MADE EASY

GATE 2024

CIVIL ENGINEERING

Exam held on
04/02/2024
(Forenoon Session)

Memory based
Questions & Solutions

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SECTION - A GENERAL APTITUDE

Q.1 If $p, q > 0$ and $\frac{p}{q} \neq 1$

For $\left(\frac{p}{q}\right)^{p/q} = \left(p^{\left(\frac{p}{q}-1\right)}\right)$, which of the following option is correct?

(a) $q^p = p^{2q}$ (b) $q^p = p^q$

(c) $\sqrt{q} = \sqrt{p}$ (d) None of these

Ans. **(b)**

Given, $p > 0$, $q > 0$ and $\frac{p}{q} \neq 1$

$$\left(\frac{p}{q}\right)^{p/q} = p^{\left(\frac{p}{q}-1\right)}$$

$\because$ $$\left(\frac{p}{q}\right)^{p/q} = p^{\left(\frac{p-q}{q}\right)}$$

$\because$ $$\left(\frac{p}{q}\right)^{p} = p^{q-q}$$

$\because$ $$\left(\frac{p}{q}\right)^{p} = \frac{p^p}{p^q}$$

$\therefore$ $$q^p = p^q$$

End of Solution

Q.2 In a given day how many times, second hand and the minute hand of a clock, cross each other during 12:05:00 to 12:55:00.

(a) 49 (b) 50

(c) 51 (d) 55

Ans. **(b)**

Between 12:05:00 to 12:55:00

There are 50 interval of 1 minute in one minute second and minute hand crosses one time. So during 12:05:00 to 12:55:00 minute and second hand crosses 50 times.

End of Solution

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Q.3 In a locality the houses are numbered in following manner.

The house number of one side of the road are consecutive odd number starting from 301 and the other side is consecutive even number starting from 302. If the number of houses are same in both sides and the difference of sum of both sides is 27, then total number of house in one side is _____.

Ans. (27)

301 303 305 ------

302 304 306 ------

Let sum of 301 + 303 + 305 + ... = A

and 302 + 304 + 306 + ... = B

Given, $A - B = 27$

and $302 - 301 = 1$

$304 - 303 = 1$

As difference of one pair is 1 and total difference is 27.

$\therefore$ Number of house in one side is 27.

End of Solution

Q.4 3, 7, 15, x, 63, 127, 255

For the above series value of x is

Ans. (31)

$3 \times 2 + 1 = 7$

$7 \times 2 + 1 = 15$

$15 \times 2 + 1 = \boxed{31}$

$31 \times 2 + 1 = 63$

$63 \times 2 + 1 = 127$

$127 \times 2 + 1 = 255$

End of Solution

■■■■

SECTION - B TECHNICAL

TRANSPORTATION

Q.1 The free mean speed is 60 km/hr on a given road. The average space headway at jam density on the road is 8 m. For a linear speed density relationship the maximum flow (in veh/hr/lane) expected on the road is

(a) 1875 (b) 1038

(c) 938 (d) 2075

Ans. (a)

Given, Free mean speed, $v_f = 60$ kmph

Speed headway, $s = 8$ m

At jam density, $k = k_j = \frac{1000}{s} = \frac{1000}{8} = 125$ veh/km

For linear speed density relationship,

Maximum flow, $q_{max} = \frac{v_f k_j}{4}$

$= \frac{60 \times 125}{4} = 1875$ veh/hr

End of Solution

Q.2 The following data is obtained from an axle load survey at a ρ, *k*:
Average rear axle load = 12000 kg
Number of commercial vehicles = 800 per day
The pavement at this site would be reconstructed over a period of 5 years from the data of survey, the design life of the pavement is 15 years. Use the standard axle load as 8160 kg. Vehicle growth rate as 4%. Assume that equivalent wheel load factor (EWLF) and vehicle damage factor (VDF) are equal.
The cumulative standard axle (in msa) for the pavement design is_____.
[Round off to 2 decimal places]

Ans. (33.22)

Number of commercial vehicles = 800 vehicles per day

For vehicle growth rate of 4%,

Number of commercial vehicles after construction period,

$A = 800 \times [1 + 0.04]^5 = 973.32$ veh

Vehicle damage factor, $F = \left(\frac{L_0}{L_5}\right)^4 = \left(\frac{12000}{8160}\right)^4 = 4.67$

$\therefore$ Cumulative standard axle (in msa)

$= \frac{365 ADF\left((1+r)^n - 1\right)}{r \times 10^6} \times LSF = \frac{365 \times 973.32 \times 1 \times 4.67 \times \left[1.04^{15} - 1\right]}{0.04 \times 10^6} = 33.22$ msa

End of Solution

Q.3 A car moving at speed of 60 kmph stops in a total distance of _____, for the given details.

Braking efficiency = 60%
Coefficient of friction = 0.7
Downward gradient = 2%
V = 60 kmph
t_R = 2.5 sec

What is SSD?

Ans. (77.1)

Given, V = 60 km/hr, t_R = 2.5 sec
Braking efficiency, η = 60%
Coefficient of friction, μ = 0.7%
Down grace, s = 2%

Stopping sight distance = Lag distance + Braking distance

$$= 0.278 \times V \times t_r + \frac{V^2}{254(\eta\mu - s)}$$

$$= 0.278 \times 60 \times 2.5 + \frac{60^2}{254(0.6\,(0.7) - 0.02)}$$

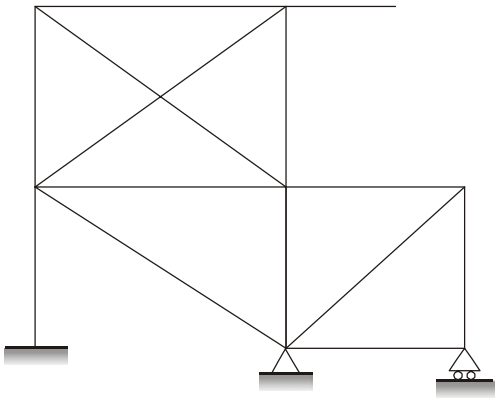
$$= 41.7 + 35.4$$

$$= 77.1 \text{ m}$$

End of Solution

STRUCTURAL ANALYSIS

Q.4 If axial deformations in members are neglected, then degree of freedom of plane frame shown below is _____.



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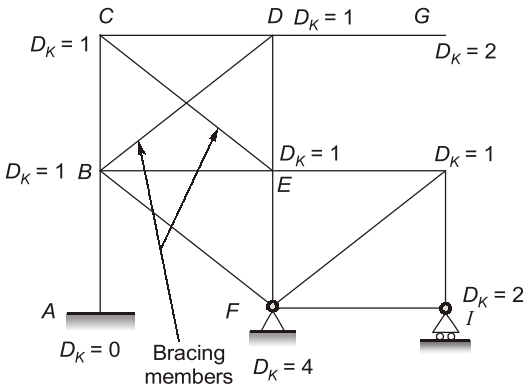
Ans. (13)



$\Rightarrow \quad D_K = 13$

End of Solution

STRENGTH OF MATERIALS

Q.5 Given below is the stress tensor

$$\sigma = \begin{bmatrix} 10 & 0 & 0 \\ 0 & 40 & 0 \\ 0 & 0 & 0 \end{bmatrix} \text{MPa}$$

Maximum shear stress at the point is _____ MPa.

(a) 15 (b) 5

(c) 20 (d) 30

Ans. (c)

$$\sigma = \begin{bmatrix} 10 & 0 & 0 \\ 0 & 40 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

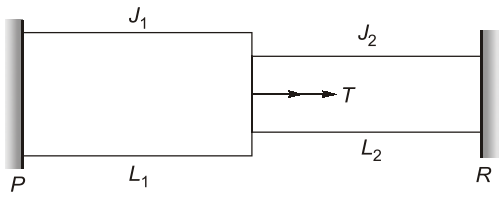
For the given 3-D stress tensor matrix,

$$\sigma_{P_1} = 40, \ \sigma_{P_2} = 10, \sigma_{P_3} = 0$$

$$\text{Maximum shear stress} = \frac{\sigma_{P_1} - \sigma_{P_3}}{2} = \frac{40 - 0}{2} = 20 \text{ MPa}$$

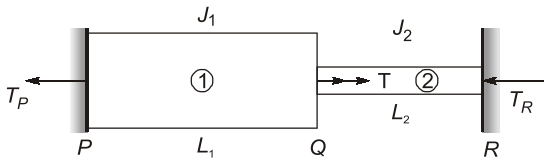
End of Solution

Q.6 For the beam shown in the figure, find the value of $\frac{L_1}{L_2}$ where L_1 and L_2 are the length of member 1 and member 2 respectively.



Given: $\frac{T_P}{T_R} = 4$, $\frac{J_1}{J_2} = 2$

Ans. (0.5)



Let T_P and T_R be the resistive torques at support P and R respectively
From equilibrium. Condition,

$$T_P + T_R = T$$

$\because$ $$T_P = 4\ T_R$$

$\Rightarrow$ $$T_R = \frac{T}{5} \text{ and } T_P = \frac{4T}{5}$$

$$\theta_{PQ} + \theta_{QR} = 0$$

$$\frac{T_P L_1}{4\ J_1} + \frac{T_R L_2}{4\ J_2} = 0$$

$$\frac{4\frac{T}{5} L_1}{J_1} + \frac{\frac{T}{5} L_2}{J_2} = 0$$

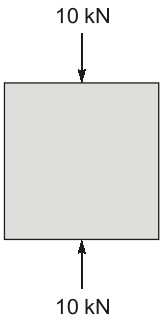
For $$J_1 = 2\ J_2$$

$$\frac{L_1}{L_2} = \frac{1}{2}$$

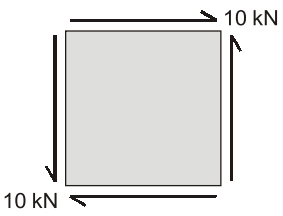
End of Solution

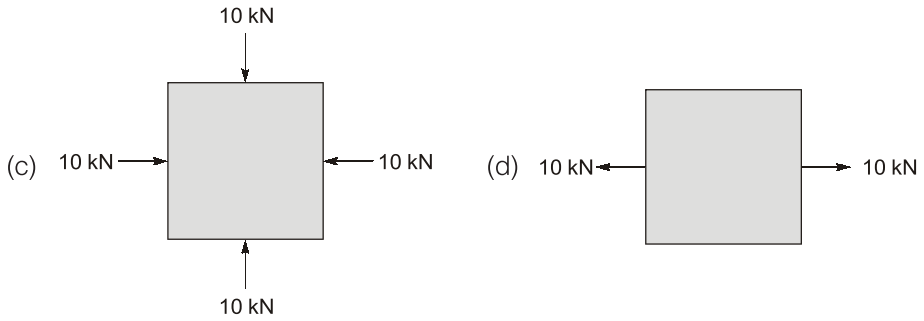
Q.7 Choose the Mohr's circle diagram corresponding to each stress elements.

(a)

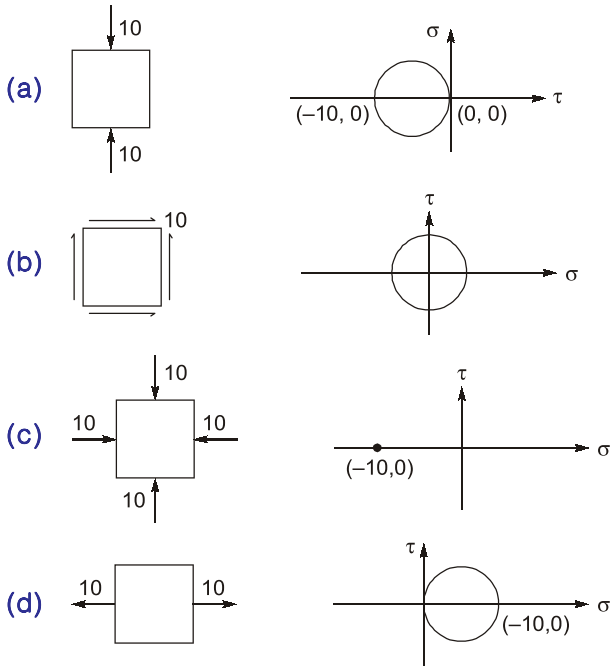


(b)



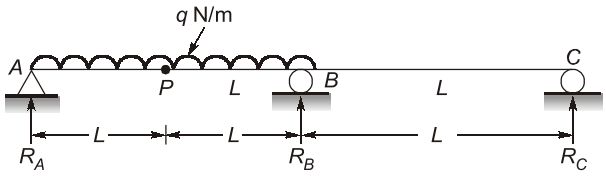


Ans. (*)

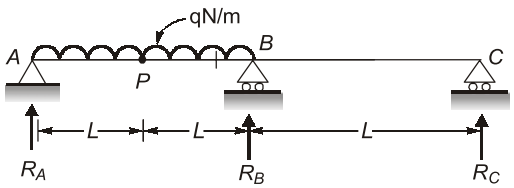


End of Solution

Q.8 What will be the value of vertical reaction at A, B and C?



Ans. (*)



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$$BM_P = 0$$

$$R_A(L) = q \cdot L \cdot \frac{L}{2} \quad \ldots(1)$$

$$-R_C(2L) + (-R_B \times L) + \left(q \times L \times \frac{L}{2}\right) = 0 \quad \ldots(2)$$

$$R_A + R_B + R_C = q(2L) \quad \ldots(3)$$

From 1, 2 and 3

$$R_A = \frac{qL}{2},\ R_B = \frac{5qL}{2},\ R_C = -qL$$

End of Solution

RCC

Q.9 A slab panel with an effective depth of 250 mm is reinforced with 0.2% main reinforcement using 8 mm diameter steel bars. The uniform centre to centre spacing (in mm) at which the 8 mm diameter bars are placed in the slab panel is _____. (Round off to the nearest integer).

Ans. (100)

$$d = 250 \text{ mm}$$
$$A_{st} = 0.2\%$$
$$\phi = 8 \text{ mm}$$
$$S = ?$$

$$A_{st}\% = \frac{A_{st}}{B.d} \times 100$$

$$0.2 = \frac{\left(n \times \frac{\pi}{4}\phi^2\right) \times 100}{B.d}$$

$$\frac{0.2}{100} = \frac{\left(\frac{B}{S}\right) \times \frac{\pi}{4} \times 8^2}{B \times 250}$$

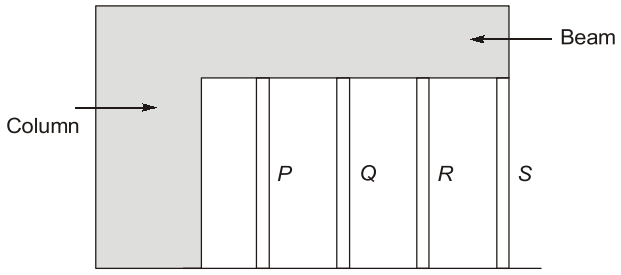
$$S = \frac{\frac{\pi}{4} \times 8^2 \times 100}{0.2 \times 250}$$

$$S = 100.53 \text{ mm}$$

Provide spacing 100 mm.

End of Solution

Q.10 Given below is a cantilever beam, supported on props P, Q, R, S during casting.



The order in which props PQRS will be removed.

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

Ans. (a)

End of Solution

Q.11 For concrete having characteristic strength as 30 MPA, if 40 specimens are tested, then how many specimens should have at least the strength of 30 MPA?

(a) 35
(b) 37
(c) 38
(d) 39

Ans. (c)

As per IS456:2000, atleast 95% of the specimen should have strength equal to more than the characteristics strength.

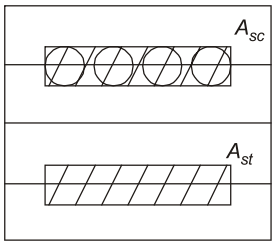
$\therefore$ specimen $= 0.95 \times 40$
$= 38$

End of Solution

Q.12 For a doubly balanced reinforced section, how can the section be made under reinforced?

(a) Increase the area of tension reinforcement
(b) Decrease the area of tension reinforcement
(c) Increase the area of compression reinforcement
(d) Decrease the area of compression reinforcement

Ans. (b, c)



For URS, $x_v < x_{v\,\lim}$

For Doubly reinforced beam,

$$x_v = \frac{0.87 f_y A_{st} - (fsc - 0.45fck)A_{sc}}{0.36fck\,B}$$

$x_v(\downarrow)$ if $A_{st}(\downarrow)$ and $A_{sc}(\uparrow)$

End of Solution

RAILWAY, AIRPORT, BMC

Q.13 Runway length of airport increases by X % for every increase in height of Y m. The values of X and Y are respectively.

Ans. (7, 300)

Runway length of airport increases by 7% for every increase in height of 300 m.

End of Solution

Q.14 The elements that do not increase the strength of structural steel are

(a) Sulphur (b) Manganese

(c) Carbon (d) Chlorine

Ans. (a, d)

Carbon and Manganese increases the strength of structural steel.

End of Solution

Q.15 The number of trains and their corresponding speed for a curved broad gauges section with the radius of 437 m are

- 20 trains at a speed of 40 kmph
- 15 trains at a speed of 50 kmph
- 12 trains at a speed of 60 kmph
- 8 trains at a speed of 70 kmph
- 3 trains at a speed of 80 kmph

If the gauge (centre to centre distance between the rail heads) is taken as 1750 mm, the required equilibrium cant (in mm) will be _____. (rounded off to the nearest integer)

Ans. (88)

$$\text{Average speed of trains} = \frac{20(40) + 15(50) + 12(60) + 8(70) + 3(80)}{20 + 15 + 12 + 8 + 3}$$

$$= \frac{3070}{58}$$

$$= 52.93 \text{ kmph}$$

$$\text{Gauge } (G) = 1750 \text{ mm}$$

$$\therefore \quad \text{Equilibrium cant} = \frac{GV_{avg}^2}{127\,R}$$

$$= \frac{1750 \times (52.93)^2}{127 \times 437}$$

$$= 88.34$$

$$= 88 \text{ mm (to nearest integer)}$$

End of Solution

OPEN CHANNEL FLOW

Q.16 The number of degree of freedom for a natural Open Channel Flow (OFC) with mobile bed is

(a) 2 (b) 3
(c) 5 (d) 4

Ans. (d)

End of Solution

Q.17 A spillway has unit discharge of 7.5 $m^3/s/m$. The flow depth at the downstream horizontal apron is 0.5 m. The tail water depth (m) required to form a hydraulic jump is _____.

Ans. (4.54)

Unit discharge(q) = 7.5 $m^3/s/m$

$$\frac{q^2}{g} = \frac{y_1 y_2 (y_1 + y_2)}{2}$$

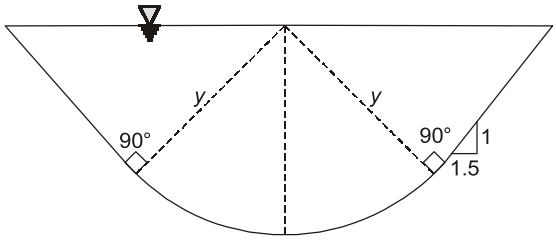
$$\frac{7.5^2}{9.81} = 0.5 y_2 \left(\frac{0.5 + y_2}{2}\right)$$

Tail water depth, y_2 = 4.54 m

End of Solution

IRRIGATION

Q.18 A standard round bottom triangle canal section as shown has a bed slope of 1 in 200. Chezy's Coefficient = 150 $m^{1/2}/s$.



The normal depth of flow (Y) in (m) for carrying discharge of 20 m^3/s is _____.

Ans. (1.10)

Discharge, $Q = A \times V$

Now, Cross-section area, $A = y^2 (\theta_{radian} + \cot\theta) = y^2 (0.588 + 1.5)$
$= 2.088\, y^2$

Perimeter, $P = 2y (\theta_{radian} + \cot\theta)$

now Hydraulic radius, $R = \frac{A}{P}$

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

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Now, $\text{Velocity, } V = C\sqrt{R.S} = 150\sqrt{\left(\frac{y}{2}\right) \times \frac{1}{200}} = \frac{150}{20} y^{1/2}$

Now, $Q = A \times V$

$$20 = 2.088\ y^2 \times \frac{150}{20} \cdot y^{1/2}$$

$\Rightarrow$ $y = 1.10$ m

End of Solution

HYDROLOGY

Q.19 The ordinates of 1 hr UH are :

Time (hr.)	0	1	2	3	4	5	6	7	8	9	10	11
Ordinates (m^3/s)	0	13	50	80	95	85	55	35	15	10	3	0

These ordinates are used to derive 3-hr. UH. The peak discharge (in m^3/s), for the derived 3-hr UH is _____.

Ans. (88.67)

	(I)	(II)	(III)	(IV)	(V) = IV/3
Time (hr)	Ordinate (m^3/s)	Lagged by 1 Hrs	Lagged by 2 Hrs	Ordinate of 3 Hrs DRH	Ordinate of 3 H UH
0	0	–	–	0	0
1	13	0	–	13	4.33
2	50	13	0	63	21
3	80	50	13	143	47.67
4	95	80	50	225	75
5	85	95	80	260	86.67
6	55	85	95	235	78.33
7	35	55	85	175	58.33
8	15	35	55	105	35
9	10	15	35	60	20
10	3	10	15	28	9.33
11	0	3	10	13	4.33
12		0	3	3	1
13			0	0	0
14					

Maximum ordinate of 3H UH is 86.67 m^3/s

End of Solution

Q.20 The return period of large earthquake for a given reason is 200 years. Assuming the earthquake occurrence follows Poisson distribution, the probability that it will exceeded at least once in 50 years is _____ %. (Round off to the nearest integer).

Ans. (22)

$$\Rightarrow \quad \text{Risk} = 1-\left[\frac{\lambda^r \cdot e^{-\lambda}}{r!}\right]$$

$$= 1-\left[\frac{\lambda^0 \cdot e^{-\lambda}}{0!}\right]$$

$$\lambda = np = 50 \times \frac{1}{200} = 0.25$$

Now, $\quad \text{Risk} = 1 - [e^{-0.25}]$

$$= 0.2211 \text{ or } 22.11\%$$

End of Solution

Q.21 A 2 m × 2 m tank of 3 m height has inflow outflow and stirring mechanisms. Initially, the tank was half filled with fresh water. At t = 0 an inflow of salt solution of concentration 5 g/m^3 @ 2 l/s and outflow of well stirred mixture @ 1 l/s are initiated. This process can be modelled using the following differential equation.

$$\frac{dm}{dt} + \frac{m}{6000 + t} = 0.01$$

where m is mass (gm) of salt at time t (sec). The mass of the salt (in gm) in tank at 75% of its capacity is _____.

Ans. (##)

Total capacity of tank = 2 × 2 × 3 = 12 m^3

At 50% capacity,

$$\text{Volume } (V_{50}) = 0.5 \times 12 = 6 \text{ m}^3$$

At 75% capacity,

$$\text{Volume } (V_{75}) = 0.75 \times 12 \text{ m}^3 = 9 \text{ m}^3$$

Now, increase in volume $\Delta V = V_{75} - V_{50} = (9 - 6)\text{m}^3 = 3 \text{ m}^3$

Also, $\quad$ Inflow (I) = 2 l/s

Outflow (Q) = 1 l/s

Rate of change storage,

$$\frac{\Delta S}{\Delta t} = I - Q = 2 - 1 = 1 \ l/\text{s}$$

$$= \frac{3000l}{1l/\text{s}} = 3000 \text{ sec}$$

Now, $\quad \frac{dm}{dt} + \frac{m}{6000 + t} = 0.01$

$$\Rightarrow \quad \frac{dm}{dt} + \frac{m}{6000 + 3000} = 0.01$$

$$\Rightarrow \quad \frac{dm}{dt} + \frac{m}{9000} = 0.01$$

$$\Rightarrow \quad \frac{dm}{0.01 - \frac{m}{9000}} = dt$$

Integrating both sides

$$\Rightarrow \int_{m_o=0}^{m} \frac{dm}{0.01-\frac{m}{9000}} = \int_{t=0}^{t=3000} dt$$

$$\Rightarrow \frac{\left[\ln\left(0.01-\frac{m}{9000}\right)\right]_0^m}{-\frac{1}{9000}} = (3000-0)$$

$$\Rightarrow \ln\left(0.01-\frac{m}{9000}\right)-\ln 0.01 = -\frac{1}{9000}\times 3000$$

$$\Rightarrow \ln\left(0.01-\frac{m}{9000}\right) = -4.938$$

$$\Rightarrow 0.01-\frac{m}{9000} = 7.165\times 10^{-3}$$

$$\Rightarrow m = 25.5\ gm$$

End of Solution

GEOTECHNICAL

Q.22 An infinite slope is made up of cohesionless soil with seepage parallel to and upto the sloping surface. The angle of slope is 30° with respect to horizontal ground surface. The unit weight of the saturated soil and water are 20 kN/m^3 and 10 kN/m^3 respectively. The minimum angle of shearing resistance of soil for critically stable condition of slope is _____.

Ans. (49.10)

$$FOS = \frac{\gamma_{sub}}{\gamma_{sat}}\times\frac{\tan\phi}{\tan\beta}$$

Here, $\beta = 30°$

$\gamma_{sat} = 20$ kN/m^3

$\gamma_w = 10$ kN/m^3

$\therefore \gamma_{sub} = \gamma_{sat} - \gamma_w$

$= 20 - 10$

$= 10$ kN/m^3

For critically stable condition, FOS = 1

$\because 1 = \frac{20-10}{20}\times\frac{\tan\phi}{\tan 30°}$

$\Rightarrow \phi = 49.10°$

End of Solution

Q.23 A soil sample was consolidated at a cell pressure of 20 kPa and a back pressure of 10 kPa for 24 hours during a consolidated undrained (CU) triaxial test. The cell pressure was increased to 30 kPa on the next day and it resulted in the development of pore water pressure of 1 kPa. The soil sample failed when the axial stress was gradually increased to 50 kPa. The pore water pressure at failure was recorded as 21 kPa. The value of skempton/s pore pressure parameter B for the soil sample is _____ (round off to 2 decimal places).

Ans. (0.1)

Given: $\sigma_3 = 20\ kN/m^2$

Back pressure $= 10\ kN/m^2$

$\Delta u_c = 1\ kPa$

$\sigma_3' = 30\ kN/m^3$

$\Delta\sigma_3 = (30 - 20)\ kN/m^2 = 10\ kN/m^2$

$$B = \frac{\Delta u_c}{\Delta\sigma_3} = \frac{1}{10} = 0.1$$

End of Solution

Q.24 The total primary consolidation settlement (S_C) of a building constructed on a 10 meter thick saturated clay layer is estimated to be 50 mm. After 300 days of the construction of the building, primary consolidation settlement was recorded as 10 mm. The additional time (in days) required to achieve 50% of SC will be _____. (Round off to the nearest integer).

Ans. (1575)

As we know, $(T_v)_{50} = \frac{C_v t}{d^2}$ where, C_v is coefficient of consolidation

$$\frac{\pi}{4}(0.5)^2 = \frac{C_v}{d^2} \times t_2 \quad ...(1)$$

For 10 mm settlement, $\%U = \frac{\Delta h}{\Delta H} \times 100 = \frac{10}{50} \times 100\% = 20\%$

$$(T_v)_{20} = \frac{C_v}{d^2} \times t$$

$$\frac{\pi}{4}(0.2)^2 = \frac{C_v}{d^2} \times 300 \quad ...(2)$$

$$\frac{\frac{\pi}{4}(0.5)^2}{\frac{\pi}{4}(0.2)^2} = \frac{\frac{C_v}{d^2} \times t_2}{\frac{C_v}{d^2} \times 300}$$

$$t_2 = \left(\frac{0.5}{0.2}\right)^2 \times 300 = 1875\ days$$

Additional number of days = (1875 – 300) days = 1575 days

End of Solution

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Q.25 Which of the following statements is/are correct?

(a) Swell potential of soil decreases with an increase in the shrinkage limit.

(b) Both loose and dense sands with different initial void ratios can attain similar void ratios at large strain during shearing.

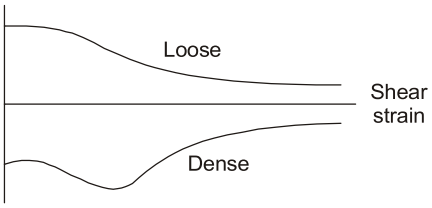
(c) Among the several corrections to be applied to the SPT value, the dilatancy correction is applied before all the corrections.

(d) In electrical resistivity tomograph, the depth of correct penetration is half of the spacing between the electrodes.

Ans. **(a, b)**

(i) Lower is the shrinkage → Higher is the swelling and shrinkage

(ii)



(iii) Over burden correction is applied before dilatency correction.

End of Solution

Q.26 A 2 m wide strip footing is founded at a depth of 1.5 m below the ground level in a homey, pure clay bed. The clay bed has unit cohesion 40 kPa. Due to seasonal fluctuations of water table from peak summer to peak monsoon period, the net ultimate bearing capacity of the footing as per Terzaghi's theory

(a) decrease (b) increase

(c) remain same (d) none of these

Ans. **(c)**

Ultimate bearing capacity,

$$q_u = CN_c^{5.7} + rD_t N_q^{1} + 0.5\,BrN_r^{0}$$

$$q_u = 5.7C + rD_t$$

$$q_{nu} = 5.7C$$

$\therefore$ remains same.

End of Solution

Q.27 P : Soil particles formed by mechanical weathering and close to their origin are generally subrounded.

Q : Activity of the clay physically signifies its swell potential.

Which one of the following option is correct?

(a) P is true and Q false. (b) Both P and Q are true.

(c) Both P and Q are false (d) P is false and Q is true.

Ans. (b)

P: • Due to chemical weathering mostly flakey particles are formed.
• Due to mechanical weathering generally subrounded particles are formed.

Q: Activity of the clay physically signifies its swell potential.

End of Solution

Q.28 An embankment is constructed with soil by maintaining the degree of saturation as 75% during compaction. The specific gravity of soil is 2.68 and moisture content is 17% during compaction. If $\gamma_w = 10\ kN/m^3$ for compaction soil, value of dry density (in kN/m^3) is ____.

Ans. (16.67)

Dry density, $\gamma_d = \dfrac{G\gamma_w}{1+e}$

$$e = \frac{w_G}{S} = \frac{0.17 \times 2.68}{0.75} = 0.6$$

$\therefore$ $$\gamma_d = \frac{2.68 \times 10}{1+0.6}$$

$$= 16.67\ kN/m^3$$

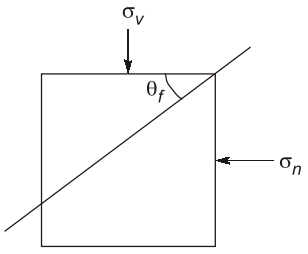
End of Solution

Q.29 A vertical smooth rigid retaining wall is supporting horizontal ground with dry cohesionless backfill having a friction angle of 30°. The inclinations of failure planes with respect to the major principal plane for Rankine's active and passive earth pressure condition, respectively are ____.

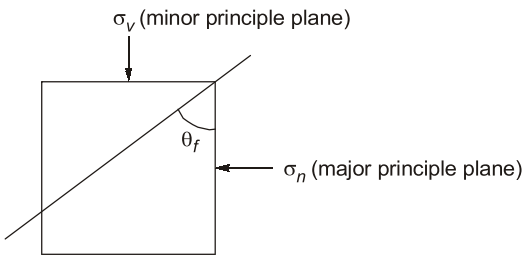
(a) 60° and 30°
(b) 30° and 60°
(c) 30° and 30°
(d) 60° and 60°

Ans. (d)

For Rankine's active pressure condition



where, $\theta_f = 45° + \dfrac{\phi}{2} = 45° + \dfrac{30°}{2} = 60°$



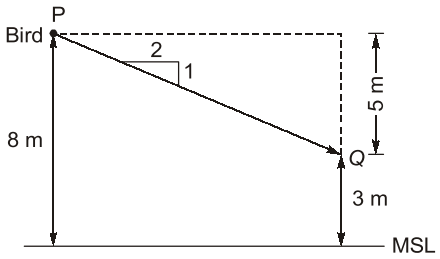
where, $\theta_f = 45° + \frac{\phi}{2} = 45° + \frac{30°}{2} = 60°$

End of Solution

GEOMETICS ENGG.

Q.30 A bird is resting on a point *P* at a height of 8 m above the mean sea level (MSL) upon hearing a loud noise, the bird flies parallel to the ground surface and reaches a point *Q* which is located at a height of 3 m above MSL. The ground surface has a falling gradient of 1 in 2. Ignoring the effects of curvature and refraction, the horizontal distance (in meters) between point *P* and *Q* is _____ (in integer)

Ans. (10)



For a falling gradient of 1 in 2,
∴ For vertical distance of 5 m between *P* and *Q*,
Horizontal distance between *P* and *Q*
$= 5 \times 2$
$= 10$ m

End of Solution

Q.31 If the sides in a closed traverse is increased from 3 to 4 then what will be the increase in sum of interior angles?

Ans. (180)

Sum of interior angles $= (n - 2) \times 180°$
for 3 sides, $= (3 - 2) \times 180°$
$= 180°$
Now, sum of interior angles
for 4 sides, $= (n - 2) \times 180°$
$= (4 - 2) \times 180°$
$= 360°$
∴ Increase in sum of interior angles,
$= 360° - 180°$
$= 180°$

End of Solution

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Q.32 If the map scale is 1 : 1000, contour interval is 1 m and the distance between contour in map is 10 mm, then what will be the gradient (in %)?

Ans. (10)

Given, contour Interval = 1 m

Distance between contour in map = 10 mm

$$\text{Map scale} = \frac{1}{1000}$$

$\therefore$ Distance between contour = 10×1000

$= 10{,}000$ mm

$$\Rightarrow \quad \text{Gradient} = \frac{\text{Contour Interval}}{\text{Distance between contour}}$$

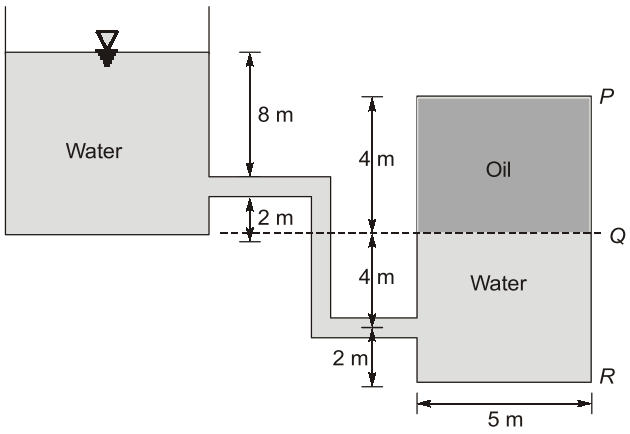
$$= \frac{1000\ \text{mm}}{10{,}000\ \text{mm}}$$

$$= \frac{1}{10} = \frac{1}{10} \times 100 = 10\%$$

End of Solution

FLUID MECHANICS

Q.33



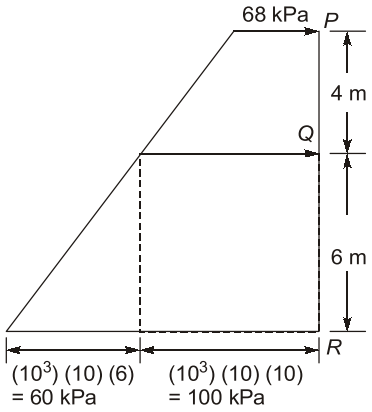
A 5 m × 5 m closed tank of 10 m height contains water, oil and is connected to an overhead water reservoir as shown.

Y_w = 10 kN/m^3 and specific gravity of oil = 0.8.

Find total force (in kN) due to pressure on the side PQR of the tank.

(Round off to nearest integer)

Ans. (5580)



$P_P + (800)(10)(4) = (10^3)(10)(10)$, where P_p is pressure at P

$P_P + (32 \times 10^3) = (100 \times 10^3)$

$P_P = 68 \times 10^3$ Pa

$P_P = 68$ kPa

Now, force on PQR, $= \left[\frac{1}{2}(68+100)4 + \frac{1}{2}(100+160)6\right]5$

$= (336 + 780)5$

$= 5580$ kN

End of Solution

Q.34 A flow velocity field $\vec{V} : \vec{V}(x,y)$ for a fluid is represented by $\vec{V} = 3\hat{i} + (5x)\hat{j}$. In the context of the fluid and the flow, which one of the following statements is correct?

(a) The fluid is compressible and the flow is irrotational.
(b) The fluid is incompressible and the flow is irrotational.
(c) The fluid is compressible and the flow is rotational.
(d) The fluid is incompressible and the flow is rotational.

Ans. (d)

Continuity equation for incompressible flow :

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

$$\frac{\partial}{\partial x}(3) + \frac{\partial}{\partial y}(5x) = 0 + 0$$

$= 0$ (Incompressible Flow)

$$w_z = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) = \frac{1}{2}\left[\frac{\partial}{\partial x}(5x) - \frac{\partial}{\partial y}(3)\right]$$

$$= \frac{1}{2}(5) = 2.5 \neq 0 \text{ (Flow is rotational)}$$

End of Solution

ENVIRONMENTAL

Q.35 Activated carbon is used to remove a pollution from wastewater in a mixed batch reactor, which follows first-order reaction kinetics.
At a reaction rate of 0.38/day, the time (in days) require remove the pollutant by 95% is _____ (rounded off to 1 decimal place).

Ans. (7.88 days)
For first order kinetics,

$$N_t = N_0 e^{-kt}$$

For efficiency of 95%,

$$N_t = \left(1 - \frac{95}{100}\right) L_0$$

$$= 0.05\ N_0$$

$$\therefore \quad 0.05 = e^{-0.38t}$$

Taking ln on both sides,

$$\ln 0.05 = -0.38t \ln e$$

$$\Rightarrow \quad t = 7.88 \text{ days.}$$

End of Solution

Q.36 Primary pollutants is/are
(a) Lead
(b) SO_2
(c) O_3
(d) H_2SO_4

Ans. (a, b)
Primary pollutants
- Particulate matter (PM)
- Hydrocarbons (HCs)
- Sulphur dioxide (SO_2)
- Nitrogen oxide (NO_X)
- Carbon Monoxide

Secondary pollutants
- Acid Rain
- Photochemical smog
- PAN

End of Solution

Q.37 A water treatment plant treats 25 MLD water with a natural alkalinity of 4.0 mg/*l* (as $CaCO_3$). It is estimated that during coagulation of this water, 450 kg/day of calcium bicarbonates ($Ca(HCO_3)_2$) is required based on alum dosage.
Consider the atomic weight as: Ca-40, H-1, C-12, O-16.
The quantity of pure quick lime CaO (in kg) required for this process per day is _____ (round off to 2 decimal places)

Ans. (155.56)

$$\text{Quantity of pure quick lime} = \frac{450\ \text{kg/d} \times \text{Eq.mass of CaO}}{\text{Equivalent mass of } Ca(HCO_3)_2}$$

$$= \frac{450\ \text{kg/d}}{81\text{g}} \times 28\ \text{g}$$

$$= 155.56\ \text{kg/d}$$

End of Solution

Q.38 In a saturated unconfined aquifer of thickness 20 m, drawdown in two observation well which are at a distance of 10 m and 100 m respectively from well of diameter 30 cm are 5 m and 1 m. If hydraulic conductivity is 10 m/day, then discharge (in m^3/day) is_____.

Ans. (1855)

Thickness of aquifer, $H = 20$ m

$r_1 = 10$ m

$r_2 = 100$ m

$h_2 = H - S_{w1} = 20 - 5 = 15$ m

$h_1 = H - S_{w2} = 20 - 1 = 19$ m

Now discharge for unconfined aquifer is given as

$$Q = \frac{\pi \cdot K\left[h_1^2 - h_2^2\right]}{\ln\left[\frac{r_2}{r_1}\right]} = \frac{\pi \times 10 \times \left[19^2 - 15^2\right]}{\ln\left[\frac{100}{10}\right]}$$

$$Q = 1855.55\ m^3/\text{day}$$

Q.39 Match the following:

List-I	List-II
(P) Cardboard	(i) Incineration
(Q) Ferrous metals	(ii) Eddy separator
(R) Aluminium	(iii) Magnetic separator
(S) Food waste	(iv) Rapid Composting

Ans. (*)

Cardboard → Incineration

Ferrous metals → Magnetic separator

Aluminium → Eddy separator

Food waste → Rapid composting

End of Solution

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CONSTRUCTION MANAGEMENT

Q.40 The initial cost of an equipment is Rs. 1,00,000. Its salvage value at the end of accounting life of 5 years is Rs. 10,000. The difference in the depreciation (in Rs.) when calculated with straight line method and double declining method is _____.
(Rounded off to nearest positive integer).

Ans. (6000)

Given:

Initial cost, C_i = 1,00,000 Rs

Salvage value, C_s = 10,000 Rs

Useful life, n = 5 years

Straight line method,

$$\text{Depreciation, } D = \frac{C_i - C_s}{n}$$

$$= \frac{10^5 - 10^4}{5}$$

$$= \text{Rs. } 18{,}000$$

As per double declining method,

$$\text{Fixed factor, } \text{FDDB} = \frac{2}{n} = \frac{2}{5} = 0.4$$

$$\therefore \quad D_1 = \text{FDDB} \times C_i = 0.4 \times 1{,}00{,}000 = 40{,}000 \text{ Rs}$$

$$\text{Book value, } B = \text{Rs. } 1{,}00{,}000 - \text{Rs. } 40{,}000 = \text{Rs. } 60{,}000$$

$$\text{Now, } D_2 = \text{FDDB} \times B_1 = 0.4 \times 60{,}000$$

$$= \text{Rs. } 24{,}000$$

$$\therefore \text{ Difference in depreciation} = \text{Rs. } 24{,}000 - \text{Rs. } 18{,}000$$

$$= \text{Rs. } 6000$$

End of Solution

ENGG. MATHEMATICS

Q.41 A vector field $\vec{P}$ and a scalar field r are given by

$$\vec{P} = (2x^2 - 3xy + z^2)\hat{i} + (2y^2 - 3y^2 + x^2)\hat{j} + (2z^2 - 3xz + x^2)\hat{k}$$

$$r = 6x^2 + 4y^2 - z^2 - 9xyz - 2xy + 3xz - yz$$

Consider the statement P and Q :

P : Curl of the gradient of the scalar field r is a null vector.

Q : Divergence of curl of the vector field $\vec{P}$ is zero.

Which one of the following option is correct?

(a) P is true and Q false.
(b) Both P and Q are true.
(c) Both P and Q are false
(d) P is false and Q is true.

Ans. (b)

$$r = 6x^2 + 4y^2 - z^2 - 9xyz - 2xy + 3xz - yz$$

$$\text{grad } r = \hat{i}\frac{\partial r}{\partial x} + \hat{j}\frac{\partial r}{\partial y} + \hat{k}\frac{\partial r}{\partial z}$$

$$= \hat{i}(12x - 9yz - 2y + 3z) + \hat{j}(8y - 9xz - 2x - z) + \hat{k}(-2z - 9xy + 3x - y)$$

So, $\text{curl}(\text{grad } \vec{r}) = \vec{\nabla} \times \text{grad } \vec{r}$

$$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ (12x - 9yz - 2y + 3z) & (8y - 9xz - 2x - z) & (-2z - 9xy + 3x - y) \end{vmatrix}$$

$$= \hat{i}(-9x - 1 + 9x + 1) - \hat{j}(-9y + 3 + 9y - 3) + \hat{k}(-9z - 2 + 9z + 2)$$

$P = \vec{0}$ i.e. $P = \text{curl (grad } \vec{r}) = \vec{0}$

$Q = \text{div (curl } \vec{P}) = 0$ (By vector identity)

Hence both are true. Hence option (b).

End of Solution

Q.42 Eigen values of the matrix $\begin{bmatrix} 2 & 1 & 1 \\ 1 & 4 & 1 \\ 1 & 1 & 2 \end{bmatrix}$ is

(a) 1, 3, 4 (b) –5, 1, 2
(c) 1, 2, 5 (d) –5, –1, 2

Ans. (c)

$$\lambda_1 + \lambda_2 + \lambda_3 = 8$$

$$\lambda_1 \lambda_2 \lambda_3 = |A| = 10$$

Only option (c) satisfied above condition.

$$1 + 2 + 5 = 8$$
$$1 \times 2 \times 5 = 10$$

End of Solution

Q.43 For $x\frac{\partial^2 u}{\partial x^2} + y\frac{\partial^2 u}{\partial y^2} = \left(\frac{x+y}{2}\right)^r$. Which of the following is/are correct?

(a) Parabolic for $x > 0$, and $y > 0$ (b) Parabolic for $x > 0$, and $y > 0$
(c) Elliptic for $x > 0$ and $y > 0$ (d) Elliptic for $x = 0$ and $y > 0$

Ans. (c)

$$x\frac{\partial^2 u}{\partial x^2} + y\frac{\partial^2 u}{\partial y^2} = \left(\frac{x+y}{2}\right)^2$$

$$A = x, \quad B = 0, \quad C = y$$

$$B^2 - 4AC$$

$$\Rightarrow \qquad 0 - 4xy = -4xy$$

If $x > 0$, $y > 0$

Then, $B^2 - 4AC < 0$ (Elliptical)

Option (c) is answer.

End of Solution

Q.44 For second order partial differential equation

$$\frac{\partial^2 u}{\partial x^2} = 2$$

(a) $u = x^2 + f(y) + yg(x)$ (b) $u = x^2 + f(y) + g(x)$

(c) $u = x^2 + xf(y) + g(x)$ (d) $u = x^2 + xf(y) + h(y)$

Ans. **(d)**

Integrating with respect to 'x'

$$\int\left(\frac{\partial^2 u}{\partial x^2}\right)dx = 2\int(1)dx + f(y)$$

$$\frac{\partial u}{\partial x} = 2x + f(y)$$

Again integrating,

$$u = x^2 + xf(y) + h(y)$$

End of Solution

Q.45 Consider the below table:

i	1	2	3
x_i	1	2	3
$f(x_i)$	0	0.3010	0.4771

Using Newton's second order interpolation, the value of $f(1.5)$ is _____.

Ans. **(0.1661)**

It is based on 2nd order interpolation

$$f(x) = y_1 + \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$$

$$f(x) = y_1 + \frac{y_2 - y_1}{x_2 - x_1}(x - x_1) + \frac{\frac{y_3 - y_2}{x_3 - x_2} - \frac{y_2 - y_1}{x_2 - x_1}}{x_3 - x_1}(x - x_1)(x - x_2)$$

Here, $y_1 = 0$, $x_1 = 1$ | $y_2 = 0.3010$, $x_2 = 2$ | $y_3 = 0.4771$, $x_3 = 3$

$$f(x) = 0 + \left[\frac{0.3010 - 0}{2 - 1}\right](x - 1) + \left[\frac{\frac{0.4771 - 0.3010}{3 - 2} - \frac{0.3010 - 0}{2 - 1}}{3 - 1}\right](x - 1)(x - 2)$$

$$f(x) = 0.3010(x-1)+\left(\frac{-0.1249}{2}\right)(x-1)(x-2)$$

$$f(x) = 0.3010(1.5-1)+\frac{-0.1249}{2}(1.5-1)(1.5-2)$$

$$f(1.5) = 0.1505 + 0.0156 = 0.1661$$

End of Solution

Q.46 Smallest +ve root of
$f(x) = x^5 - 5x^4 - 10x^3 + 50x^2 + 9x - 45 = 0$ lies in
(a) $2 \le x \le 4$ (b) $0 \le x \le 2$
(c) $10 \le x \le 100$ (d) C.N.D

Ans. **(b)**
Taking option (b) $0 \le x \le 2$

$$f(0) = 0 - 45 < 0$$
$$f(2) = 2^5 - 5(2)^4 - 10(2)^3 + 50(2)^2 + 9 \times 2 - 45$$
$$= +45 > 0$$

$\left.\begin{matrix} f(0) < 0 \\ f(2) > 0 \end{matrix}\right] \Rightarrow$ hence there will be one root in this interval which will be smallest root as per the given option.

End of Solution

■■■■