of the chalk-sticks. The ratio of the occupied space to the empty space of the container is

(a) 5/2 (b) 3
(c) 9/2 (d) 7/2

Sol. **(d)**

Given,



Where, diameter of cylinder container = D

Diameter of cylindrical chalk = d

Length of container = Length of chalk = L

→ Volume of occupied space = $7 \times \frac{\pi}{4} \times d^2 \times L$

→ Volume of empty space = $\frac{\pi}{4} \times D^2 L - 7 \times \frac{\pi}{4} \times d^2 L$

$$= \frac{\pi}{4} L\left[(3d)^2 - 7d^2\right]$$

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

∴ (Ratio of occupied space to empty space of container) = $\dfrac{7 \times \frac{\pi}{4} \times d^2 L}{2 \times \frac{\pi}{4} \times d^2 L} = \left(\frac{7}{2}\right)$

[MCQ]

Q.9. 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) $\sqrt{5}$ (b) 5

(c) 2 (d) $\sqrt{2}$

Sol. **(a)**

P·q

$$\Rightarrow \frac{pq - \frac{p}{q}}{pq} \times 100 = 80.$$

$$\Rightarrow \frac{q\left(1 - \frac{1}{q^2}\right)}{q} = \frac{8}{10}$$

$$\Rightarrow 1 - \frac{1}{q^2} = \frac{8}{10}$$

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

$$\Rightarrow q = \sqrt{5}$$

[MCQ]

Q.10. 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

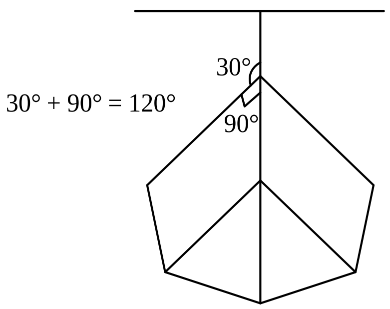
(a) 120° (b) 60°

(c) 90° (d) 180°

Sol. **(a)**

Edge of cube aligned to vertical axis

View of edge on the top to same view is 90 + 30 = 120



[MCQ]

Q.1. A partial differential equation

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

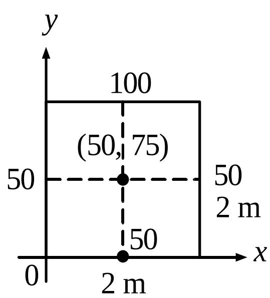
is defined for the two-dimensional field T:T (x,y), inside a planar square domain of size 2 m × 2 m. Three boundary edges of the square domain are maintained at value T = 50, whereas the fourth boundary edge is maintained at T = 100.

The value of T at the center of the domain

(a) 87.5 (b) 62.5

(c) 75.0 (d) 50.0

Sol. **(b)**



$$\frac{\partial_T^2}{\partial_x^2}+\frac{\partial_T^2}{\partial_y^2}=0$$

$\therefore$ Temperature at center $=\dfrac{50+75}{2}=62.5$

[MCQ]

Q.2. What is the CORRECT match between the air pollutants and treatment techniques given in the table?

Air pollutants	Treatment technique
P–NO_2	i–Flaring
Q–SO_2	ii–Cyclonic separator
R–CO	iii–Lime scrubbing
S–Particles	iv–NH_3 injection

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

Sol. **(a)**

Air pollutant	Treatment technique
NO_2	NH_3 injection
SO_2	Lime scrubbing
CO	Flaring
Particulates	Cyclonic separator

[MCQ]

Q.3. 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) (–) 50 days
(c) (+) Rs. 50
(d) (–) Rs. 50

Sol. **(d)**

Schedule variance (SV) = (BCWP – BCWS)

= (150 – 200)

= – Rs 50

Civil Engineering

[MCQ]

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

(a) Minima point (b) Maxima point

(c) Saddle point (d) Inflection point

Sol. **(a)**

$f(x) = x^3 - 27x + 4$

$f'(x) = 0$

differentiation of f(x) is given by

$\Rightarrow f'(x) = 3x^2 - 27 = 0 \Rightarrow x = \pm 3$

$f''(x) = 6x$

So in given domain we have only one turning point x = 3

Now, at $f''(3) = 6 \times 3 = 18 > 0$

So x = 3 is point of minima.

[NAT]

Q.5. A reinforced concrete pile of 10 m length and 0.7 in 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).

Sol. **(550)**

$$q_{np} = \alpha \bar{c}\, A_s$$

$$\alpha \bar{c}\, A_s = 0.5 \times 50 \times \pi \times 0.7 \times 10 = 549.77 \text{ kN}$$

$q_{np} = 549.77 \simeq 550$ kN

[MCQ]

Q.6. In general, the outer edge is raised above the inner edge in horizontal curves for

(a) Railways and Taxiways only

(b) Highways and Railways only

(c) Highways. Railways, and Taxiways

(d) Highways only

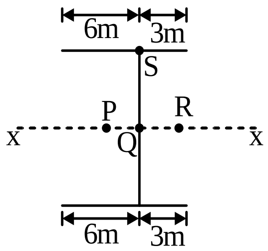
Sol. **(b)**

To counteract the centrifugal force on running wheels, the outer edge of the road or track is raised above the inner edge, through out the length of the horizontal curve. This is termed as super-elevation or cant or banking.

In general, it is provided for highways and railways only.

[MCQ]

Q.7. 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.

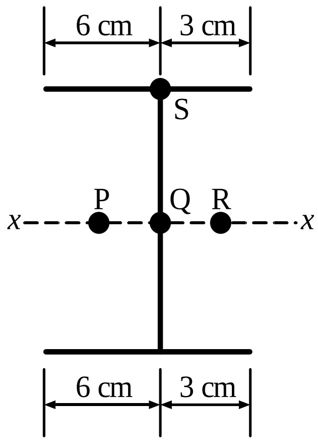


Qualitatively, the shear center of the section lies at

(a) Q (b) P

(c) R (d) S

Sol. **(c)**



→ Shear centre is the point in or outside a section through which the shear force applied produces no torsion or twist of the member.

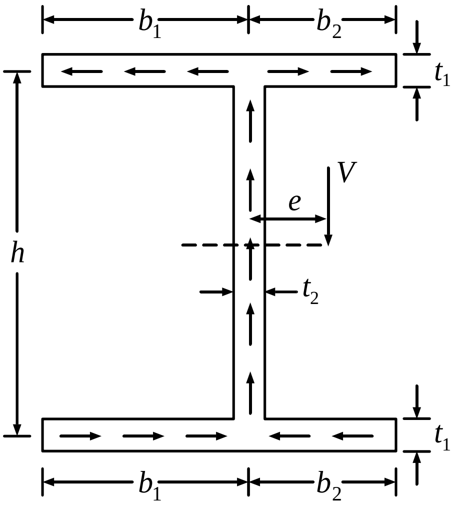
→ For a beam with two axes of symmetry, the shear centre coincides with the centroid.

→ For sections having one axis of symmetry, shear centre does not coincide with the centroid, though it lies on the axis of symmetry.

→ In case of I-section with unequal flange on either side, the shear centre will lie on the smaller flange length side.

Thus, here, shear centre will lie @ R

Note:



$$e = \frac{h^2 t_1}{4I}\left(b_1^2 - b_2^2\right)$$

[MCQ]

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-iii. Q-iv. R-i. S-ii

(c) P-i. Q-iii. R-ii. S-iv

(d) P-ii. Q-iii. R-iv. S-i

Sol. **(a)**

→ The "bubble tube" or "spirit level" or "level vial" is used for levelling work.

→ The "plumb bob" is used while measuring distances on slope and in all instruments that require centring.

→ In levelling instruments, a clamp and fire tangent screw, are also provided to control the movement in the horizontal plane.

→ Stadia cross-wire is provided in tacheometry.

[MCQ]

Q.9. 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 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 nonhomogeneous ODE and Q is an exact ODE.

Sol. **(c)**

P: This Differential Equation is homogeneous because each term is of same degree.
Q: This Differential Equation is not exact because it is not satisfying the condition $\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$

For, $\frac{dy}{dx} = \frac{-y^2}{x^2}$ or $y^2dx + x^2dy = 0$

On comparison, with Mdx + Ndy = 0

We get $M = y^2$

$\because \frac{\partial M}{\partial y} = 2y$

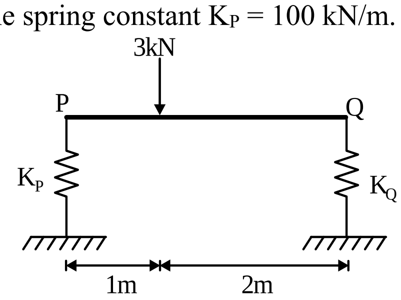
$N = x^2$

$\frac{\partial N}{\partial x} = 2x$

Hence not exact.

[MCQ]

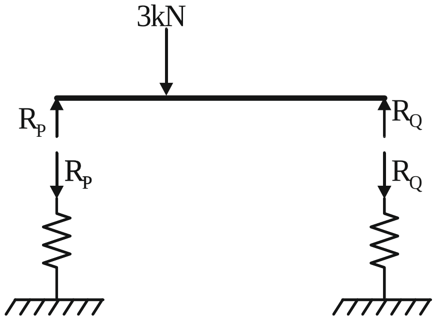
Q.10. A 3 m long, horizontal, rigid, uniform beam PQ has negligible mass. The beam is subjected to a 3 kN concentrated vertically downward force at 1 m from P. as shown in the figure. The beam is resting on vertical linear springs at the ends P and Q. For the spring at the end P. the spring constant K_P = 100 kN/m.



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 is

(a) 50
(b) 200
(c) 150
(d) 100

Sol. **(a)**



$\Delta_P = \Delta_Q$

$$\frac{R_P}{K_P} = \frac{R_Q}{K_Q}$$

$$\Rightarrow \frac{\frac{3\times 2}{3}}{K_P} = \frac{\frac{3\times 1}{3}}{K_Q}$$

$$\Rightarrow \frac{2}{K_P} = \frac{1}{K_Q}$$

$$\Rightarrow K_Q = \frac{K_P}{2} = 50 \text{ kN/m}$$

[MCQ]

Q.11. 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) Working stress method.
(d) Load factor method.

Sol. (c)

WSM → Don't take factor of safety into account.

LSM → We take factor of safety into consideration while designing.

[MCQ]

Q.12. 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) 200 (b) 100
(c) 150 (d) 125

Sol. (c)

Given data

$$\text{Scale (S)} = \frac{1}{13000}$$

Flying height (H) = 3000m

Average terrain elevation (h_1) = 1050m

$$S = \frac{f}{H - h_1}$$

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

f = 150 mm

[MCQ]

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 l_x 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) $(l_x/l_y)^2$
(b) $(l_y/l_x)^2$
(c) l_x/l_y
(d) l_y/l_x

Sol. **(b)**

$M_{ux} = \alpha_x w l_x^2$

$M_{uy} = \alpha_y w l_x^2$

Where

$$\alpha_x = \frac{1}{8}\left[\frac{r^4}{1+r^4}\right]; \alpha_y = \frac{1}{8}\left[\frac{r^2}{1+r^4}\right] \text{and}$$

$$r = \left(\frac{l_y}{l_x}\right)$$

$$\therefore \frac{M_{ux}}{M_{uy}} = \left(\frac{\alpha_x}{\alpha_y}\right) = r^2 = \left(\frac{l_y}{l_x}\right)^2$$

[MCQ]

Q.14. Which one of the following products is NOT obtained in anaerobic decomposition of glucose?

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

Sol. **(b)**

Anaerobic decomposition is an incomplete breakdown of carbohydrates in the absence of oxygen.

The anaerobic decomposition of glucose is called glycolysis or fermentation of glucose

The ultimate end products of glycolysis are methane (CH_4) and Carbon dioxide (CO_2)

$$\underset{\text{(Glucose)}}{C_6H_{12}O_6} \xrightarrow[rk^n]{\text{Anaerobic}} 3CH_4 + 3CO_2$$

(Out of remaining two, option b is the most appropriate answer)

[MCQ]

Q.15. 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 comer = S_{wl}^{c}

Warping stress at interior = S_{t}^{i}

Warping stress at edge = S_{t}^{e}

Warping stress at comer = 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) $S_{wl}^{c} + S_{t}^{c}$

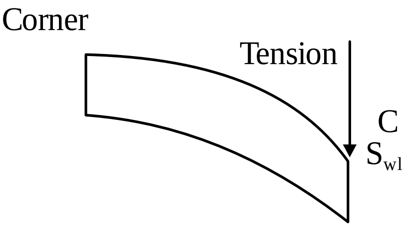
(b) $S_{wl}^{e} + S_{t}^{e} + S_f$

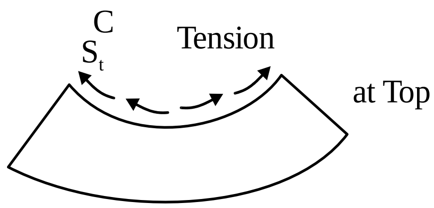
(c) $S_{wl}^{c} + S_{t}^{c} + S_f$

(d) $S_{wl}^{e} + S_{t}^{e} - S_f$

Sol. **(a)**

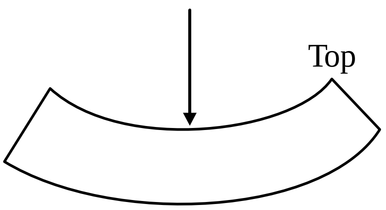
Summer midnight

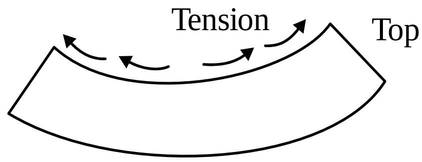




Combination = $S_{wl}^{c} + S_{t}^{c}$ (Since friction stress at corner is 0)

At Edge





In summer frictional stress is compressive

Top : $S_{wl}^{e} + S_{t}^{e} - S_f$

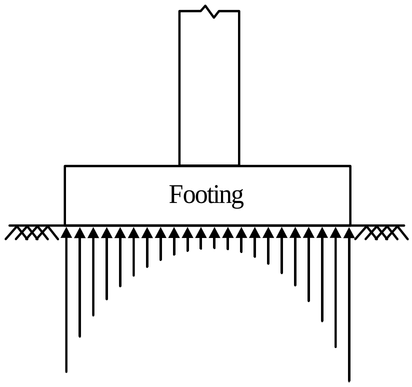
Bottom : $S_{wl}^{e} - S_{t}^{e} - S_f$

Most critical is $S_{wl}^{c} + S_{t}^{c}$ (at corner)

Civil Engineering

[MCQ]

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.

Sol. **(b)**

Since contact pressure are varying with maximum contact pressure at ends.
Rigid footing on cohesive soil

[MCQ]

Q.17. 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

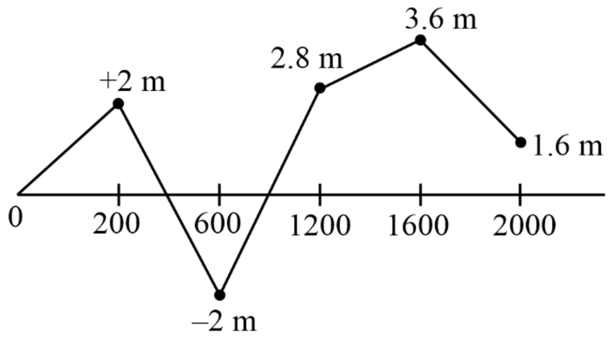
(a) 0.02%
(b) 0.35%
(c) 0.28%
(d) 0.18%

Sol. **(c)**

There is no effect of RL (100 m) on calculation therefore we can start with 0 m

Assuming RL to be 0 m

$$\text{Airport : Effective gradient} = \frac{\text{Highest elevation} - \text{Lowest elevation}}{\text{Total length of runway}}$$



$$= \frac{3.6-(-2)}{2000} \times 100 = 0.28\%$$

[MCQ]

Q.18. 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) P is FALSE and Q is TRUE
(b) Both P and Q are FALSE
(c) P is TRUE and Q is FALSE
(d) Both P and Q are TRUE

Sol. **(d)**

The advantages of pure project organizations are:

- The project manager maintains complete authority over the project and has maximum control over the project.
- The lines of communication are strong and open, and the system is highly flexible and capable of rapid reaction times. Thus, the structure can react quickly to the special and changing project needs.
- The project is the only real concern of the project employees. The pure project structure provides a unity of purpose in terms of effectiveness. It brings together all the administrative, technical and support personnel needed to bring a project from the early stages of development through to operational use.
- The appraisal of employees is based upon the performance of the project.
- The focus of resources is towards the achievement of organization goals rather than the provision of a particular function.

The disadvantages are:

- There could be a duplication of efforts.
- It is very difficult to find a project manager having both general management expertise and diverse functional expertise.

- The administrative duties of a project manager may be demanding and the job could be quite stressful.
- Due to the fear of impediments in career growth, some employees may not prefer to leave their departments.

Advantages of the matrix structure are:

- The structure facilitates quick response to changes, conflicts and project needs.
- There is a flexibility of establishing independent policies and procedures for each project, provided that they do not contradict company policies and procedures.
- There is a possibility of achieving better balance between time, cost and performance than is possible with the other structures such as functional or project forms.
- The project manager has authority to commit company resources provided the schedule does not cause conflicts with other projects.
- The strong base of technical expertise is maintained.

The disadvantages are:

- Successful matrix authority application tends to take years to develop, especially if the company has never used dual authority relationships before.
- Initially, more effort and time is needed to define policies, procedures, responsibilities and authority relationships.
- The balance of power between functional and project authority must be carefully monitored.
- Functional managers may be biased according to their own set of priorities.
- Reaction times in a fast-changing project are not as fast as in the pure project authority structure.

[MCQ]

Q.19. 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° 30'20" (b) 30° 30' 00"
(c) 30° 29'40" (d) 30° 31'20"

Sol. **(a)**

$$\text{(Most probable value)} = \left[\frac{30°30'00' + 30°29'40" + 30°30'20" + 30°31'20"}{4}\right]$$

= 30'30'20"

[MCQ]

Q.20. Which one of the following saturated fine-grained soils can attain a negative Skempton's pore pressure coefficient (A)?

(a) Normally-consolidated clays (b) Over-consolidated clays

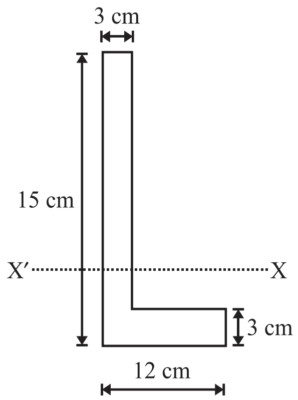
(c) Lightly-consolidated clays (d) Quick clays

Sol. **(b)**

Over consolidated clay can attain a negative Skempton's pore pressure coefficient (A).

[NAT]

Q.21. 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.

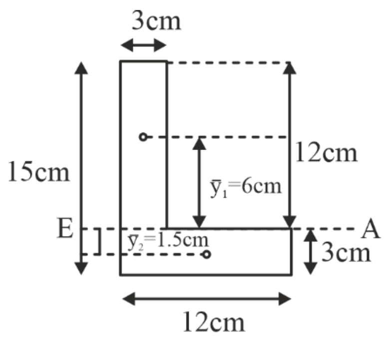


The shape factor of the section is__________*(rounded off to 2 decimal places)*.

Sol. **(1.79)**

Given data

elastic section modulus = 150.92 cm^3



$Z_e = 150{\cdot}92\ cm^3$

S.F. = ?

$A = 72\ cm^2,\ A/2 = 36\ cm^2$

$$Z_p = \frac{A}{2}(\bar{y}_1 + \bar{y}_2)$$

$$= 36(6 + 1.5) = 270 cm^3$$

$$S.F = \frac{Z_p}{Z_e} = \frac{270}{150.92} = 1.789$$

[MCQ]

Q.22. 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) $\frac{1}{12h^2}[-f_{i+2} + 16f_{i+1} - 30f_i + 16f_{i-1} + f_{i-2}]$

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

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

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

Sol. **(d)**

Standard Formula for finding 2nd Derivative using 4th order divided difference formula is an follows,

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

Comparision the given option with above Result, the Correct option is (d).

[NAT]

Q.23. 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 in/s^2. the critical depth of flow (in meters) is_______*(rounded off to 2 decimal places)*.

Sol. **(2.914)**

Given data

Channel type = rectangular

Width = 2 m

Slope = $\frac{1}{300}$

Civil Engineering

Discharge = 30 m^3/s

$\alpha = 1.1$

$g = 10\ m/s^2$

$y_c = ?$

$$E = y + \frac{\alpha V^2}{2g}$$

$$E = y + \frac{\alpha q^2}{y^2 \times 2g}$$

For $\frac{dE}{dy} = 0$

$$\frac{dE}{dy} = 1 + \frac{\alpha q^2}{2g}\frac{(-2)}{y^3} = 0$$

$$y^3 = \frac{\alpha q^2}{g}$$

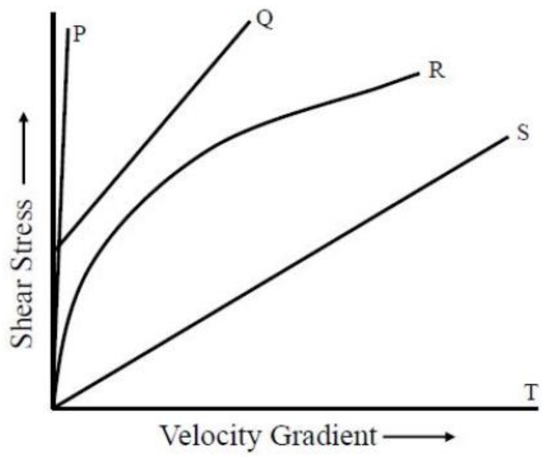
$$y_c = \left(\frac{\alpha q^2}{g}\right)^{1/3}$$

$$y_c = \left(\frac{1.1 \times 15^2}{10}\right)^{1/3} \qquad \left[q = \frac{Q}{B} = \frac{30}{2} = 15\text{m}^3/\text{sec/m}\right]$$

$y_c = 2.914$ m

[MCQ]

Q.24. 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 → Real solid: Q → Newtonian fluid

R → Ideal Bingham plastic: T → Ideal Fluid

(b) P → Ideal Fluid: Q → Ideal Bingham plastic

R → Non-Newtonian fluid: T → Real solid

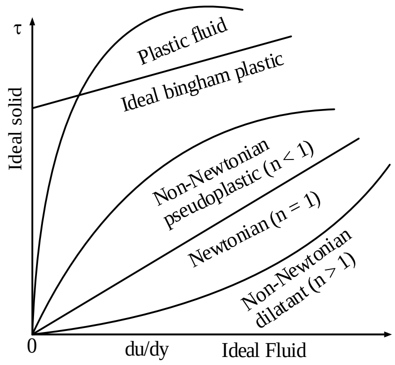
(c) P → Ideal Fluid: Q → Ideal Bingham plastic

R → Non-Newtonian fluid: S → Newtonian fluid

(d) P → Real solid; Q → Ideal Bingham plastic

S → Newtonian fluid; T → Ideal Fluid

Sol. **(d)**



Shear stress and deformation rate relationship of different fluids

[MCQ]

Q.25. 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) Both P and Q are FALSE

(b) P is FALSE and Q is TRUE

(c) Both P and Q are TRUE

(d) P is TRUE and Q is FALSE

Sol. **(d)**

P: It is obviously true because transpose is distributed over addition. i.e. $(A + B)^T = A^T + B^T$

Q: It is false because, in matrix multiplication transpose should follow reversal law i.e. $(AB)^T = B^T A^T$.

[MCQ]

Q.26. 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) P is TRUE and Q is FALSE

(b) P is FALSE and Q is TRUE

(c) Both P and Q are TRUE

(d) Both P and Q are FALSE

Sol. **(c)**

$$C_s = \frac{54000-30000}{15-12} = \frac{24000}{3} = \frac{8000}{day}$$

P: Direct Cost = 8000

Indirect Cost = 8500

$\Rightarrow$ Direct Cost – Indirect Cost = 8000 –8500 = – 800/day

Q: Direct Cost = 8000

Indirect Cost = 10000

$\Rightarrow$ Direct Cost – Indirect Cost = 8000 –10000 = – 2000/day

[MSQ]

Q.27. Three vector $\vec{p}, \vec{q}$ and $\vec{r}$ are given as

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

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

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

Which of the following is/are CORRECT?

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

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

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

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

Sol. **(a, b, d)***

As per vector txiple product

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

(b) $\vec{r}.(\vec{p}\times\vec{q}) = 0 = (\vec{q}\times\vec{p}).\vec{r}$

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

$(\vec{p}.\vec{r})\vec{q} - (\vec{p}.\vec{q})\vec{r} = (\vec{p}.\vec{r})\vec{q} - (\vec{q}.\vec{r})\vec{q}$ -

$-(\vec{p}.\vec{q})\vec{r} \neq -(\vec{q}.\vec{r})\vec{q}$ (Wrong)

(d) $\vec{p}\times(\vec{q}\times\vec{r})+\vec{q}\times(\vec{r}\times\vec{p})+\vec{r}\times(\vec{p}\times\vec{q})$

$=(\vec{p}.\vec{r})\vec{q}-(\vec{p}.\vec{q})\vec{r}+(\vec{q}.\vec{p})\vec{r}-(\vec{q}.\vec{r})\vec{p}+(\vec{r}.\vec{q})\vec{p}-(\vec{r}.\vec{p})\vec{q}=0$

[NAT]

Q.28. An organic waste is represented as $C_{240}O_{200}H_{180}N_5S$.
(Atomic weights: S-32. H-1. C-12. Ō-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).

Sol. **(10.1)**

$C_{240}\,O_{200}\,H_{180}\,N_5\,S + O_2 \rightarrow 200\,CO_2 + \ldots + 1SO_2$

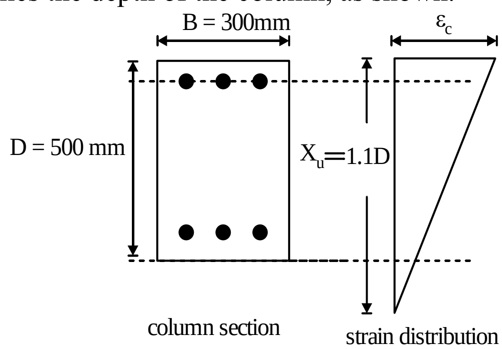
$240 \times 12 + 200 \times 16 + 180 + 5 \times 14 + 32 = 6330$ gm

6330gm of SW → 64 gm of SO_2

1000 gm → $\frac{64}{6330}\times 1000 = 10.11$ gm of SO_2

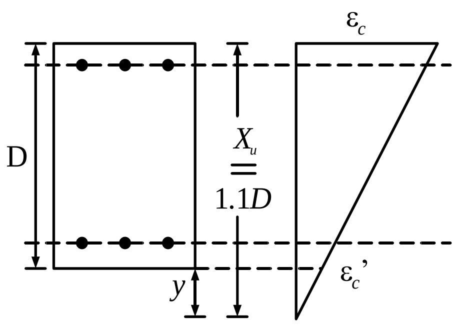
[NAT]

Q.29. A concrete column section of size 300 nun × 500 nun 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.



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).

Sol. **(3.27)**



Combined axial load and bending (Not tension)

Max. comp. strain, (as per IS 456)

Civil Engineering

$\varepsilon_c = 0.0035 - 0.75\ \varepsilon_c'$

$$\frac{y}{x_u} = \frac{\varepsilon_c'}{\varepsilon_c}$$

$$\frac{0.1D}{1.1D} = \frac{\varepsilon_c'}{\varepsilon_c} \Rightarrow \varepsilon_c' = \frac{\varepsilon_c}{11}$$

$\varepsilon_c = 0.0035 - 0.75 \times \varepsilon_c'$

$$\varepsilon_c\left(1+\frac{0.75}{11}\right) = 0.0035$$

$\Rightarrow \varepsilon_c = 3.2766 \times 10^{-3}$

[MCQ]

Q.30. 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) 70
(b) 55
(c) 50
(d) 65

Sol. **(b)**

Cumulative

Average speed	No. of observation	Cumulative number of vehicles	Percentile
5	7	7	$\frac{7}{500}\times100=1.4$
15	31	38	7.6
25	76	114	22.8
35	129	243	48.6
45	104	347	69.4
55	78	425	85
65	29	454	90.8
75	24	478	95.6
85	13	491	98.2
95	9	500	100

Thus, upper speed limit = 85^{th} percentile speed $=\left[\frac{50+60}{2}\right]$ = 55 kmph.

[MCQ]

Q.31. 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.

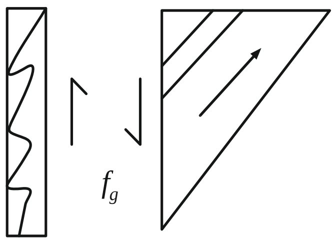
Q: Most of the earth pressure theories calculate the earth pressure due to surcharge by neglecting the actual distribution of stresses due to surcharge.

Which one of the following options is CORRECT?

(a) Both P and Q are FALSE (b) P is FALSE and Q is TRUE
(c) Both P and Q are TRUE (d) P is TRUE and Q is FALSE

Sol. **(c)**

When rough retaining wall moves towards the backfill, the soil will try to move inward and upward and thus the friction and shearing resistance mobilizes in downward direction along the soil mass while friction will be mobilised in upward direction along the wall.



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

[NAT]

Q.32. A 2 m × 1.5 in 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 (round off to 2 decimal places).

Sol. **(103.98)**

$$\text{Time required} = \frac{A}{C_d \times A_{\text{orifice}} \times \sqrt{2g}} \times \left[2\left(\sqrt{H_1} - \sqrt{H_2}\right)\right]$$

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

= 103.985 sec

[MCQ]

Q.33. 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.

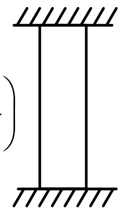
The differential increase in temperature {rounded off to the nearest integer) at which the bar buckles is

(a) 250 °C (b) 85 °C

(c) 400 °C (d) 298 °C

Sol. **(d)**

$$\left(L_e = \frac{L}{2}\right)$$



$$\alpha \Delta T E = f_{cc} = \frac{\pi^2 E}{\left(\frac{L_e}{r}\right)^2}$$

$$\Delta T = \frac{\pi^2}{\alpha\left(\frac{L_e}{r}\right)^2} = \frac{\pi^2}{\alpha\left(\frac{L}{2r}\right)^2}$$

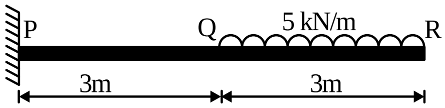
$$\frac{L}{r} = 105 \text{ (given)}$$

$$\frac{L}{2r} = 52.5$$

$$\Delta T = \frac{\pi^2}{12 \times 10^{-6} \times (52.5)^2} = 298°C$$

[NAT]

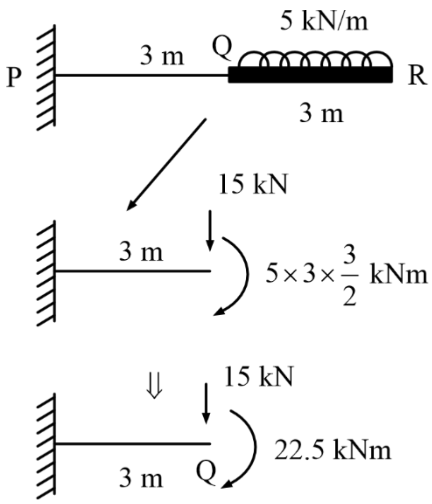
Q.34. For the 6 m long horizontal cantilever beam PQR shown in the figure. Q is the mid-point. Segment PQ of the beam has flexural rigidity EI = 2×10^5 kN. m^2 whereas the segment QR has infinite flexural rigidity. Segment QR is subjected to uniformly distributed, vertically downward load of 5 kN/m.



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

Sol. **(1.18)**

$$(EF)_{PQ} = 2 \times 10^5 kNm^2 \text{ (given)}$$



$$\Delta_Q = \frac{22.5 \times 3^2}{2EI} + \frac{15 \times 3^3}{3EI}$$

$$\Delta_Q = \frac{22.5 \times 3^2 \times 10^{12} \text{ Nmm}^4}{2 \times 2 \times 10^5 \times 10^9 \text{ Nmm}^3}$$

$$= \frac{15 \times 3^3 \times 10^{12} \text{ Nmm}^4}{3 \times 2 \times 10^5 \times 10^9 \text{ Nmm}^3}$$

$\Delta_Q = 1.181$ mm

Civil Engineering

[MCQ]

Q.35. 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:IV. If Manning's roughness coefficient is 0.013, the flow depth (in meters) will be in the range of

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

Sol. **(a)**

$$\tan\theta = \frac{1}{1.25} \Rightarrow \theta = \tan^{-1}\left(\frac{1}{1.25}\right)$$

= 0.6747 radian

And,

Cot θ = 1.25

$A = y^2 (\theta + \cot\theta) = y^2 \times 1.9247$

Welted perimeter (P) = 2y (θ + cot θ) = 3.8494 y

$$\therefore\ R = \left(\frac{A}{P}\right) = \frac{y}{2}$$

And, As per Manning's Formula,

$$Q = \frac{1}{n} AR^{2/3} (S)^{1/2}$$

$$25 = \frac{1}{0.013} \times 1.9247 y^2 \times \left(\frac{y}{2}\right)^{2/3} \times \sqrt{\frac{1}{150}}$$

$$y = \left[\frac{25 \times 0.013 \times (2)^{2/3} \times \sqrt{1500}}{1.9247}\right]^{3/8}$$

= 2.40488 m

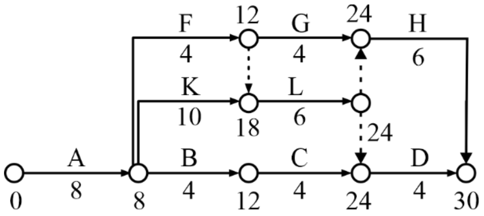
[NAT]

Q.36. The table shows the activities and then durations and dependencies hi 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).

Sol. **(30)**



Project completion time = 30 days

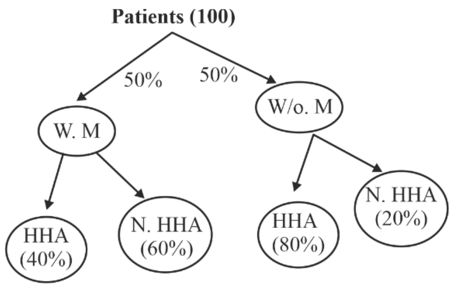
[MCQ]

Q.37. 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) 30% (b) 60%

(c) 40% (d) 20%

Sol. **(d)**



Required Probability = 50 × 40% $= \frac{50}{100} \times \frac{40}{100}$

$= \frac{20}{100} \times 100 = 20\%$

Civil Engineering

[MSQ]

Q.38. In the context of pavement material characterization, the CORRECT statement(s) is/are

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

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

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

(d) 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).

Sol. **(a, c, d)**

Grading of normal (unmodified) bitumen binders is done based on viscosity test results.
The toughness and hardness of road aggregates are determined by aggregate impact and Los Angeles abrasion test, respectively.
The load penetration curve of CBR test may need origin correction due to the non-vertical penetrating plunger of the loading machine.
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).

[NAT]

Q.39. 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).

Sol. **(0.64)**

Total Rainfall = 11 cm, P = 11 cm

Runoff = 6 cm, R = 6 cm

ϕ-index = ? cm/hr

t (hrs)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
P (cm)	$P_1 = 0.5$	$P_2 = 1$	$P_3 = 1.6$	$P_4 = 2.4$	$P_5 = 1.8$	$P_6 = 1.6$	$P_7 = 1.3$	$P_8 = 0.8$
i = p/t cm /hr	$i_1 = 0.5$	$i_2 = 1$	$i_3 = 1.6$	$i_4 = 2.4$	$i_5 = 1.8$	$i_6 = 1.6$	$i_7 = 1.3$	$i_8 = 0.8$

Trial– 1: Assume $t_e = 8$ hrs

$P_e = P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 + P_8 = 11$ cn

$$\phi_1 - \text{index} = \frac{P_e - R}{t_e} = \frac{11-6}{8} = 0.625 \text{ cm/hr}$$

As i ϕ_1 – index, no runoff in 1st hour

Go for trial-2 by eliminating i

Trial–2: Assume $t_e = 7$ hrs

$P_e = P - P_1 = 11 - 0.5 = 10.5$ cm

$$\phi_2 - \text{index} = \frac{P_e - R}{t_e} = \frac{10.5-6}{7} = 0.643 \text{ cm/hr}$$

As,

$i_2, i_3, i_4, i_5, i_6, i_7$ & $i_8 > \phi_2$– index

Answer obtained in 2nd trial is correct

ϕ–index = 0.64 cm/hr

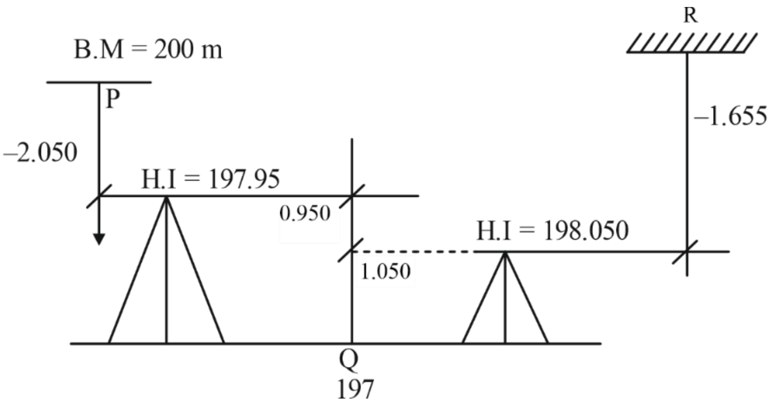
[NAT]

Q.40. 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 meter) of the point R is _________ (rounded off to 3 decimal places)

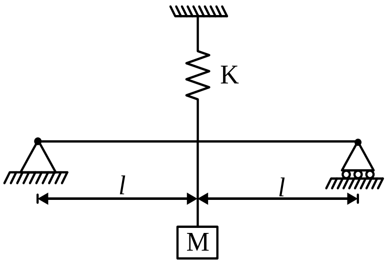
Sol. **(199.705)**



198.050 + 1.655 = 199.705

[MCQ]

Q.41. A linearly elastic beam of length 2/ with flexural rigidity EI has negligible mass. A massless spring with a spring constant A' and a rigid block of mass w are attached to the beam as shown in the figure.



The natural frequency of this system is

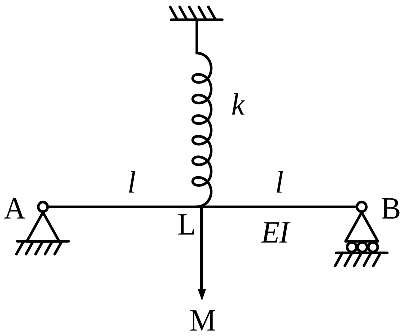
(a) $\sqrt{\dfrac{48EIK}{(kl^3+48EI)m}}$

(b) $\sqrt{\dfrac{kl^3+48EI}{ml^3}}$

(c) $\sqrt{\dfrac{6EIK}{(kl^3+6EI)m}}$

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

Sol. **(d)**



$F = k\Delta$

$$\Delta = \frac{P(2l)^3}{48EI} = \frac{Pl^3}{6EI}$$

$$P = \frac{6EI}{23}\Delta$$

$$W = \sqrt{\frac{k_{eq}}{m}}$$

$$k_{eq} = k_{sp} + k_3$$

$$k_{eq} = k + \frac{6EI}{l^3}$$

$$W = \sqrt{\frac{k + \frac{6EI}{l^3}}{m}} = \sqrt{\frac{kl^3 + 6EI}{ml^3}}$$

[MCQ]

Q.42. 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 panicles 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 panicles is 0.20 mm

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

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

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

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

Sol. **(b)**

(i) Anthracite Coal (D_{10} = 0.9 to 1 mm, S = 1.4 to 1.5)

(ii) Silica sand (D_{10} = 0.5 mm, S = 2.67)

(iii) Garnet (D_{10} = 0.15 mm, S = 4.2)

[NAT]

Q.43. The expression for computing the effective interest rate (i_{eff}) using 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)

Sol. **(5.13)**

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

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

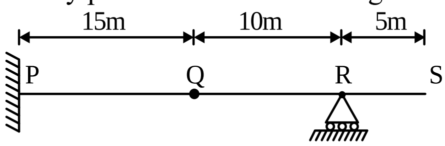
$= e^{0.05} - 1 = 1.05127 - 1$

$= 0.05127$

$= 5.13\%$

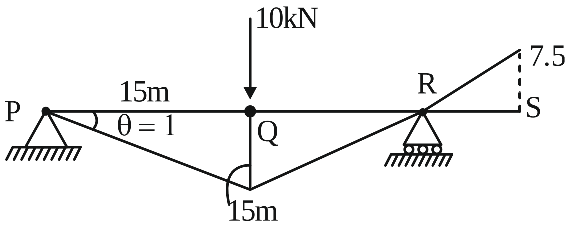
[NAT]

Q.44. 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 (P) of 10 kN can act at any point over the entire length of the beam.



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

Sol. **(150)**



$\frac{15}{10} \times 5$

$(M_P)_{max} = 10 \times 15$

$= 150$ kNm

[MSQ]

Q.45. 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.

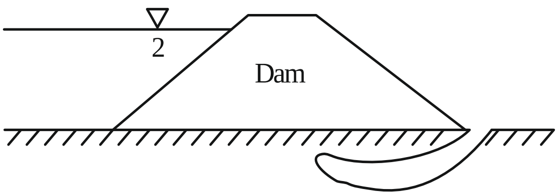
R: The piping phenomenon occurring below the dam foundation is typically known as blowout piping.

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

(a) Both P and R are TRUE
(b) Both Q and R are FALSE
(c) P is TRUE and R is FALSE
(d) P is FALSE and Q is TRUE

Sol. **(b, c)**

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 backward-erosion piping.



Pervious foundation
Backward-erosion piping.

Note: Blowout piping or heaving may occur on the downstream of a sheet pile cut off wall provided near the downstream end of a dam or weir on pervious foundation material.

[NAT]

Q.46. 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).

Sol. **(3.55)**

Given data

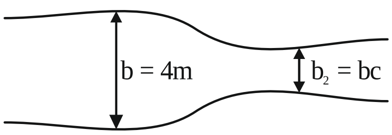
Channel type = rectangular

Width (b) = 4m

Discharge (Q) = 2 m^3/s

Depth (y) = 0.4 m

$b_2 = bc$



$$y_c = \left(\frac{q^2}{g}\right)^{1/3} = 0.294 \text{ m}$$

$E_1 = E_2$

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

$$0.4 + \frac{1}{2g}\left(\frac{4}{(4\times 0.4)^2}\right) = y_c + \frac{1}{2g}\left(\frac{4}{b_c^2 \times y_c^2}\right)$$

$$0.4 + \frac{1}{2g}\left(\frac{4}{(4\times 0.4)^2}\right) = 0.294 + \frac{1}{2g}\left(\frac{4}{b_c^2 \times (0.294)^2}\right)$$

$b_c = 3.55$ m

[NAT]

Q.47. 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).

Sol. **(10)**

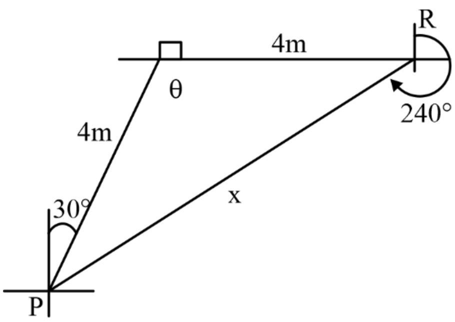
$$AB = \begin{bmatrix} 2 & 1 & 4 \\ 1 & 0 & 3 \end{bmatrix}\begin{bmatrix} -1 & 0 \\ 2 & 3 \\ 1 & 4 \end{bmatrix} = \begin{bmatrix} 4 & 19 \\ 2 & 12 \end{bmatrix}$$

So |AB| = (4) (12) – (2) (19) = 48 – 38 = 10

[NAT]

Q.48. 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).

Sol. **(7)**



$4 \cos 30° + 4 \cos 90° + x \cos 240° = 0$

$x = 6.928$ m

$x = 7$

Civil Engineering

[NAT]

Q.49. 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).

Sol. **(13.33)**

$$P_r = \frac{\frac{1}{\gamma_{d,\min}} - \frac{1}{\gamma_d}}{\frac{1}{\gamma_{d,\min}} - \frac{1}{\gamma_{d,\max}}}$$

$$e = \frac{n}{1-n} = \frac{0.5}{1-0.5} = 1$$

$$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.7\times 1}{1+1} = \frac{2.7}{2}$$

$$P_r = \frac{\frac{1}{1.3} - \frac{1}{1.35}}{\frac{1}{1.3} - \frac{1}{1.8}} \times 100\% = 13.33\%$$

[NAT]

Q.50. A 500 m long water distribution pipeline P with diameter 1.0 m. is used to convey 0.1 m^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).

Sol. **(0.76)**

In both pipes, head loss are equal,

$$(h_L)_P = (h_L)_Q$$

$$\Rightarrow \frac{f_p l\, Q^2}{12.1 D_p^5} = \frac{f_Q\, l Q^2}{12.1\, D_Q^5}$$

$$\Rightarrow D_Q^5 = \frac{f_Q}{f_P} \times D_P^5$$

$$\Rightarrow D_Q = \left[\frac{0.01}{0.04} \times (1)^5\right]^{1/5}$$

= 0.7578 m
= 0.76 m

Civil Engineering

[NAT]

Q.51. 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/m^2/day. The height (in meters) of the water column in the tank is_________ (rounded off to 2 decimal places).

Sol. **(3.33)**

Q = 10 MLD

DT = 2 hr

SLR = 40,000 l/m^2/d

$$SA = \frac{Q}{SLR} = \frac{10\times10^6}{40000}$$

$$\boxed{SA = 25000^2}$$

$Vol^m = Q \times T$

$$= \frac{10\times10^6\times10^{-3}}{24}\times2$$

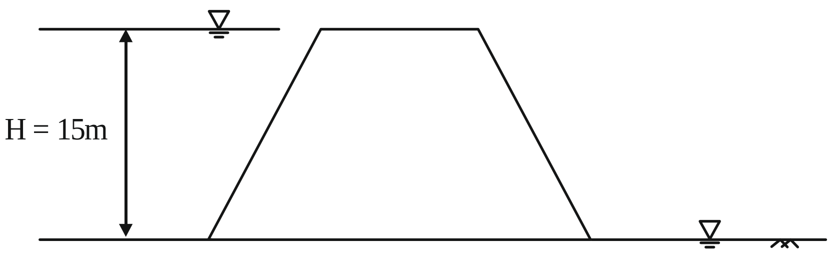
$Vol^m = 833.33\ m^3$

$$\text{depth} = \frac{Vol^m}{SA} = \frac{833.33}{25u} = 3.33\text{ m}$$

[NAT]

Q.52. 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).

Sol. **(0.65)**



$N_D = 10,\ l = 3m$

$G_s = 2.65,\ FOS = 2.0$

$e = ?$

Civil Engineering

$$i_c = \frac{h_l}{l} = \frac{\frac{15}{10}}{3} = 0.5$$

$$FOS = \frac{i_{cr}}{i_e}$$

$$i_{cr} = 2 \times 0.5 = 1 = \frac{G_s - 1}{1+e}$$

e = 2.65 – 1 – 1

= 0.65

[NAT]

Q.53. 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 70 kmph. 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 nearest integer).

Sol. **(113)**

V_{avg} = 70 kmph

(BG) G = 1.750 m

CD = 10 cm

R = 1080 m

$$\frac{GV_a^2}{127R} - \frac{GV_e^2}{127R} = 100$$

$$V_a^2 - V_e^2 = \frac{100 \times 127 \times 1080}{1750}$$

$$V_a = \sqrt{\frac{100 \times 127 \times 1080}{1750} + 70^2}$$

V_a = 112.86 kmph

If we use railway board formula.

$$V_a = 0.27\sqrt{R(Ca + C_{d\,\max})}$$

$$V_a = 0.27\sqrt{1080(62.518 + 100)}$$

= 113 kmph

[NAT]

Q.54. 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 = 80 kmph

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

Slopping 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 io 1 decimal places).

Sol. **(117.9)**

N = 8%

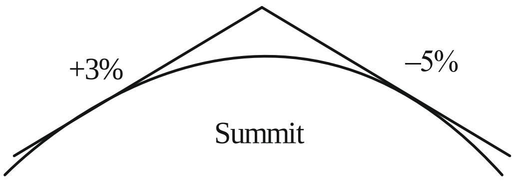
H = 2.3 m

h = 0.35 m

t_r = 2 sec

f = 0.36

V = 80 kmph



(1) l > 80

$$SSD = vtr + \frac{v^2}{2gf}$$

$$= \left(80\times\frac{5}{18}\right)\times 2 + \frac{\left(80\times\frac{5}{18}\right)^2}{2\times 9.81\times 0.36}$$

SSD = 114.36 m

$$l = \frac{NS^2}{\left(\sqrt{2H}+\sqrt{2h}\right)^2}$$

$$= \; = \frac{0.08\times(114.36)^2}{2\left(\sqrt{2.3}+\sqrt{0.35}\right)^2} = 117.9\,\text{m}$$

l = 117.9 m

[NAT]

Q.55. 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 100 kN/m^2 from an initial confining pressure of 300 kN/m^2.
The angle of shearing plane (in degrees) with respect to horizontal is_______ (rounded off to nearest integer).

Sol. **(49)***

$\sigma_1 = \sigma_d + \sigma_c = 400$ kN/m^2
$\sigma_3 = \sigma_c = 300$ kN/m^2
$\sigma_1 = \sigma_3 \tan^2 (45 + \phi/2)$
$45 + \phi/2 = \tan^{-1}\sqrt{4/3}$
$= 49.10°$
$= 49°$

❑❑❑

PW GATE WALLAH

SOLDIERS

THANK YOU