General Aptitude

Q.1 to Q.5 Carry ONE Mark Each

Question 1 **[Verbal Ability : Sentence Completion]**

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) bicker (B) bog

(C) dither (D) dodge

Ans. (A)

Sol. **Given :**

[drizzle $\rightarrow$rain $\rightarrow$ downpour]

'$\rightarrow$' denote increasing order of intensity

[___ $\rightarrow$ quarrel $\rightarrow$ feud]

Meaning of the given words are

drizzle $\rightarrow$to rain in very small drops or very lightly

rain $\rightarrow$the drops of water that fall from the sky

downpour $\rightarrow$a heavy, sudden fall of rain

quarrel $\rightarrow$ an angry argument or disagreement

fend $\rightarrow$an angry and serious argument between two people or groups that continues over a long period of time.

From options

(A) bicker : to argue about unimportant things

(B) bag : an area of ground that is very soft and wet

(C) dither to be unable to decide something, to hesitate

(D) dodge : to move quickly in order to avoid

From the above options are there meanings we see that options (B), (C) and (D) are not appropriate for given analogy and option (A) is logical in the analogy.

Hence, the correct option is (A).

Question 2 **[Numerical Ability : Permutation & Combination]**

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 II and III

(C) Only I and III (D) Only III

Ans. (B)

Sol. **Given :**

S1 : All heroes are winners.

S2 : All winners are lucky people.

According to the statement given in the question we can form Venn diagram as shown below,

From this Venn diagram inferences II and III can be logically deduced.

Hence, the correct option is (B).

Question 3 **[Numerical Ability : Number System & Series]**

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) 5 (B) $\sqrt{2}$

(C) 2 (D) $\sqrt{5}$

Ans. (D)

Sol. **Given :** Positive real numbers p and q

Percentage error in students answer = 80%

Actual answer of student = pq

Wrong answer of student $= p/q$

$$\text{Percentage error in student's answer} = \frac{\text{Actual answer} - \text{Wrong answer}}{\text{Actual answer}} \times 100$$

$$= \frac{pq - p/q}{pq} \times 100$$

$$= \frac{q\left[p - \frac{p}{q^2}\right]}{pq} \times 100$$

$$= \frac{pq\left[1-\frac{1}{q^2}\right]}{pq} \times 100$$

$$= \left(1-\frac{1}{q^2}\right) \times 100 \qquad \ldots(i)$$

According to question

Percentage error in student answer = 80%

Hence, $80 = \left(1-\frac{1}{q^2}\right) \times 100$

$$80 = \left(1-\frac{1}{q^2}\right) \times 100$$

$$\frac{80}{100} = 1-\frac{1}{q^2}$$

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

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

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

$$q^2 = 5$$

$$q = \sqrt{5}$$

Hence, the correct option is (D).

Question 4 **[Numerical Ability : Number System & Series]**

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

(A) 1 (B) 20

(C) 2 (D) ½

Ans. (A)

Sol. Sum of first two consecutive odd numbers is

$$1+3=4=2^2$$

Sum of first three consecutive odd numbers is

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

Sum of first four consecutive odd numbers is

$$1+3+5+7=16=4^2$$

Sum of first five consecutive odd numbers is

$$1+3+5+7+9=25=5^2$$

Hence, we can conclude that the sum of first n consecutive odd numbers is n^2

i.e., $\underbrace{1+3+5....}_{n \text{ numbers}}=n^2$

Sum of first 20 consecutive odd numbers is $=20^2$

$$\underbrace{1+3+5+7....}_{20 \text{ numbers}}=20^2$$

The sum of first 20 consecutive positive odd numbers divided by

$$20^2=\frac{20^2}{20^2}=1$$

Hence, the correct option is (A).

Question 5 **[Numerical Ability : Probability & Statistics]**

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) 250 (D) 175

Ans. (B)

Sol. **Given :** Total number of students (boys and girls) in classes VIII and IX is 450 and 360.

Number of girls in classes VIII and IX is the same.

Let the number of girls in class VIII and IX $=x$

then, number of boys in class VIII $=450-x$

and number of boys in class IX $=360-x$

According to question,

Ratio of number of girls to boys in class VIII is the same as the ratio of the number of boys to girls in class IX.

i.e., $$\frac{x}{450-x}=\frac{360-x}{x}$$

$$x^2=(450-x)(360-x)$$

$$x^2=162000-450x-360x+x^2$$

$$x(450+360)=162000$$

$$x(810)=162000$$

$$x=\frac{162000}{810}$$

$x = 200$

Hence, number of girls in each class is 200.

Hence, the correct option is (B).

Q.6 - Q.10 Carry TWO mark Each

Question 6 **[Verbal Ability : Sentence Completion]**

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 the fellow, after she stood __(iii)__ her writings that stand __(iv)__ freedom of speech.

(A) (i) out (ii) down (iii) in (iv) for
(B) (i) down (ii) out (iii) by (iv) in
(C) (i) down (ii) out (iii) for (iv) in
(D) (i) out (ii) down (iii) by (iv) for

Ans. (D)

Question 7 **[Numerical Ability : Average, Percentage & Ratio]**

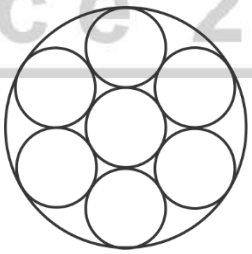
Seven identical cylindrical chalk-sticks are fitted tightly in a cylindrical container. The figure below shows the arrangement of the chalk-sticks inside the cylinder.

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) 5/2
(B) 7/2
(C) 9/2
(D) 3

Ans. (B)

Sol. **Given :** Seven identical cylindrical chalk sticks are fitted tightly in a cylindrical container as shown in figure.

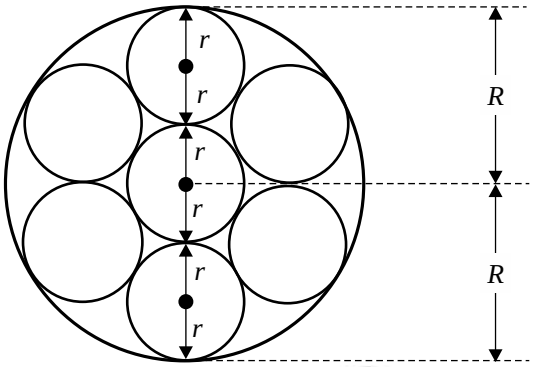


and length of container = Length of chalk sticks

Let the length of container and chalk stick = l

Let the radius of cylinder = R

Let the radius of chalk stick = r



From the above figure

$$R + R = r + r + r + r + r + r$$

$$2R = 6r$$

$$r = \frac{2}{6}R$$

$$r = \frac{R}{3} \qquad \ldots(\text{i})$$

Now volume of cylinder $= \pi R^2 h$

$$= \pi R^2 l$$

Volume of chalk stick $= \pi r^2 h$

$$= \pi r^2 l$$

$$= \pi\left(\frac{R}{3}\right)^2 l \qquad [\text{From equation (i) } r = \frac{R}{3}]$$

$$= \pi \frac{R^2}{9} l$$

Occupied space of container = $7 \times$ Volume of chalk stick

$$= 7\pi \frac{R^2}{9} l$$

Empty space of container = [Volume of cylinder] – 7(Volume of chalk sticks)

$$= \pi R^2 l - \frac{7}{9}\pi R^2 l$$

Ratio of occupied space to empty space of the container

$$= \frac{7\pi \frac{R^2}{9} l}{\pi R^2 l - \frac{7}{9}\pi R^2 l}$$

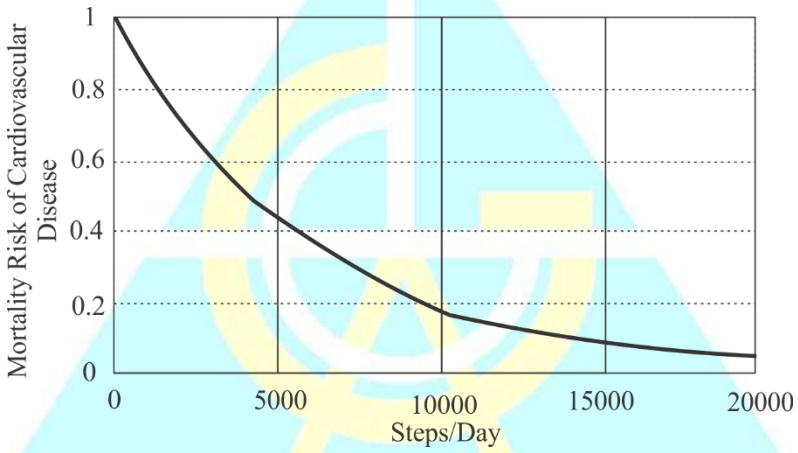
$$= \frac{\left(\frac{7}{9}\right)\pi R^2 l}{\left[1-\frac{7}{9}\right]\pi R^2 l}$$

$$= \frac{\frac{7}{9}}{\frac{2}{9}} = \frac{7}{2}$$

Hence, the correct option is (B).

Question 8 **[Logical Reasoning : Data Interpretation]**

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 10000 is less than the risk reduction on increasing the steps/day from 10000 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) For any 5000 increment in steps/day the largest risk reduction occurs on going from 0 to 5000.

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

Ans. (C)

Question 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*.

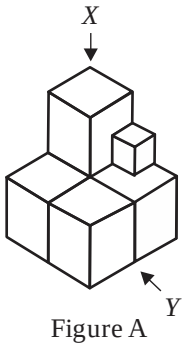


Figure A

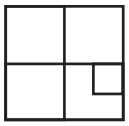
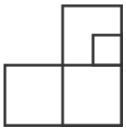


Figure B

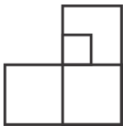
If viewed from direction *Y*, the planar image of the assembly (Figure A) will appear as

(A)



(B)

(C)



(D)

Ans. (A)

Question 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°

Ans. (A)

Technical Section

Q.11 - Q.35 Carry ONE mark Each

Question 11 **[Engineering Mathematics : Differential Equations]**

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 $2m\times 2m$. Three boundary edges of the square domain are maintained at value $T=50$, whereas the fourth boundary edge is maintained at $T=100$.

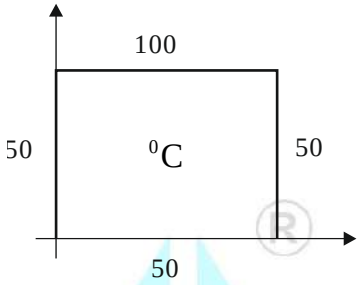
The value of T at the center of the domain is

(A) 50.0
(B) 62.5

(C) 75.0 (D) 87.5

Ans. (B)

Sol. Temperature at centre = Average of temperature at sides



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

Hence, the correct option is (B).

Question 12 **[Engineering Mathematics : Linear Algebra]**

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

P: $(\mathbf{A}+\mathbf{B})^{\mathrm{T}} = \mathbf{A}^{\mathrm{T}} + \mathbf{B}^{\mathrm{T}}$

Q: $(\mathbf{AB})^{\mathrm{T}} = \mathbf{A}^{\mathrm{T}}\mathbf{B}^{\mathrm{T}}$

Which one of the following options is CORRECT?

(A) *P* is TRUE and *Q* is FALSE (B) Both *P* and *Q* are TRUE

(C) *P* is FALSE and *Q* is TRUE (D) Both *P* and *Q* are FALSE

Ans. (A)

Sol. **Given :**

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

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

According to properties of a matrix.

(i) $(A+B)^T = A^T + B^T$

The sum of transpose of matrices is equal to the transpose of the sum of two matrices.

(ii) $(AB)^T = B^T A^T$

The product of the transpose of two matrices in reverse order is equal to the transpose of the product of them.

Hence the correct option is (A).

Question 13 **[Engineering Mathematics : Numerical Methods]**

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

Ans. (A)

Sol. Standard formula for computing second derivative of function f by using the fourth-order Central Divided Difference method with a step length h is

$$f''(x)=\frac{-f(x_0+2h)+16f(x_0+h)-30f(x_0)+16f(x_0-h)-f(x_0-2h)}{12h^2}$$

Comparing it with given options, option (A) is in the form of above equation

i.e.

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

Hence, the correct option is (A).

Key Point

The second order central difference formula for calculating second derivative is

$$f''(x)=\frac{f(x_0+h)-2f(x_0)+f(x_0-h)}{h^2}$$

Question 14 **[Engineering Mathematics : Maxima & Minima]**

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

(A) Maxima point (B) Minima point

(C) Saddle point (D) Inflection point

Ans. (B)

Sol. **Given :** $f(x)=x^3-27x+4,\ 1\le x\le 6$

Differentiating function $f(x)$ with respect to x

$$f'(x) = 3x^2 - 27 \quad \ldots(i)$$

The stationary points are given by

$$f'(x) = 0$$

$$3x^2 - 27 = 0$$

$$(x^2 - 9) = 0$$

$$(x+3)(x-3) = 0$$

$$x = -3, +3$$

Differentiating equation (i) with respect to x

$$f''(x) = (2\times 3)x = 6x$$

At $x = -3$

$$f''(x)\big|_{x=-3} = 6(-3) = -18 < 0 \text{ (Maxima)}$$

At $x = 3$

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

But given function $f(x)$ has range $1 \le x \le 6$

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

$x = 3$ point lies between [1, 6]. So,

At $x = 3$,

$$f''(x) > 0 \text{ (Minima)}$$

$$x = 3 \varepsilon [1,6]$$

Hence, the function $f(x)$ has minima point in the interval $1 \le x \le 6$.

Hence, the correct option is (B).

Question 15 **[Engineering Mathematics : Differential Equations]**

Consider two Ordinary Differential Equations (ODEs):

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

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

Which one of the following options is CORRECT?

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

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

(C) P is a nonhomogeneous ODE and Q is an exact ODE.

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

Ans. (B)

Sol. **Given :** Two ordinary differential equations (ODES)

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

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

(i) Homogeneous ordinary differential equation

Key Point

The differential equation

$$\frac{dy}{dx} = \frac{f(x,y)}{\phi(x,y)}$$

is homogeneous differential equation if $f(x,y)$ and $\phi(x,y)$ are homogeneous function of same degree.

i.e. $$\frac{f(kx,ky)}{\phi(kx,ky)} = k^n \frac{f(x,y)}{\phi(x,y)}$$

For P : $$\frac{dy}{dx} = \frac{x^4 + 3x^2y^2 + 2y^4}{x^3y} = \frac{f(x,y)}{\phi(x,y)}$$

$$\frac{f(x,y)}{\phi(x,y)} = \frac{x^4 + 3x^2y^2 + 2y^4}{x^3y}$$

$$\frac{f(kx,ky)}{\phi(kx,ky)} = \frac{(kx)^4 + 3(kx)^2(ky)^2 + 2(ky)^4}{(kx)^3(ky)}$$

$$= \frac{k^4[x^4 + 3x^2y^2 + 2y^4]}{k^4[x^3y]}$$

$$\frac{f(kx,ky)}{\phi(kx,ky)} = k^0 \frac{f(x,y)}{\phi(x,y)}$$

Hence, $f(x,y)$ and $\phi(x,y)$ are homogeneous function of same degree.

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

is a homogeneous ordinary differential equation.

(ii) Exact ordinary differential equation

Key Point

A differential equation

$$Mdx + Ndy = 0$$

is exact if

$$\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$$

For Q :

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

$$x^2dy = -y^2dx$$

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

$$M = y^2 \quad N = x^2$$

$$\frac{\partial M}{\partial y} = 2y, \quad \frac{\partial N}{\partial x} = 2x$$

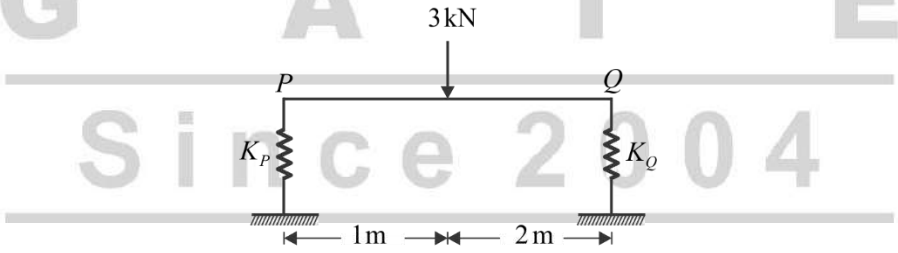
$$\frac{\partial M}{\partial y} \neq \frac{\partial N}{\partial x}$$

Hence, Q is non-exact differential equation.

Hence, correct option is (B).

Question 16 **[Engineering Mechanics]**

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 $K_P = 100\,kN/m$.



(Figure Not to scale)

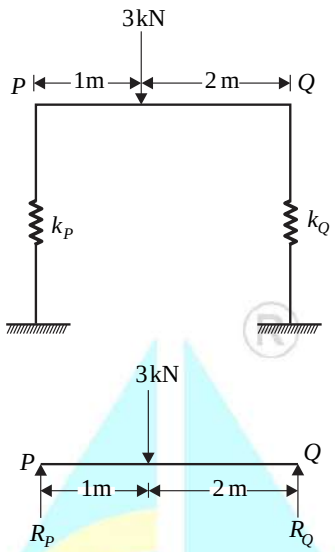
If the beam DOES NOT rotate under the application of the force and displaces only vertically, the value of the spring constant K_Q (in kN/m) for the spring at the end Q is

(A) 150 (B) 100

(C) 50 (D) 200

Ans. (C)

Sol.



$$\sum f_y = 0$$

$$R_P + R_Q = 3$$

$$\sum M_P = 0$$

$$R_Q \times 3 - 3 \times 1 = 0$$

$$R_Q = 1 \text{ kN},\ R_P = 2 \text{ kN}$$

$$\therefore \quad \Delta_P = \Delta_Q$$

$$\frac{2}{100} = \frac{1}{K_Q}$$

$$K_Q = 50 \text{ kN/m}$$

Hence, the correct option is (C).

Question 17 **[Construction Materials & Management]**

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) Both *P* and *Q* are FALSE
(D) *P* is FALSE and *Q* is TRUE

Ans. (A)

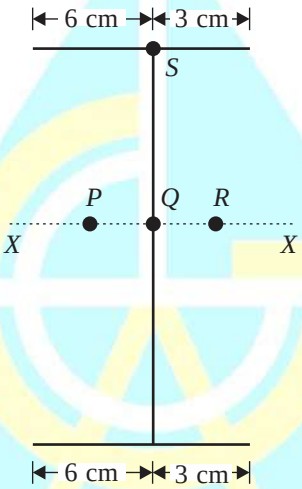
Sol. P: In a pure project organization, the project manager has the complete authority and control over the project.

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

Hence, the correct option is (A).

Question 18 **[Strength of Materials : Theory of Columns and Shear Centre]**

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) *Q*

(C) *R* (D) *S*

Ans. (C)

Question 19 **[Construction Materials & Management]**

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) (–) Rs. 50 (B) (–) 50 days

(C) (+) Rs. 50 (D) (+) 50 days

Ans. (A)

Sol. We know that,

Schedule variance $= \text{BCWP} - \text{BCWS}$

$= 150 - 200$

$= -50\,\text{Rs.}$

Hence, the correct option is (A).

Question 20 **[RCC Structures : Design & Analysis of Beam and Slab]**

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 (B) l_y / l_x

(C) $\left(l_x / l_y\right)^2$ (D) $\left(l_y / l_x\right)^2$

Ans. (D)

Sol. Rankine Grashof method

$$M_{u_x} = \frac{r^4}{8(1+r^4)} \times W_u l_x^2$$

$$M_{u_y} = \frac{r^2}{8(1+r^4)} \times W_u l_x^2$$

$$\frac{M_{u_x}}{M_{u_y}} = r^2$$

Where, $r = \dfrac{l_y}{l_x}$

$$\frac{M_{u_x}}{M_{u_y}} = \left(\frac{l_y}{l_x}\right)^2$$

Hence, the correct option is (D).

Question 21 **[RCC Structures : IS Recommendations & Fundamentals]**

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

(A) working stress method. (B) load factor method.

(C) ultimate load method. (D) limit state method.

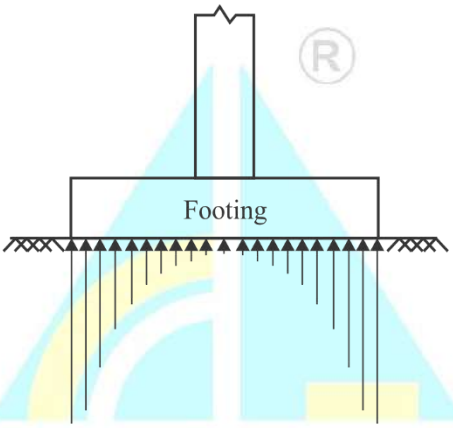
Ans. (A)

Sol. In working stress method, safety is accounted for by considering factor of safety in material strength only and no factor is considered in load.

Hence, the correct option is (A).

Question 22 **[Geotechnical Engineering : Compressibility & Consolidation]**

The contact pressure distribution shown in the figure belongs to a



(A) rigid footing resting on a cohesionless soil.

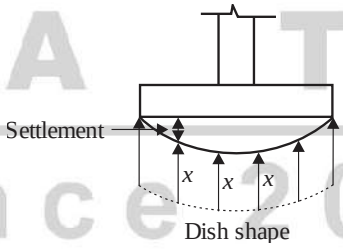
(B) rigid footing resting on a cohesive soil.

(C) flexible footing resting on a cohesionless soil.

(D) flexible footing resting on a cohesive soil.

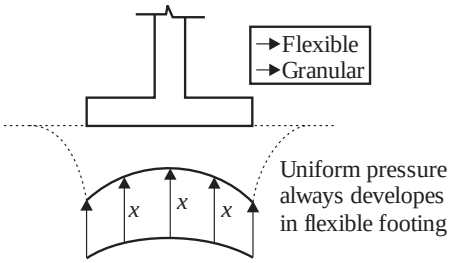
Ans. (B)

Sol. 1. **Flexible footing over clayey soil:** In flexible footing, the contact pressure at the interface between footing and soil is uniformly distributed producing dish-shape pattern in clayey soil.

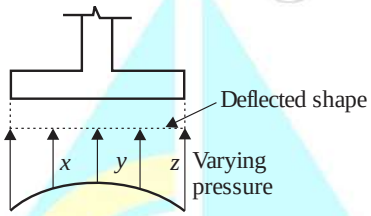


Flexible footing over clayey soil

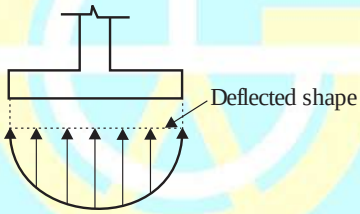
2. **Flexible footing over Granular soil :** In granular soil, modulus of elasticity (E_S) varies across the width being maximum at the centre and minimum at edge. As E is maximum at centre, deflection is less at centre. As E is less at edge deflection is more at edge.



3. **Rigid footing on Clayey soil:** In case of flexible footing, deflection is more at centre. Hence pressure developed at centre is less. Deflection is less in flexible footing at edge, hence in rigid footing pressure developed is more at edge.



4. **Rigid footing on Granular soil**



Hence, the correct option is (B).

Question 23 **[Geotechnical Engineering : Shear Strength of Soil]**

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

(A) Quick clays (B) Normally-consolidated clays

(C) Lightly-consolidated clays (D) Over-consolidated clays

Ans. (D)

Sol.

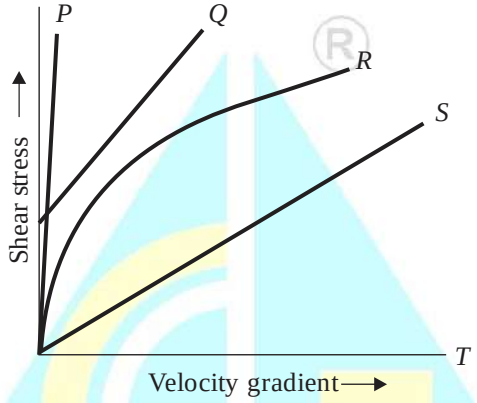
Soils	Skempton's pore pressure coefficient (A)
Normally consolidated clay (NCC)	0.5 to 1
Over consolidated clay (OC)	Equals to OCR
heavily over consolidated clay	– 0.5 to 0

Very loose saturated fine sand	2 to 3

Hence, the correct option is (D).

Question 24 **[Fluid Mechanics : Properties of Fluids]**

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-Newtonian fluid; S → Newtonian fluid

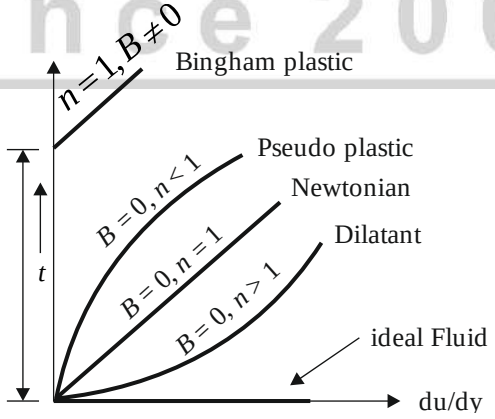
(B) P→ Real solid; Q → Ideal Bingham plastic
S→ Newtonian fluid: T→ Ideal Fluid

(C) P→ Ideal Fluid: Q→ Ideal Bingham plastic
R→ Non-Newtonian fluid: T→ Real solid

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

Ans. (B)

Sol. $B =$ Initial yield stress (i.e., $B \neq 0$)



- Various types of newtonian & non-newtonian fluids are shown in the figure.
- Fluids which follows Newton's law of viscosity $\left(\tau = \mu \frac{du}{dy}\right)$ are called **Newtonian Fluids** and those fluids which do not obey this rule are called **Non-Newtonian Fluids**.
- General relationship between shear stress and velocity gradient is given by

$$\tau = A\left(\frac{du}{dy}\right)^n + B$$

- In the figures shown above, slope of the curve is called apparent viscosity.
- Fluid for which apparent viscosity increases with du/dy are called **Dilatant.**
- Dilatant fluids are also called shear thickening fluids. Examples of dilatant fluids are solution with suspended starch or sand, sugar in water.
- Fluids for which apparent viscosity decreases with du/dy are called **Pseudo Plastic**.
- Pseudo plastic fluid are also called shear thinning fluid. Examples are paints, polymer solutions, blood, paper pulp, syrup, molasses, milk, gelatine.
- Bingham Plastic (ideal plastic) fluids require a certain minimum shear stress t_y (yield stress) before they start flowing. Examples : tooth paste, sewage sludge, drilling mud have time dependent Newtonian Behaviour.

Hence, the correct option is (B).

Question 25 **[Environmental Engineering : Air Pollution]**

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 separator
(R)	CO	(iii)	Lime scrubbing
(S)	Particles	(iv)	NH_3 injection

(A) P-i, Q-ii, R-iii, S-iv (B) P-ii, Q-i, R-iv, S-iii

(C) P-ii, Q-iii, R-iv, S-i (D) P-iv, Q-iii, R-i, S-ii

Ans. (D)

Sol. (I) Following treatment techniques are used to remove particulate Matter (PM).

(a) Settling chambers

(b) Inertial or Impact separators

(c) Centrifugal separators or Cyclonic separators

(d) Filters

(e) Electrostatic precipitators

(f) Scrubbers or wet collectors

(II) Following treatment techniques are used to remove/control gaseous contaminants

(a) Combustion techniques

- This method is used when gases are of organic nature.
- Equipments used in combustion are:

(i) vapour incinerators

(ii) after burners

(iii) Flares (process is called as flaring)

Note: Flaring (i.e. combustion method) is suitable for the removal of carbon monoxide because during combustion, carbon reacts with carbon monoxide to form CO_2.

(b) Absorption

- In this method, effluent gases are passed through absorbers (or scrubbers) which contain liquid absorbents that remove various gaseous pollutants.

Gaseous pollutant	Common absorbent used as solid form
SO_2	Dimethylaniline, ammonium sulphite, sodium sulphite etc.
H_2S	Mixture of NaOH & phenol, soda Ash etc.
NO_x	Water, qeueous nitric acid
HF	Water, NaOH

(c) Adsorption technique

- In this method, the effluent gases are passed through adsorbers which contain solids of porous structure.

Gaseous pollutant	Common adsorbent used as solid form
SO_2	Pulverised limestone or Dolomite
H_2S	Iron oxide

NO_x	Silica gel
HF	Lump limestone

Hence, correct option is (D).

Question 26 **[Environmental Engineering : Air Pollution]**

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

(A) CO_2 (B) CH_4

(C) H_2S (D) H_2O

Ans. (C)

Sol. Glucose does not contain Sulphur so, anaerobic decomposition of glucose does not release H_2S.

Hence, the correct option is (C).

Question 27 **[Transportation Engineering : Railway, Runway and Taxiway Design]**

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%

Ans. (C)

Sol. 1. Given, RL of 0 m = 100 m

2. RL for 0 to 200 m (gradient + 1%)

$$= 100 + 200 \times \frac{1}{100}$$
$$= 102 \text{ m}$$

3. RL for 200 to 600 m (gradient – 1%)

$$= 102 - (600 - 200) \times \frac{1}{100}$$

$$= 98 \text{ m}$$

4. RL for 600 to 1200 m (gradient + 0.8%)

$$= 98 + 600 \times \frac{0.8}{100}$$

$$= 102.8$$

5. RL for 1200 to 1600 m (gradient + 0.2%)

$$= 102.8 + 400 \times \frac{0.2}{100}$$

$$= 103.6$$

6. RL for 1600 to 2000 m (gradient – 0.5%)

$$= 103.6 - 400 \times \frac{0.5}{100}$$

$$= 101.6$$

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

Hence, the correct option is (C).

Question 28 **[Transportation Engineering : Railway, Runway and Taxiway Design]**

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

(A) Highways, Railways, and Taxiways (B) Highways and Railways only

(C) Railways and Taxiways only (D) Highways only

Ans. (B)

Sol. Highways and railways, the outer edge is raised above the inner edge in horizontal curve.

Hence, the correct option is (B).

Question 29 **[Transportation Engineering : Pavement Design]**

Various stresses in jointed plain concrete pavement with slab size of $3.5m \times 4.5m$ 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) $S_{wl}^c + S_t^c$ (B) $S_{wl}^e + S_t^e + S_f$

(C) $S_{wl}^e + S_t^e - S_f$ (D) $S_{wl}^c + S_t^c + S_f$

Ans. (A)

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

Hence, the correct option is (A).

Question 30 **[Geomatics Engineering : Field Astronomy & Photogrammetric Surveying]**

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) 100 (B) 150

(C) 125 (D) 200

Ans. (B)

Sol. Given,

Flying height $(H) = 3000$ m

Elevation $(h) = 1050$ m

Scale $(S) = 1:13000$

We know that,

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

Where,

f = focal length

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

$$\frac{1}{13000} = \frac{f}{1950}$$

$$f = \frac{1950}{13000} = 0.15 \text{ m} = 150 \text{ mm}$$

Hence, the correct option is (B).

Question 31 **[Geomatics Engineering : Theodolites & Plane Table Surveying]**

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-ii, Q-iii, R-iv, S-i (B) P-iv, Q-iii, R-ii, S-i

(C) P-i, Q-iii, R-ii, S-iv (D) P-iii, Q-iv, R-i, S-ii

Ans. (B)

Sol.

- Bubble tube is used for levelling
- Plumb bob is used for centering
- Tangent screw in theodolite is used for minor movements
- Stadia cross wire is used in Tacheometry

Hence, the correct option is (B).

Question 32

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 $30^0 30' 00'', 30^0 29' 40'', 30^0 30' 20''$ and $30^0 31' 20''$. Assuming that each measurement is taken with equal precision, the most probable value of the bearing is

(A) $30^0\ 29'\ 40''$ (B) $30^0\ 30'\ 20''$

(C) $30^0\ 30'\ 00''$ (D) $30^0\ 31'\ 20''$

Ans. (B)

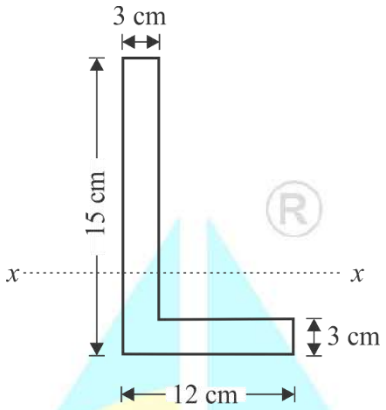
Sol. The most probable value $= \dfrac{30^0 30' 00'' + 30^0 29' 40'' + 30^0 30' 20'' + 30^0 31' 20''}{4}$

$$= 30^0 30' 20''$$

Hence, the correct option is (B).

Question 33 **[Steel Structures : Plastic Analysis]**

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



(Figure NOT to scale)

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

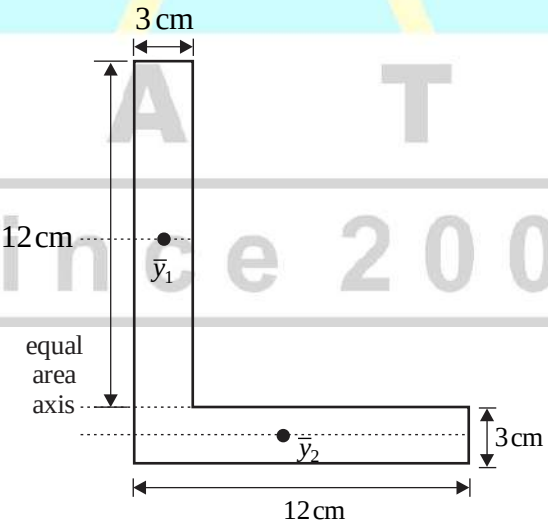
Ans. **1.75 to 1.85**

Sol. Given,

$$Z_e = 150.92 cm^2$$

We know that,

$$\text{Shape factor} = \frac{Z_p}{Z_e}$$



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

$$= \frac{72}{2}(6+1.5) = 270$$

$$\text{SF} = \frac{270}{150.92} = 1.79$$

Question 34 **[Geotechnical Engineering : Pile Foundation]**

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. 545 to 555

Sol. Given,

$L = 10$ m

$d = 0.7$ m

$C = 50$ kPa

$\alpha = 0.5$

Net ultimate uplift pullout capacity

$$Q_{net} = \alpha C \pi d L$$

$$= 0.5 \times 50 \times \pi \times 0.7 \times 10$$

$$= 549.78 \text{ kN/m}$$

Question 35 **[Fluid Mechanics : Open Channel Flow]**

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. 2.88 to 2.94

Sol. Given,

$$B = 2 \text{ m},\ Q = 30 \text{ m}^3/\text{s},\ S = \frac{1}{300}$$

$$\alpha = 1.1,\ g = 10 \text{ m/s}^2$$

At critical condition,

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

Where,

$$A_c = 2y_c$$

$$T_c = B$$

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

$$2y_c = \left(\frac{1.1\times 30^2 \times 2}{10}\right)^{1/3}$$

$$2y_c = 5.83$$

$$y_c = \frac{5.83}{2}$$

$$y_c = 2.915 \text{ m}$$

Q.36 to Q.65 Carry TWO Marks Each

Question 36 **[Engineering Mathematics : Probability & Statistics]**

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) 20% (D) 30%

Ans. (C)

Sol. **Given :**

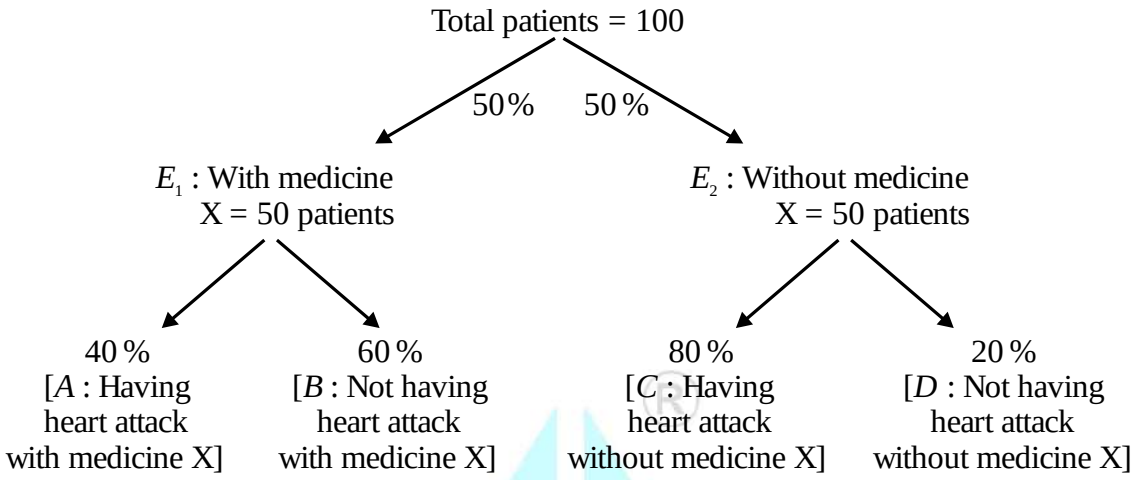
Probability of having heart attack without medicine X = 80 %

Since, medicine X reduces the probability of having a heart attack by 50 %

Therefore, probability of having a heart attack with medicine X.

$$= (80\%)\times 0.5$$

$$= 40\%$$



Hence, probability that a random selected patient, out of 100 patients, takes medicine X and has heart attack is

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

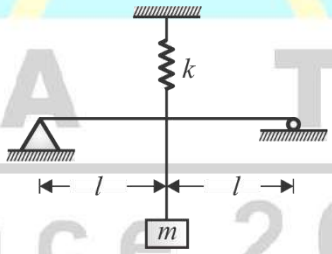
$$= \frac{50}{100} \times \frac{40}{100} = \frac{20}{100}$$

$$= 20\%$$

Hence, correct option is (C).

Question 37 **[Engineering Mechanics]**

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) $\sqrt{\frac{kl^3 + 6EI}{ml^3}}$

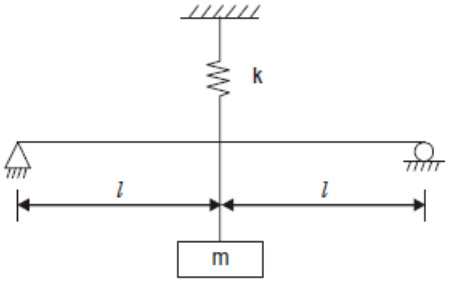
(B) $\sqrt{\frac{kl^3 + 48EI}{ml^3}}$

(C) $\sqrt{\frac{6EIk}{(kl^3 + 6EI)m}}$

(D) $\sqrt{\frac{48EIk}{(kl^3 + 48EI)m}}$

Ans. (A)

Sol.



Let us consider stiffness of beam as k_b.

Here both the stiffness elements are in parallel.

$$\Rightarrow \quad k_{eq} = k_1 + k_2$$

$$= k + \frac{48EI}{(2\ell)^3} = k + \frac{6EI}{\ell^3}$$

Natural frequency $\omega_n = \sqrt{\frac{k_{eq}}{m}}$

$$= \sqrt{\frac{\left(k + \frac{6EI}{\ell^3}\right)}{m}} = \sqrt{\frac{k\ell^3 + 6EI}{m\ell^3}}$$

Hence, the correct option is (A).

Question 38 **[Construction Materials & Management]**

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) Both P and Q are FALSE
(D) P is FALSE and Q is TRUE

Ans. (MTA)

Sol.

$$C/s = \frac{54000 - 30000}{15 - 12} = 8000\,\text{Rs/day}$$

Note : If C/s is less than indirect cost per day then it would be economically advisable to complete the activity early by crashing. Hence both the statements P&Q are correct.

Question 39 **[Strength of Materials : Theory of Columns and Shear Centre]**

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 $12\times10^{-6}/^{0}\,\mathrm{C}$. 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) $298^{0}\mathrm{C}$ (B) $85^{0}\mathrm{C}$

(C) $400^{0}\mathrm{C}$ (D) $250^{0}\mathrm{C}$

Ans. (A)

Sol. Given

Slenderness ratio $\left(\frac{l}{r}\right)=105$

Coefficient of thermal expansion of steel $(\alpha)=12\times10^{-6}/^{o}\mathrm{C}$

Effective length of bar $(l_{eff})=0.5l$

We know that,

Temperature stress $(\sigma_{temp})=E\alpha\Delta T$

Buckling/critical stress $(\sigma_{cr})=\frac{\pi^2E}{\lambda_{eff}^2}$

$$=\frac{\pi^2E}{\left(\frac{l_{eff}}{r}\right)^2}$$

$$\therefore\quad E\alpha\Delta T=\frac{\pi^2E}{\left(\frac{0.5l}{r}\right)^2}$$

$$\Delta T=\frac{\pi^2}{\alpha\times\lambda^2}=\frac{\pi^2}{12\times10^{-6}\times(105\times0.5)^2}$$

$\Delta T=298.40^{0}\mathrm{C}\simeq298^{0}\mathrm{C}$

Hence, the correct option is (A).

Question 40 **[Geotechnical Engineering : Retaining Wall & Earth Pressure]**

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?

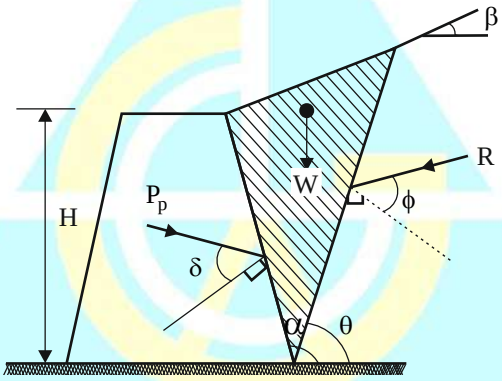
(A) Both P and Q are TRUE (B) P is TRUE and Q is FALSE

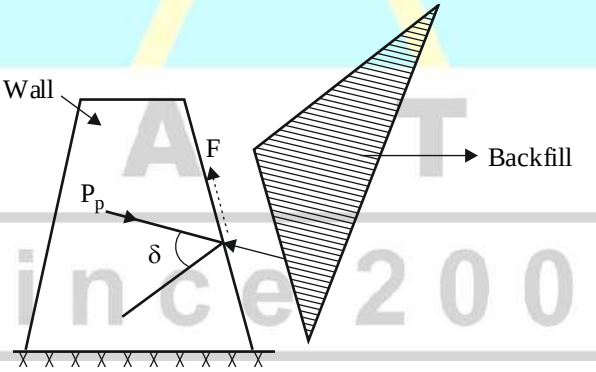
(C) Both P and Q are FALSE (D) P is FALSE and Q is TRUE

Ans. (D)

Sol.

- When rough retaining wall moves toward the back fill passive earth pressure (P_P) condition will develop which can be represented with the help of diagram shown below.





- Hence wall friction force/resistance (F) mobilizes in upward direction along the wall.
- Earth pressure due to surcharge is assumed to be constant along the depth of retaining wall & actual variation of stress due to surcharge is neglected.

Hence, the correct option is (D).

Question 41 **[Fluid Mechanics : Open Channel Flow]**

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) 2.39 to 2.42 (B) 1.94 to 1.97

(C) 2.24 to 2.27 (D) 2.61 to 2.64

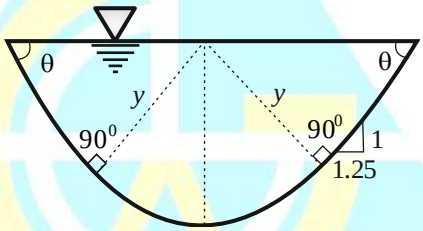
Ans. (A)

Sol. Given,

$$S = \frac{1}{1500}, Q = 25\ m^3/s$$

$$n = 0.013$$

Side slope $= 1.25H:1V$



$$\cot\theta = 1.25$$

$$\tan\theta = \frac{1}{1.25}$$

$$\theta = 38.659 \approx 38.66^0$$

$$\theta = 0.6747 \approx 0.675 \text{ radian}$$

We know that,

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

Where,

$Q =$ Discharge

$A =$ Cross Sectional Area

$$= y^2(\theta + \cot\theta)$$

$$= y^2(0.675 + 1.25)$$

$$= 1.925y^2$$

$R =$ Hydraulic radius $= \dfrac{A}{P}$

$P =$ Perimeter

$= 2y(\theta + \cot\theta)$

$$R = \frac{y^2(\theta+\cot\theta)}{2y(\theta+\cot\theta)}$$

$$= \frac{y}{2}$$

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

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

$$25 = 76.923 \times 1.925 \times \left(\frac{1}{2}\right)^{2/3} \times y^2 \times y^{2/3} \times 0.0258$$

$$25 = 3.820 \times \left(\frac{1}{2}\right)^{2/3} \times y^{8/3}$$

$$25 = 3.820 \times 0.6299 \times y^{8/3}$$

$$y^{8/3} = \frac{25}{3.820 \times 0.6299}$$

$$y^{8/3} = 10.389$$

$$y = (10.389)^{\frac{3}{8}}$$

$$y = 2.40 \text{ m}$$

Hence, the correct option is (A).

Question 42 **[Environmental Engineering : Treatment of Water]**

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 less than 0.64 mm and diameter of ilmenite particles is slightly less than 0.10 mm

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

Ans. (A)

Sol. Given,

For anthracite particles

$$G_1 = 1.50, d_1 = ?$$

For silica

$$G_2 = 2.60, d_2 = 0.20\,\text{mm}$$

For ilmenite sand

$$G_3 = 4.20, d_3 = ?$$

After backwashing the particles should settle forming three layers,

Coarse anthracite $G_1 = 1.5, d_1 = ?$
Silica sand $G_2 = 2.60, d_2 = 0.20\,\text{mm}$
Ilmenite sand $G_3 = 4.20, d_3 = ?$

For coarse anthracite

$$V_S = \frac{1}{18\mu} \times \rho g d_1^2 (G_1 - 1)$$

$$V_S = \frac{1}{18\mu} \times \rho g d_1^2 (1.5 - 1) \qquad \ldots (i)$$

For silica sand,

$$V_S = \frac{1}{18\mu} \times \rho g d_2^2 \left(G_2 - 1\right)$$

$$V_S = \frac{1}{18\mu} \times \rho g d_2^2 \left(2.60 - 1\right) \quad \ldots \text{(ii)}$$

For ilmenite sand,

$$V_S = \frac{1}{18\mu} \times \rho g d_3^2 \left(G_3 - 1\right)$$

$$V_S = \frac{1}{18\mu} \times \rho g d_3^2 \left(4.20 - 1\right) \quad \ldots \text{(iii)}$$

From equation (i) and (ii)

$$\frac{1}{18\mu} \times \rho g d_1^2 \left(1.5 - 1\right) = \frac{1}{18\mu} \times \rho g d_2^2 \left(2.60 - 1\right)$$

$$(1.5 - 1) d_1^2 = (2.6 - 1) d_2^2$$

$$0.5 \times d_1^2 = 1.6 \times 0.20^2$$

$$d_1^2 = \frac{1.6 \times 0.20^2}{0.5}$$

$$d_1^2 = 0.128$$

$$d_1 = \left(0.128\right)^{1/2}$$

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

From equation (ii) and (iii)

$$(2.6 - 1) \times 0.20^2 = (4.20 - 1) \times d_3^2$$

$$0.064 = 3.20 \times d_3^2$$

$$d_3 = \left(\frac{0.064}{3.20}\right)^{1/2}$$

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

So, the diameter of the anthracite particles slightly less than 0.35 mm and diameter of the ilmenite particles is slightly greater than 0.141 mm

Hence, the correct option is (A).

Question 43 **[Transportation Engineering : Traffic Engineering]**

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) 65 (D) 70

Ans. (B)

Sol.

Speed range (kmph)	Number of observations	Cumulative number of vehicles	Cumulative % Passed $= \frac{\text{cumulative number of vehicle}}{\sum N} \times 100$
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%
	$\sum N = 500$		

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

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

Hence, the correct option is (B).

Question 44 **[Engineering Mathematics : Vector Calculus]**

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) $\vec{p}\times(\vec{q}\times\vec{r})+\vec{q}\times(\vec{r}\times\vec{p})+\vec{r}\times(\vec{p}\times\vec{q})=\vec{0}$ (B) $\vec{p}\times(\vec{q}\times\vec{r})=(\vec{p}\cdot\vec{r})\vec{q}-(\vec{p}\cdot\vec{q})\vec{r}$

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

Ans. (A, B, D)

Sol. **Given :**

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

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

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

From option (A) :

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

Note :

Vector triple product :

For vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$. We define the Vector triple product as.

$\vec{A}\times(\vec{B}\times\vec{C})=\vec{B}.(\vec{A}.\vec{C})-\vec{C}.(\vec{A}.\vec{B})$

This is obtained using the "bac−cab" rule.

Now, $\vec{q}.(\vec{p}.\vec{r})-\vec{r}(\vec{p}.\vec{q})+\vec{r}(\vec{q}.\vec{p})-\vec{p}(\vec{q}.\vec{r})+\vec{p}.(\vec{r}.\vec{q})-\vec{q}(\vec{r}.\vec{p})$ ...(i)

The dot product obeys the following :

Law	Expression
Commutative	$\vec{A}.\vec{B}=\vec{B}.\vec{A}$
Distributive	$\vec{A}.(\vec{B}+\vec{C})=\vec{A}.\vec{B}+\vec{A}.\vec{C}$

From equation (i)

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

Correct option.

From option (B) :

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

This is standard form of vector triple product.

Correct option.

From option (C) :

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

$\vec{p}\times(\vec{q}\times\vec{r})$ cannot be equal to $(\vec{p}\times\vec{q})\times\vec{r}$

because $\vec{p}\times(\vec{q}\times\vec{r})\perp\vec{p}$ and $(\vec{p}\times\vec{q})\times\vec{r}\perp\vec{r}$

so $\vec{p}\times(\vec{q}\times\vec{r})\neq(\vec{p}\times\vec{q})\times\vec{r}$

Incorrect option.

From option (D) :

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

Note :

Scalar Triple product :

$$\vec{A}.(\vec{B}\times\vec{C})=\vec{B}(\vec{C}\times\vec{A})=\vec{C}.(\vec{A}\times\vec{B})$$

If the order is Non cycle then value changes.

$$\vec{A}.(\vec{B}\times\vec{C})\neq\vec{B}(\vec{A}\times\vec{C})$$

$\vec{r}.(\vec{p}\times\vec{q})$ cannot be equal to $(q\times\vec{p}).\vec{r}$

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

Incorrect option.

Hence the correct options are (A, B, D).

Question 45 **[Geotechnical Engineering : Seepage Analysis]**

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) P is FALSE and Q is TRUE

(C) P is TRUE and R is FALSE (D) Both Q and R are FALSE

Ans. (C, D)

Sol. Effect of compaction on structure is found to be more prominent in fine grained soils in comparison to coarse grained soils with increase in water content at a particular compactive effort, orientation of the soil particles improves. Hence structure on dry of optimum ($w<\text{OMC}$) is found to be flocculated and wet of optimum ($w>\text{OMC}$).

- Compacted fine grained soils with flocculated structure has isotropic permeability.

- Phreatic line is the top most flow line in the body of the earth dam. It separates the saturated soil mass from the unsaturated soil mass.
    - Pressure below the phreatic line is hydrostatic and above the phreatic line is atmospheric.
- Heave or blowout typically initiates when the reservoir reaches a critical elevation for the first time, backward erosion piping can occur many years after initial impoundment due to progressive the material transport.

Hence, the correct options are (C, D).

Question 46 **[Transportation Engineering : Highway Materials]**

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

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

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

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

(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)

Ans. (A, C, D) OR (A, C)

Sol.

- In a bituminous mix

$\text{VMA} = \text{Voids in mineral aggregate}$

$\text{VMA} = V_b\% + V_v\%$

where, $V_b\% = \text{Percentage volume of bitumen}$

$V_v\% = \text{Percentage air voids}$

- Toughness is determined by aggregate impact test and hardness is determined by loss angeles abrasion test.
- An initial concavity in CBR curve indicate errors which may occur due to following reasons and also require correction.

(a) Top layer of soil too soft

(b) Top surface of soil specimen is not even

(c) The penetration plunger of the loading machine is not vertical and the bottom of plunger is not horizontal.

Hence, the correct options are (A, C, D) or (A, C).

Question 47

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. 5.11 to 5.15

Sol. **Given :** $i_{eff} = \lim_{m\to\infty}\left(1+\frac{0.05}{\mathrm{m}}\right)^{\mathrm{m}} - 1$

As we know that standard Result of Limits :

(1) $\lim_{x\to\infty}(1+nx)^{\frac{1}{x}} = e^{n}$

(2) $\lim_{x\to\infty}\left(1+\frac{n}{x}\right)^{x} = e^{n}$

Now, from Result (2).

$$i_{eff} = e^{(0.05)} - 1$$
$$= (1.05127 - 1) = 0.05127$$
$$i_{eff} \text{ (in percentage)} = 0.05127\times 100 = 5.127\%$$

Hence, the effective interest rate (in percentage) is 5.13.

Question 48 **[Engineering Mathematics : Linear Algebra]**

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 $\boldsymbol{AB}$ is _____ (in integer).

Ans. 10 to 10

Sol. **Given :** $A = \begin{bmatrix} 2 & 1 & 4 \\ 1 & 0 & 3 \end{bmatrix}$

$$B = \begin{bmatrix} -1 & 0 \\ 2 & 3 \\ 1 & 4 \end{bmatrix}$$

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

$$AB = \begin{bmatrix} (-2)+2+4 & 0+3+16 \\ -1+0+3 & 0+0+12 \end{bmatrix}$$

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

$$|AB| = [48-38]$$

$$|AB| = 10$$

Hence, the determinant of the matrix AB is 10.

Question 49 **[Strength of Materials : Deflection of Beams]**

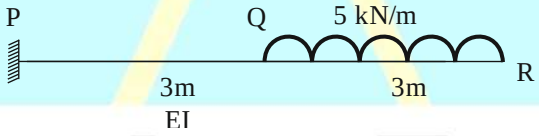
For the 6 m long horizontal cantilever beam PQR shown in the figure, Q is the mid-point. Segment PQ of the beam has flexural rigidity $EI = 2\times10^5$ kN. m^2 whereas the segment QR has infinite flexural rigidity. Segment QR is subjected to uniformly distributed, vertically downward load of 5 kN/m.

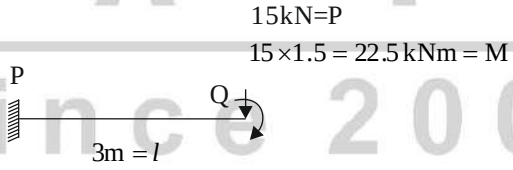
(Figure NOT to scale)

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

Ans. **1.176 to 1.186**

Sol.





Vertical deflection at $Q = \dfrac{Pl^3}{3EI} + \dfrac{Ml^2}{2EI}$

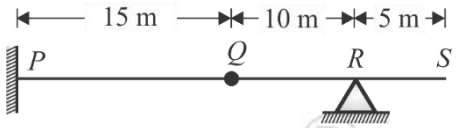
$$\Delta_Q = \frac{(15\text{kN})(3\text{m})^3}{3\times2\times10^5\,\text{kNm}^2} + \frac{(22.5\,\text{kNm})\times3^2}{2\times2\times10^5}$$

$$\Delta_Q = \left(6.75\times10^{-4} + 5.0625\times10^{-4}\right)\text{m}$$

$\Delta_Q = 1.181\text{mm}$

Question 50 **[Structural Analysis : Influence Line Diagram and Rolling Loads]**

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.

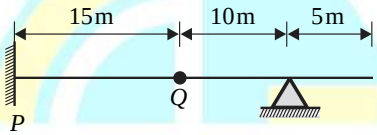


(Figure NOT to scale)

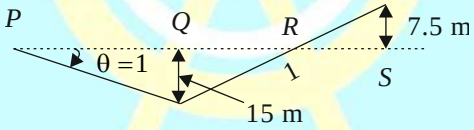
The maximum magnitude of the moment reaction (in kN. m) that can act at the support P due to V is _____ (in integer).

Ans. 150 to 150

Sol.



ILD for moment at *P*,

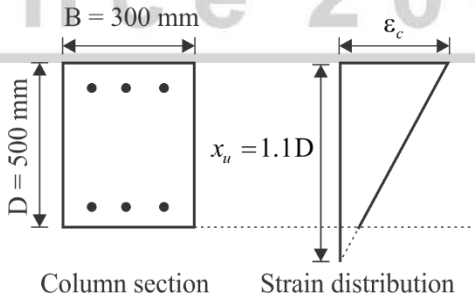


$\therefore$ Maximum moment at *P* will be when load is at *Q*,

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

Question 51 **[RCC Structures : Design & Analysis of Beam and Slab]**

A concrete column section of size $300\ \text{mm} \times 500\ \text{mm}$ 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)

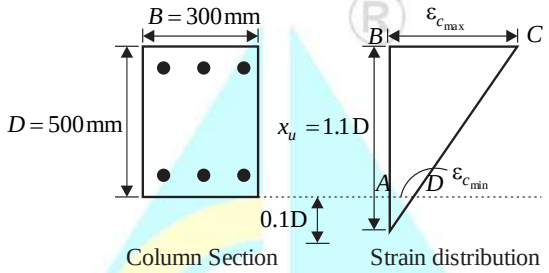
The maximum compressive strain (ε_c) at highly compressive extreme fiber in concrete, where there is no tension in the section, is _____ $\times 10^{-3}$ (rounded off to 2 decimal places)

Ans. 3.20 to 3.40

Sol. The minimum compressive strain in the column

$$\varepsilon_{c_1 \max} = 0.0035 - 0.75\varepsilon_{c_1 \min}$$

$$\varepsilon_{c_1 \min} = \text{strain in the least compressed fibre}$$



In the strain diagram,

From triangle ΔOAD and ΔOBC

$$\Rightarrow \quad \frac{\varepsilon_{c_1 \max}}{1.1D} = \frac{\varepsilon_{c_1 \min}}{0.1D} \Rightarrow \varepsilon_{c_1 \min} = \frac{1}{11}\varepsilon_{c_1 \max}$$

$$\varepsilon_{c_1 \max} = 0.0035 - 0.75 \times \frac{1}{11}\varepsilon_{c_1 \max}$$

$$\Rightarrow \quad \varepsilon_{c_1 \max} = 3.276 \times 10^{-3} = 3.28 \times 10^{-3}$$

Question 52 **[Construction Materials & Management]**

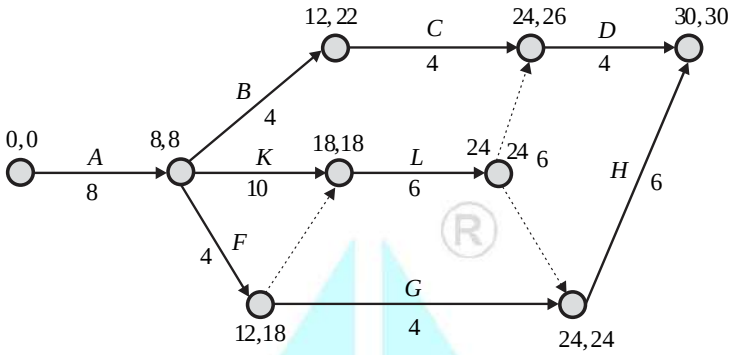
The table shows the activities and their durations and dependencies in a project.

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 to 30

Sol.



Critical path :

$A - K - L - H$

Project duration $= 30$ days

Question 53 **[Geotechnical Engineering : Seepage Analysis]**

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. 0.63 to 0.67

Sol. Given,

$$\Delta H = 15\,\text{m},\ G = 2.65$$

$$N_d = 10,\ \text{FOS} = 2$$

$$L = 3\,\text{m},\ e = ?$$

We know that,

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

Where,

$i_c =$ critical hydraulic gradient

$e =$ void ratio

$$\therefore \quad \Delta h = \frac{\Delta H}{N_d} = \frac{15}{10} = 1.5\ \text{m}$$

$$i = \frac{\Delta h}{L} = \frac{1.5}{3} = 0.5$$

$$\therefore \quad \text{FOS} = \frac{i_{cr}}{i}$$

$$2 = \frac{i_{cr}}{0.5}$$

$$i_{cr} = 1$$

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

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

$$1+e = \frac{1.65}{1}$$

$$e = 1.65-1$$

$$e = 0.65$$

Question 54 **[Geotechnical Engineering : Origin of Soil & Their Properties]**

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. 0.12 to 0.14 OR 12 to 14

Sol. Given,

$$\gamma_{d_{max}} = 1.8 \text{ g/cm}^3$$

$$\gamma_{d_{min}} = 1.3 \text{ g/cm}^3$$

$$G = 2.7$$

We know that,

$$\text{Relative density } (I_D) = \frac{\gamma_{d_{max}}\left(\gamma_d - \gamma_{d_{min}}\right)}{\gamma_d\left(\gamma_{d_{max}} - \gamma_{d_{min}}\right)}$$

$\therefore$ Percentage of air voids (n_a)

$$n_a = a_c \times n$$

$$50\% = 1 \times n$$

$$n = 50\% = 0.5$$

$\therefore$ Void ratio

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

$\therefore$ Dry density (γ_d)

$$(\gamma_d) = \frac{G\gamma_w}{1+e}$$

$$= \frac{2.7 \times 1}{1+1}$$

$$= 1.35 \text{ g/cm}^3$$

$$I_D = \frac{\gamma_{d_{max}}(\gamma_d - \gamma_{d_{min}})}{\gamma_d(\gamma_{d_{max}} - \gamma_{d_{min}})}$$

$$I_D = \frac{1.8(1.35-1.3)}{1.35(1.8-1.3)}$$

$$I_D = 0.1333$$

$$I_D = 13.33\%$$

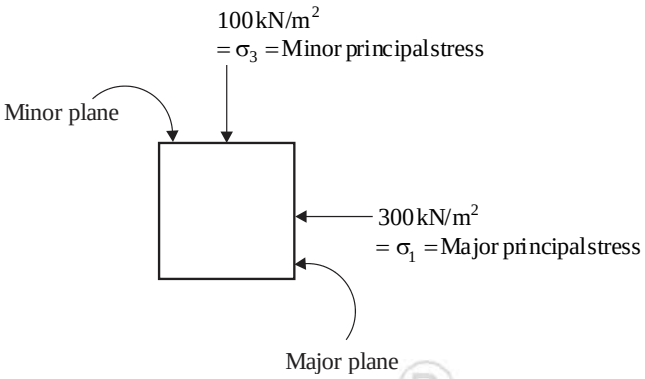
Question 55 **[Geotechnical Engineering : Shear Strength of Soil]**

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 the nearest integer).

Ans. 30 to 30

Sol. In stress-path triaxial testing, we can control both radial and axial stress.

Failure situation



$$\sigma_1 = \sigma_3 \tan^2\left(45^0 + \frac{\phi}{2}\right) + 2C\tan\left(45^0 + \frac{\phi}{2}\right)$$

$$300 = 100\tan^2\left(45^0 + \frac{\phi}{2}\right) + 0$$

[Since for drained test $C = 0$]

$\Rightarrow \quad \phi = 30^0$

Angle between normal to major plane and failure plane is $45 + \frac{\phi}{2}$.

Angle between normal to minor plane and failure plane is $45^0 - \frac{\phi}{2}$.

$\Rightarrow$ Angle between minor plane and failure plane

$$= 45^0 - \frac{\phi}{2} = 45^0 - \frac{30^0}{2} = 30^0$$

Question 56 **[Engineering Hydrology : Infiltration]**

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 $\phi-$index of this storm is _____ cm/hr (rounded off to 2 decimal places)

Ans. 0.64 to 0.65

Sol.

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

$$=11-6=5\text{cm}$$

$$\therefore \quad \text{W-index} = \frac{5}{8} = 0.625 \text{ cm/hr}$$

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

So, ϕ-index $= \dfrac{5-0.5\times1}{(8-1)} = 0.6428\,\text{cm/hr}$

Question 57 **[Fluid Mechanics : Flow Through Pipes]**

A 500 m long water distribution pipeline P with diameter 1.0 m, is used to convey $0.1\,\text{m}^3/\text{s}$ 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. 0.70 to 0.80

Sol. Given,

$$L_P = 500\,\text{m},\ D_p = 1\text{m},\ Q_p = 0.1\text{m}^3/\text{s}$$

$$L_Q = 500\,\text{m},\ Q_Q = 0.1\text{m}^3/\text{s}$$

$$f_P = 0.04,\ f_Q = 0.01$$

$$\frac{f_P L_P Q_P^2}{12.1 D_P^5} = \frac{f_Q L_Q Q_Q^2}{12.1 D_Q^5}$$

$$\frac{0.04}{12.1\times 1^5} = \frac{0.01}{12.1\times D_Q^5}$$

$$D_Q^5 = \frac{0.01\times 12.1\times 1^5}{0.04\times 12.1}$$

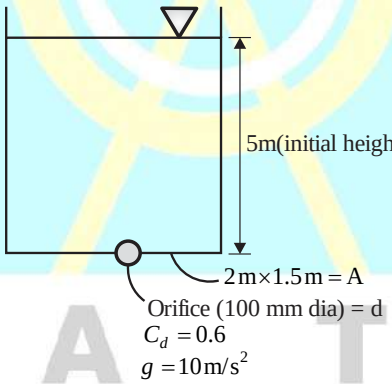
$$D_Q = 0.757\,\text{m}$$

Question 58 **[Fluid Mechanics : Fluid Dynamics]**

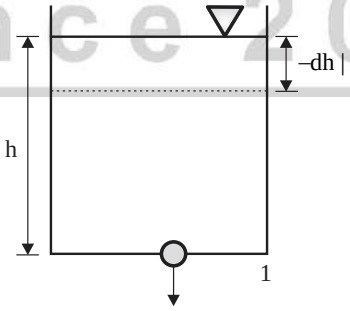
A $2\,\text{m}\times 1.5\,\text{m}$ tank of 6 m height is provided with a 100 mm diameter orifice at the center of its base. The orifice is plugged and the tank is filled up to 5 m height. Consider the average value of discharge coefficient as 0.6 and acceleration due to gravity (g) as $10\,\text{m/s}^2$. 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. 102.00 to 106.00

Sol.



Let at any instant depth of liquid in tank is '*h*' m and in time (*dt*), the depth falls by (–*dh*)



$$Q.dt = A_0(-dh)$$

$$\left(C_d \cdot \left(\frac{\pi d^2}{4}\right)\sqrt{2gh}\right)dt = A_0(-dh)$$

$$t = \int dt = \frac{A_0}{C_d \cdot \frac{\pi d^2}{4}\sqrt{2g}} \int_{H_1}^{H_2} \left(\frac{-dH}{\sqrt{h}}\right)$$

$$t = \frac{A_0}{C_d \cdot \frac{\pi d^2}{4}\sqrt{2g}} \left[2\left(\sqrt{H_1} - \sqrt{H_2}\right)\right]$$

$$t = \left[\frac{2 \times 1.5\,m^2}{0.6 \times \frac{\pi}{4}(0.1)^2\,m^2\sqrt{2 \times 10\,\frac{m}{s^2}}} \times 2\left(\sqrt{5} - \sqrt{3.5}\right)m^{1/2}\right] \text{sec}$$

$$t = 103.985 \text{sec}$$

Question 59 **[Fluid Mechanics : Open Channel Flow]**

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. 3.30 to 3.70

Sol. Width of channel, $B = 4\,\text{m}$

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

Depth of flow, $y = 0.4\,\text{m}$

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

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

Where y_c is depth at section of critical maximum contraction

$$0.4796 = 1.5\,y_c$$

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

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

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

$$q = 0.566\,\text{m}^3/\text{s}/\text{m}$$

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

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

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

Alternatively,

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

where, $E_1 = 0.4796\,\text{m}$

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

Question 60 **[Environmental Engineering : Treatment of Water]**

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).

Ans. 3.00 to 3.40

Sol. Given,

Discharge, $Q = 10\,\text{MLD}$

Detention period, $t_d = 2\,\text{hr}$

Overflow rate, $V_0 = 40{,}000$ litres/m^2/day

$H = ?$

$$\text{Surface area of tank} = \frac{\text{Discharge}}{\text{Over flow rate}} = \frac{Q}{V_0}$$

So,

$$\text{S.A.} = \frac{10\times10^6 \text{ L/day}}{40{,}000 \text{ L/m}^2\text{/day}}$$

$$\text{S.A.} = 250 \text{ m}^2$$

$$\text{Volume of tank } (V) = Q \times t_d$$

$$= \frac{10\times10^6\times10^{-3}}{24}\times 2\,\text{m}^3$$

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

Hence,

Height of water in tank

$$\text{or} \qquad = \frac{V}{S.A}$$

Height of setting zone

$$H = \frac{833.33\,\text{m}^3}{250\,\text{m}^2}$$

$$H = 3.33\,\text{m}$$

Note : In reality, height of water in tank OR height of settling zone is estimated by above approach but if the bottom of sedimentation tank is assumed to be sloping or hoppered (i.e., sludge zone is also considered) then height of water in tank is determined as follows:

Using,

$$\text{Volume of tank } (V) = D^2\left(\frac{\pi}{4}H + 0.011D\right) \qquad \ldots \text{(i)}$$

As,

$$\text{S.A.} = \frac{\pi}{4}D^2 = 250 \text{ m}^2$$

$$D = 17.835\,\text{m}$$

So, $833.33 = (17.835)^2 \left(\frac{\pi}{4} H + 0.011(17.835) \right)$

So, $H = 3.085\,\text{m}$

Question 61 **[Environmental Engineering : Treatment of Sewage]**

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. 9.9 to 10.2

Sol. Organic waste $= C_{240}O_{200}H_{180}N_5S$

Weight of organic waste $= 1\text{kg}$

Burning of organic waste converts

Sulphur into Sulphur dioxide as follows :

$$\underset{(6362\text{ g})}{C_{240}\ O_{200}\ H_{180}N_5S} + O_2 \rightarrow xCO_2 + yH_2O + zH_2O + \underset{(64\text{ g})}{SO_2}$$

i.e., 6362 of organic waste produces 64g of Sulphur dioxide.

So,

1 kg of organic waste produces $\frac{64}{6362} \times 1000\,\text{gm of } SO_2$

So, Amount of SO_2 produced $= 10.05\,\text{gm/kg}$

Question 62 **[Transportation Engineering : Railway, Runway and Taxiway Design]**

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 the nearest integer).

Ans. 112 to 116

Sol. Given,

$R = 1080\text{ m}$

$V_{eq} = 70\text{ kmph}$

$C_D = 10$ cm

$V_{max} = ?$

We know that,

$$e_{th} = e_{act} + C_D$$

$$e_{th} = \frac{GV^2}{127R} + C_D$$

$$= \frac{G \times V^2}{127R} + C_D$$

$$= \frac{1.75 \times 70^2}{127 \times 1080} + 0.1$$

$$= 0.1625$$

$$\therefore e_{th} = \frac{GV_{max}^2}{127R}$$

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

$$\frac{1.75 \times V_{max}^2}{127 \times 1080} = 0.1625$$

$$V_{max}^2 = \frac{0.1625 \times 127 \times 1080}{1.75}$$

$$V_{max}^2 = 12736.285$$

$$V_{max} = (12736.285)^{1/2}$$

$$V_{max} = 112.85 \text{ kmph}$$

Question 63 **[Transportation Engineering : Geometrical Design of Highway]**

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

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. 117.00 to 120.00

Sol. $n_1 = +3\%$

$n_2 = -5\%$

$v = 80\,\text{km/h}$

$h_1 = 2.30\,\text{m}$

$h_2 = 0.35\,\text{m}$

$t_r = 2\,\text{sec.}$

$f = 0.36$

Deflection angle, $N = |n_1 - n_2| = |3-(-5)| = 8\%$

Now stopping sight distance, S is given as

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

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

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

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

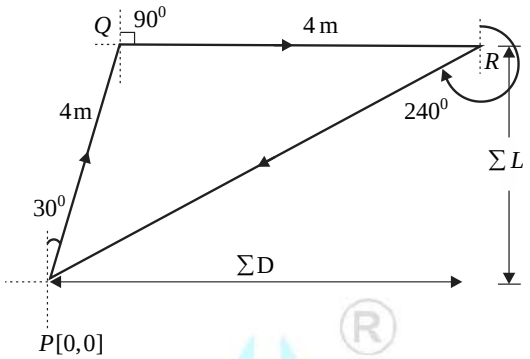
$$= 117.93\,\text{m} > 114.47$$

Question 64 **[Geomatics Engineering : Traversing]**

A child walks on a level surface from point P to point Q at a bearing of 30^0, from point Q to point R at a bearing of 90^0 and then directly returns to the starting point P at a bearing of 240^0. 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. 6 to 8

Sol.



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

$$= PQ\sin 30^0 + QR\sin 90^0$$

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

$$= 6\,\text{m}$$

Vertical distance of traverse from P to $R = \sum L$

$$= PQ\cos 30^0 + QR\cos 90^0$$

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

$$\Rightarrow \quad PR = \sqrt{(\sum L)^2 + (\sum D)^2}$$

$$= \sqrt{(6)^2 + \left(2\sqrt{3}\right)^2} = \sqrt{48} = 6.93\,\text{m} \simeq 7\,\text{m}$$

Question 65 **[Geomatics Engineering : Levelling]**

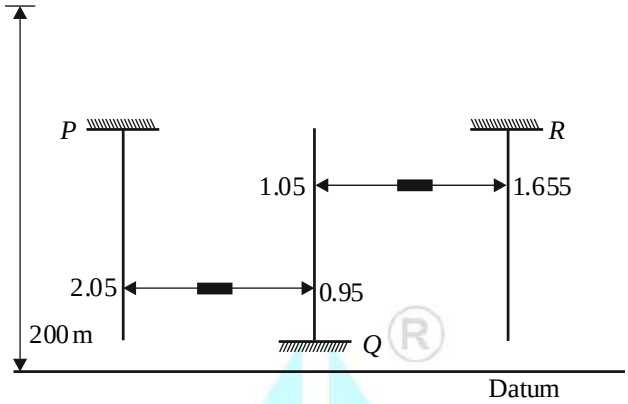
Differential levelling is carried out from point P (BM: +200.000 m) to point R. The readings taken are given in the table.

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. 199.704 to 199.706

Sol.



Using go through line (starting from P)

$$-2.05+(1.05-0.95)+1.655=-0.295$$

(Means R is 0.295 lower than P)

$$\therefore \quad RL\,of\ R=200-0.295=199.705$$