GATE 2023 [Forenoon Session]
Civil Engineering

General Aptitude Part

Q.1 to Q.5 Carry One Mark Each

Question 1

"I have not yet decided, what will I do this evening; I_____ visit a friend".

(A) Mite
(B) Would
(C) Might
(D) Didn't

Ans. (C)

Sol. **Given :**

"I have not yet decided, what will I do this evening; I **might** visit a friend".

Hence, the correct option is (C).

Question 2

Eject : Insert :: Advance : _____. (By word meaning)

(A) Advent
(B) Progress
(C) Retreat
(D) Loan

Ans. (C)

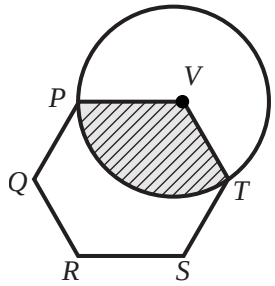
Sol. **Given :**

Eject is related to insert in a special manner as they are opposite in meaning for each other. In the same way of relationship advance will be related to retreat, as advance means forward and retreat means backward.

Hence, the correct option is (C).

Question 3

In the given figure, PQRSTV is a regular hexagon with each side of length 5 cm. A circle is drawn with its centre at V such that it passes through P. What is the area (in cm^2) of the shaded region? (The diagram is representative)



(A) $\frac{25\pi}{3}$
(B) $\frac{20\pi}{3}$
(C) 6π
(D) 7π

Ans. (A)

Sol. Sum of interior angles = $(n-2)180^0$

Each angle of regular hexagon, $\frac{(n-2)180^0}{n} = 120^0$

$$\text{Required Area} = \frac{\theta}{360^0}\pi R^2 = \frac{120^0}{360^0}\pi 5^2 = \frac{25\pi}{3}$$

Hence, the correct option is (A).

Question 4

A duck named Donald Duck says "All ducks always lie."

Based only on the information above, which one of the following statements can be logically inferred with *certainty*?

(A) Donald Duck always lies.

(B) Donald Duck always tells the truth.

(C) Donald Duck's statement is true.

(D) Donald Duck's statement is false.

Ans. (D)

Sol. Given :

A duck named Donald Duck says "All ducks always lie."

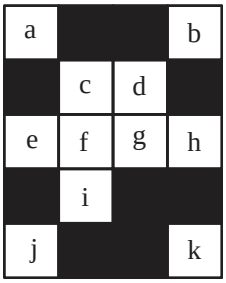
According to the given information Donald Duck's statement is false.

Hence, the correct option is (D).

Question 5

A line of symmetry is defined as a line that divides a figure into two parts in a way such that each part is a mirror image of the other part about that line.

The figure below consists of 20 unit squares arranged as shown. In addition to the given black squares, upto 5 more may be coloured black. Which one among the following options depicts the minimum number of boxes that must be coloured black to achieve two lines of symmetry? (The figure is representative)



(A) d

(B) c, d, i

(C) c, i

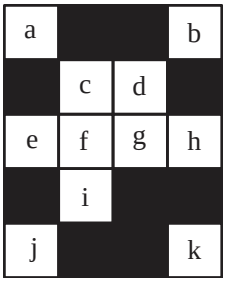
(D) c, d, i, f, g

Ans. (B)

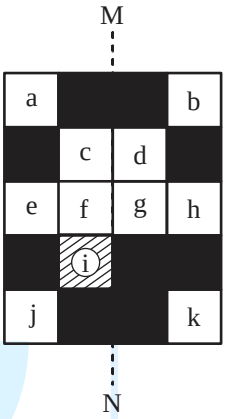
Sol. Given :

A line of symmetry is defined as a line that divides a figure into two parts in a way such that each part is a mirror image of the other part about that line.

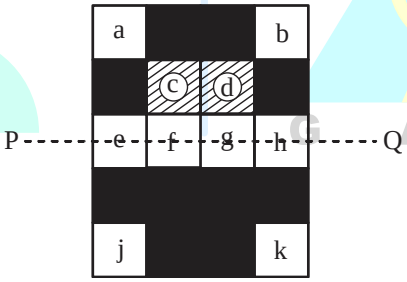
The figure below consists of 20 unit squares arranged as shown. In addition to the given black squares, upto 5 more may be coloured black.



In the figure given below, MN is the vertical line of symmetry for the figure, for which we have to colour the box 'i'.



In the figure given below, PQ is the horizontal line of symmetry for the figure, for which we have to colour box 'c' and 'd'.



Therefore, we have to colour 3 boxes c, d, i to achieve two line of symmetry MN and PQ.

Hence, the correct option is (B).

Q.6 to Q.10 Carry Two Marks Each

Question 6

Based only on the truth of the statement 'Some humans are intelligent', which one of the following options can be logically inferred with certainty?

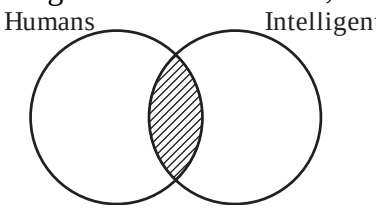
(A) No human is intelligent
(B) All humans are intelligent
(C) Some non-humans are intelligent
(D) Some intelligent beings are humans

Ans. **(D)**

Sol. **Given :**

Statement 'Some humans are intelligent'.

Can be represented by given venn diagram as shown below,



Option (A) No human is intelligent, is wrong as some human are intelligent.

Option (B) All humans are intelligent, is wrong as we have no information about remaining part of human.

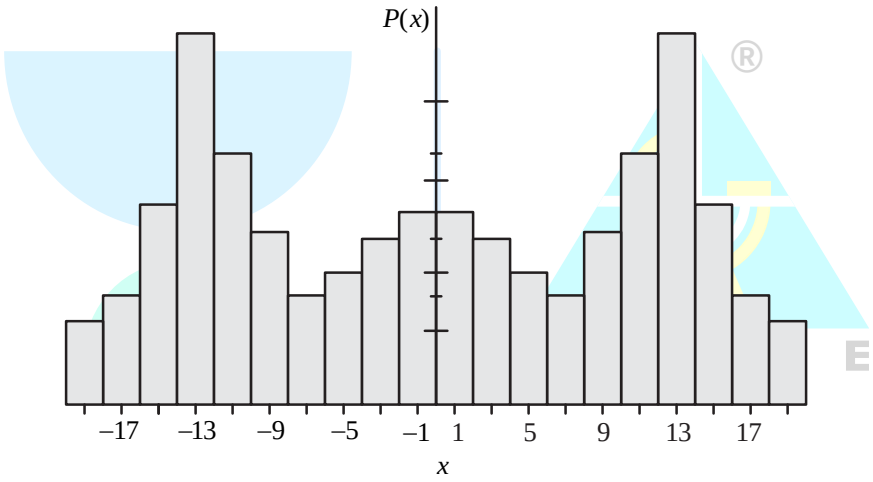
Option (C) Some non-humans are intelligent, is wrong as we have no information about non-humans.

Option (D) Some intelligent beings are humans, can be inferred as some intelligent being are human can be seen in the diagram.

Hence, the correct option is (D).

Question 7

Which one of the options can be inferred about the mean, median, and mode for the given probability distribution (*i.e.* probability mass function), $P(x)$, of a variable x?



(A) mean = median ≠ mode

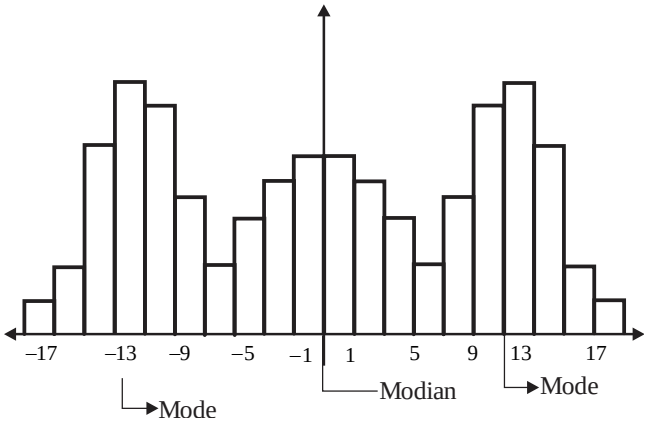
(B) mean = median = mode

(C) mean ≠ median = mode

(D) mean ≠ mode = median

Ans. (A)

Sol.



Median $= \dfrac{-1+1}{2} = 0$

Mode = –13, 13

So, Median $\neq$ Mode

Hence, the correct option is (A).

Question 8

The James Webb telescope, recently launched in space, is giving humankind unprecedented access to the depths of time by imaging very old stars formed almost 13 billion years ago. Astrophysicists and cosmologists believe that this odyssey in space may even shed light on the existence of dark matter. Dark matter is supposed to interact only via the gravitational interaction and not through the electromagnetic-, the weak- or the strong-interaction. This may justify the epithet "dark" in dark matter.

Based on the above paragraph, which one of the following statements is FALSE?

(A) No other telescope has captured images of stars older than those captured by the James Webb telescope.

(B) People other than astrophysicists and cosmologists may also believe in the existence of dark matter.

(C) The James Webb telescope could be of use in the research on dark matter.

(D) If dark matter was known to interact via the strong-interaction, then the epithet "dark" would be justified.

Ans. (D)

Sol. **Given :**

The James Webb telescope, recently launched in space, is giving humankind unprecedented access to the depths of time by imaging very old stars formed almost 13 billion years ago. Astrophysicists and cosmologists believe that this odyssey in space may even shed light on the existence of dark matter. Dark matter is supposed to interact only via the gravitational interaction and not through the electromagnetic-, the weak- or the strong-interaction. This may justify the epithet "dark" in dark matter.

According to the given paragraph statement in option (D) is FALSE.

As, "Dark matter is supposed to interact only via the gravitational interaction and not through the electromagnetic-, the weak- or the strong-interaction."

Hence, the correct option is (D).

Question 9

Let $a = 30!$, $b = 50!$ & $c = 100!$ Consider the following numbers :

$\log_a c,\ \log_c a,\ \log_b a,\ \log_a b$

Which one of the following inequalities is CORRECT?

(A) $\log_c a < \log_b a < \log_a b < \log_a c$

(B) $\log_c a < \log_a b < \log_b a < \log_b c$

(C) $\log_c a < \log_b a < \log_a c < \log_a b$

(D) $\log_b a < \log_c a < \log_a b < \log_a c$

Ans. (A)

Sol. $\log_a^c, \log_c^a, \log_a^b, \log_b^a$ $\left[\log_n^m = \frac{\log m}{\log n}\right]$

$$\frac{\log 100!}{\log 30!}, \frac{\log 30!}{\log 100!}, \frac{\log 50!}{\log 30!}, \frac{\log 30!}{\log 50!}$$

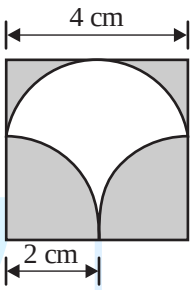
$$\log_c a < \log_b a < \log_a b < \log_a c$$

Hence, the correct option is (A).

Question 10

A square of side length 4 cm is given. The boundary of the shaded region is defined by one semi-circle on the top and two circular arcs at the bottom, each of radius 2 cm, as shown.

The area of the shaded region is _____ cm^2.



(A) 8 (B) 4

(C) 12 (D) 10

Ans. (A)

Sol. Bottom shaded area $(A) = 2 \times \frac{1}{4}\pi(2)^2 = 2\pi$

Top shaded area = $4 \times 2 - \frac{\pi \times 2^2}{2} = 8 - 2\pi$

Total shaded area = $8 - 2\pi + 2\pi = 8$

Hence, the correct option is (A).

Technical Part

Q.11 to Q.35 Carry One Mark Each

Question 11

For the integral

$$I = \int_{-1}^{1} \frac{1}{x^2} dx$$

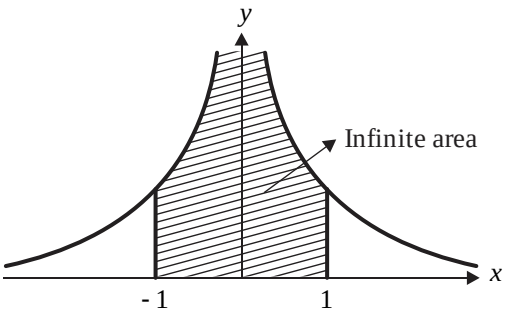
which of the following statements is TRUE?

(A) $I = 0$ (B) $I = 2$

(C) $I = -2$ (D) The integral does not converge

Ans. (D)

Sol. Given : $I = \int_{-1}^{1} \frac{1}{x^2} dx$



$f(x) = \frac{1}{x^2}$ is not defined at $x = 0$

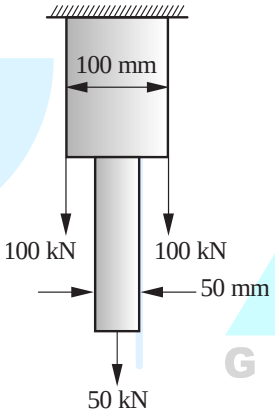
So, $I = \int_{-1}^{0} \frac{1}{x^2} dx + \int_{0}^{1} \frac{1}{x^2} dx = \left(-\frac{1}{x}\right)_{-1}^{0} + \left(-\frac{1}{x}\right)_{0}^{1} = \infty$

Here, $\frac{1}{x}$ is also not defined at $x = 0$. So, the integral does not converge.

Hence, the correct option is (D).

Question 12

A hanger is made of two bars of different sizes. Each bar has a square cross-section. The hanger is loaded by three-point loads in the mid vertical plane as shown in the figure. Ignore the self-weight of the hanger. What is the maximum tensile stress in N/mm^2 anywhere in the hanger without considering stress concentration effects?



(A) 15.0 (B) 25.0

(C) 35.0 (D) 45.0

Ans. (B)

Sol.

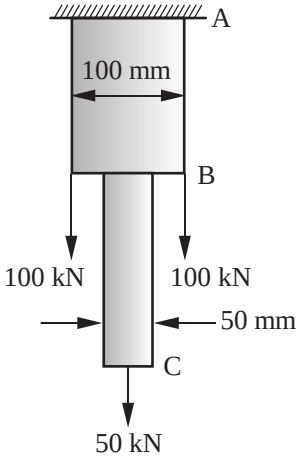


Fig. (i)

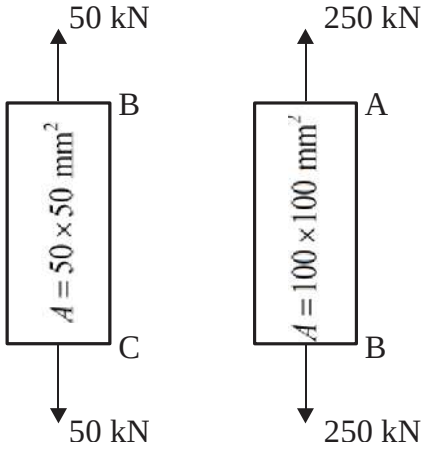


Fig. (ii) FBD of member BC and AB

Stress in member BC,

$$\sigma_B = \frac{P_B}{A_B} = \frac{50\times10^3}{50\times50} = 20 \text{ N/mm}^2$$

Stress in member AB,

$$\sigma_A = \frac{P_A}{A_A} = \frac{250\times10^3}{100\times100} = 25 \text{ N/mm}^2$$

So, maximum tensile stress $= 25$ N/mm^2

Hence, the correct option is (B).

Question 13

Creep of concrete under compression is defined as the _____.

(A) increase in the magnitude of strain under constant stress

(B) increase in the magnitude of stress under constant strain

(C) decrease in the magnitude of strain under constant stress

(D) decrease in the magnitude of stress under constant strain

Ans. (A)

Sol. Creep is the time dependent deformation due to a continuous static loading (stress) acting on a elastic material for a long period of time.

Creep strain = Elastic strain × Creep coefficient

Hence, the correct option is (A).

Key Point :

Age of loading	7 days	28 days	1 year
Creep coefficient (θ)	2.2	1.6	1.1

Question 14

A singly reinforced concrete beam of balanced section is made of M20 grade concrete and Fe415 grade steel bars. The magnitudes of the maximum compressive strain in concrete and the tensile strain in the bars at ultimate state under flexure, as per IS 456: 2000 are _____ respectively. (round off to four decimal places)

(A) 0.0035 and 0.0038

(B) 0.0020 and 0.0018

(C) 0.0035 and 0.0041

(D) 0.0020 and 0.0031

Ans. (A)

Sol. **Given :**

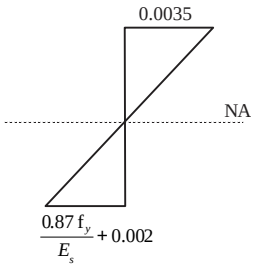
Grade of concrete and steel: M20, Fe415

Strain in concrete, $\varepsilon_C = 0.0035$

Strain in tension reinforcement, $\varepsilon_{steel} = 0.002 + \frac{0.87 f_y}{E_s} = 0.002 + \frac{0.87\times415}{2\times10^5}$

$\varepsilon_{steel} = 0.0038$

Hence, the correct option is (A).



Strain diagram under flexure

Question 15

In cement concrete mix design, with the increase in water-cement ratio, which one of the following statements is TRUE?

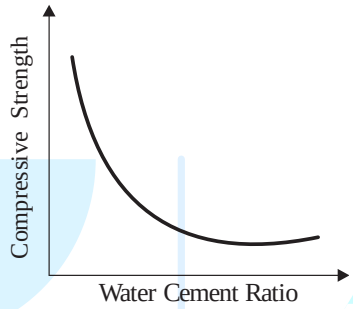
(A) Compressive strength decreases but workability increases
(B) Compressive strength increases but workability decreases
(C) Both compressive strength and workability decrease
(D) Both compressive strength and workability increase

Ans. (A)

Sol. (i) Increase in water cement ratio, decrease in compressive strength of concrete because higher volume of water occupies the volume of concrete and introduces voids.

(ii) Increase in w/c ratio, increase in workability of concrete due to availability of water, reduce the friction between the particles.

As per Abram's law :



Hence, the correct option is (A).

Question 16

The specific gravity of a soil is 2.60. The soil is at 50% degree of saturation with a water content of 15%. The void ratio of the soil is _____.

(A) 0.35 (B) 0.78
(C) 0.87 (D) 1.28

Ans. (B)

Sol. **Given :** $S = 50\%,\ w = 15\%,\ G = 2.60$

We know that, $wG = eS$

$0.15 \times 2.60 = e \times 0.5$

$e = 0.78$

Hence, the correct option is (B).

Question 17

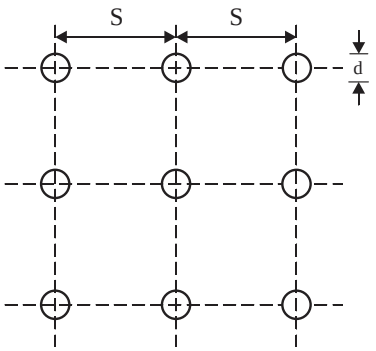
A group of 9 friction piles are arranged in a square grid maintaining equal spacing in all directions. Each pile is of diameter 300 mm and length 7 m. Assume that the soil is cohesionless with effective friction angle $\phi' = 32°$. What is the center-to-center spacing of the piles (in m) for the pile group efficiency of 60%?

(A) 0.582 (B) 0.486
(C) 0.391 (D) 0.677

Ans. (B)

Sol. **Given :** $N = 9$ piles, $D = 300$ mm, $L = 7$ m, $C = 0$

$\phi = 32^0$, $S = ?$ and $n_g = 60\%$



Group efficiency of pile $\left(\eta_g\right) = \dfrac{Q_{ug}}{\eta Q_{up}}$

$$0.6 = \frac{\frac{1}{2}(\gamma L)\tan\delta(2s+d)l \times 4}{9 \times \frac{1}{2}(\gamma L)\tan\delta(\pi dl)}$$

$$0.6 = \frac{(2s+d)\times 4}{9\times \pi d}$$

$$S = \frac{1}{2}\left[\frac{0.6\times 9\times \pi \times 0.3}{4} - 0.3\right] = 0.486 \text{ m}$$

Hence, the correct option is (B).

Question 18

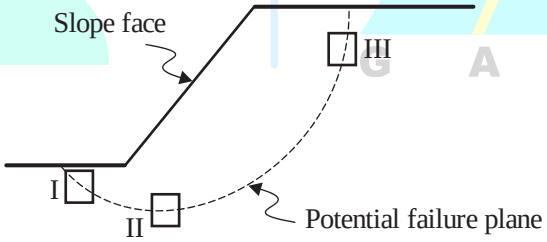
A possible slope failure is shown in the figure. Three soil samples are taken from different locations (I, II and III) of the potential failure plane. Which is the most appropriate shear strength test for each of the sample to identify the failure mechanism? Identify the correct combination from the following options:

P: Triaxial compression test

Q: Triaxial extension test

R: Direct shear or shear box test

S: Vane shear test



(A) I-Q, II-R, III-P

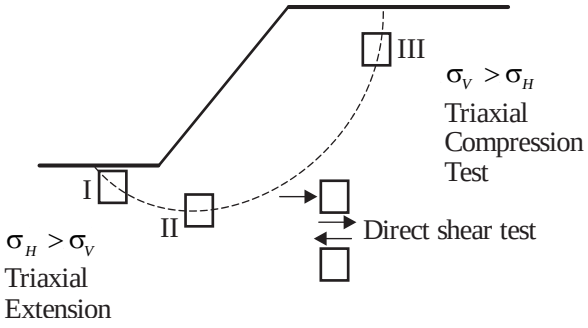
(B) I-R, II-P, III-Q

(C) I-S, II-Q, III-R

(D) I-P, II-R, III-Q

Ans. **(A)**

Sol.



Hence, the correct option is (A).

Question 19

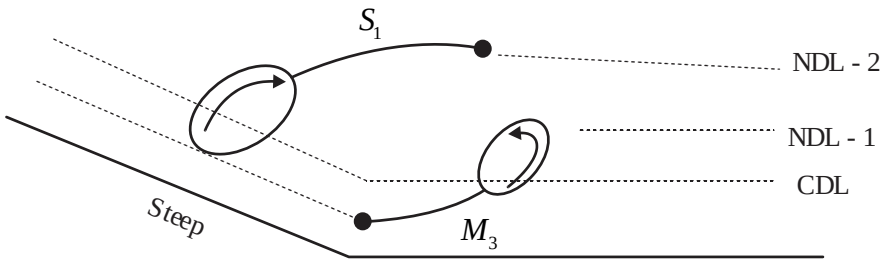
When a supercritical stream enters a mild-sloped (M) channel section, the type of flow profile would become _____.

(A) M_1 (B) M_2

(C) M_3 (D) M_1 and M_2

Ans. (C)

Sol. When a supercritical stream enters a mild slope:



The type of flow profile would be M_3 or S_1.

Hence, the correct option is (C).

Question 20

Which one of the following statements is TRUE for Greenhouse Gas (GHG) in the atmosphere?

(A) GHG absorbs the incoming short wavelength solar radiation to the earth surface, and allows the long wavelength radiation coming from the earth surface to pass through

(B) GHG allows the incoming long wavelength solar radiation to pass through to the earth surface, and absorbs the short wavelength radiation coming from the earth surface

(C) GHG allows the incoming long wavelength solar radiation to pass through to the earth surface, and allows the short wavelength radiation coming from the earth surface to pass through

(D) GHG allows the incoming short wavelength solar radiation to pass through to the earth surface, and absorbs the long wavelength radiation coming from the earth surface

Ans. (D)

Sol. Green House Gas allow short wave radiation to pass through to the earth surface and absorbs the long wavelength radiation coming from the earth surface. CO_2, methane and nitrous oxide are the major GHGs.

Hence, the correct option is (D).

Question 21

G_1 and G_2 are the slopes of the approach and departure grades of a vertical curve, respectively.

Given $|G_1| < |G_2|$ and $|G_1| \neq |G_2| \neq 0$

Statement 1: + G_1 followed by + G_2 results in a sag vertical curve.

Statement 2: − G_1 followed by − G_2 results in a sag vertical curve.

Statement 3: + G_1 followed by − G_2 results in a crest vertical curve.

Which option amongst the following is true?

(A) Statement 1 and Statement 3 are correct; Statement 2 is wrong

(B) Statement 1 and Statement 2 are correct; Statement 3 is wrong

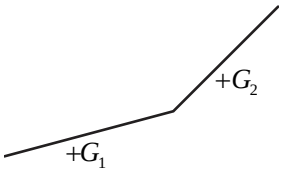
(C) Statement 1 is correct; Statement 2 and Statement 3 are wrong

(D) Statement 2 is correct; Statement 1 and Statement 3 are wrong

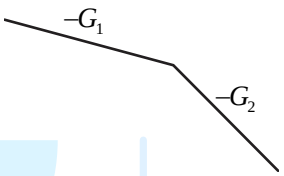
Ans. (A)

Sol. **Given :** $|G_1| < |G_2|$ and $|G_1| \neq |G_2| \neq 0$

Statement 1: This is form as vertical sag curve.



Statement 2: This is form as vertical crest curve.



Statement 3: This is form as vertical crest curve.

Hence, the correct option is (A).

Question 22

The direct and reversed zenith angles observed by a theodolite are 56º00'00" and 303º00'00", respectively. What is the vertical collimation correction?

(A) + 1º00'00" (B) − 1º00'00"

(C) − 0º30'00" (D) + 0º30'00"

Ans. (D)

Sol. **Given :** Observed value of direct zenith angle $(\phi_1) = 56°00'00"$

Observed value of reversed zenith angle $(\phi_2) = 303°00'00"$

$$\text{Error} = \frac{(\phi_1 + \phi_2) - 360°}{2} = \frac{(56° + 303°) - 360°}{2} = -30'$$

$\therefore$ Correction $= +30'$

Hence, the correct option is (D).

Question 23

A student is scanning his 10 inch × 10 inch certificate at 600 dots per inch (dpi) to convert it to raster. What is the percentage reduction in number of pixels if the same certificate is scanned at 300 dpi?

(A) 62 (B) 88

(C) 75 (D) 50

Ans. (C)

Sol. Percentage reduction in number of pixels

$$=\frac{10\times600\times10\times600-100\times300\times10\times300}{10\times600\times10\times600}\times300$$

$$=\frac{600^2-300^2}{600^2}\times100=75\%$$

Hence, the correct option is (C).

Question 24

If M is an arbitrary real $n\times n$ matrix, then which of the following matrices will have non-negative eigenvalues?

(A) M^2 (B) MM^T

(C) M^TM (D) $(M^T)^2$

Ans. (B), (C)

Sol. $MX=\lambda X$ ...(i) [λ is Eigen value of (M)]

$MMx=\lambda MX$

$M^2X=\lambda(\lambda X)$

$M^2X=\lambda^2X$ ...(ii) [λ^2 (non negative) is Eigen value of M^2]

$MX=\lambda X$

$M^TX=\lambda X$ .... (iii) [M, MT have same Eigen values]

$MM^TX=\lambda MX$

$MM^TX=\lambda(\lambda X)$

$MM^TX=\lambda^2X$ ....(iv) [λ^2 (none negative) is Eigen value of MM^T]

$MX=\lambda X$

$M^TX=\lambda X$

$M^TMX=\lambda MX$

$M^TMX=\lambda(\lambda X)$

$M^TMX=\lambda^2X$ ...(v) [λ^2 (non negative) is Eigen value of M^TM]

$MX=\lambda X$

$MMx=\lambda MX$

$M^2X=\lambda(\lambda X)$

$(M^T)^2=\lambda^2X$ [$\because M, M^T$ have same Eigen value]

$(M^T)^2X=\lambda^2X$ …(vi) [λ^2 is Eigen value of $(M^T)^2$ which non negative]

Hence, the correct options are (B) & (C).

Question 25

The following function is defined over the interval $[-L, L]$: $f(x) = px^4 + qx^5$

If it is expressed as a Fourier series, $f(x) = a_0 + \sum_{n=1}^{\infty}\left\{a_n \sin\left(\frac{\pi x}{L}\right) + b_n \cos\left(\frac{\pi x}{L}\right)\right\}$

which options amongst the following are true?

(A) $a_n, n-=1,2,...,\infty$ depend on p

(B) $a_n, n-=1,2,...,\infty$ depend on q

(C) $b_n, n-=1,2,...,\infty$ depend on p

(D) $b_n, n-=1,2,...,\infty$ depend on q

Ans. **(B), (C)**

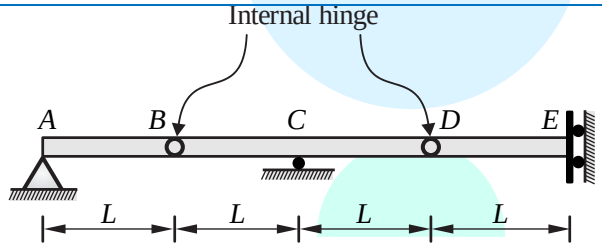
Sol. $a_n = \frac{1}{l}\int_{-l}^{l} f(x).\sin\left(\frac{n\pi x}{l}\right)dx = \frac{1}{l}\int_{-l}^{l}\underbrace{\left(px^4 + 2x^5\right)}_{even}\underbrace{\sin\left(\frac{n\pi x}{l}\right)dx}_{odd}$ = Depends on q

$b_n = \frac{1}{l}\int_{-l}^{l} f(x).\cos\left(\frac{n\pi x}{l}\right)dx = \frac{1}{l}\int_{-l}^{l}\underbrace{(px^4 + qx^5)}_{odd.}.\underbrace{\cos\left(\frac{n\pi x}{l}\right)}_{even.}dx$ = Depends on p

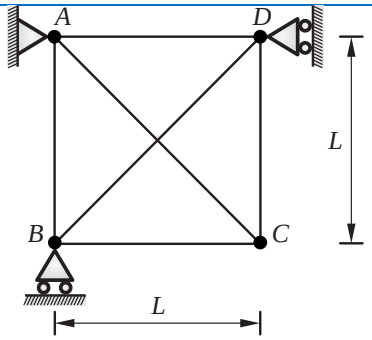
Hence, the correct options are (B) & (C).

Question 26

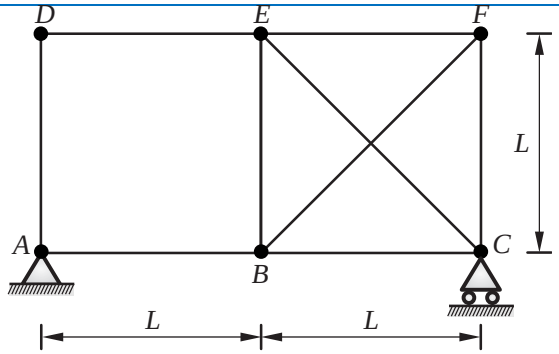
Consider the following three structures:



Structure I: Beam with hinge support at A, roller at C, guided roller at E, and internal hinges at B and D.



Structure II: Pin-jointed truss, with hinge support at A, and rollers at B and D



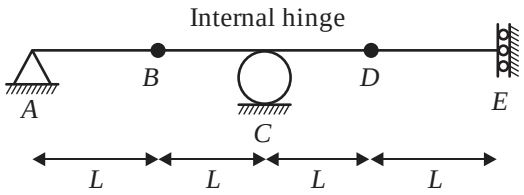
Structure III: Pin jointed truss, with hinge support at A and roller at C.

Which of the following statements is/are TRUE?

(A) Structure I is unstable
(B) Structure II is unstable
(C) Structure III is unstable
(D) All three structures are stable

Ans. **(A), (B), (C)**

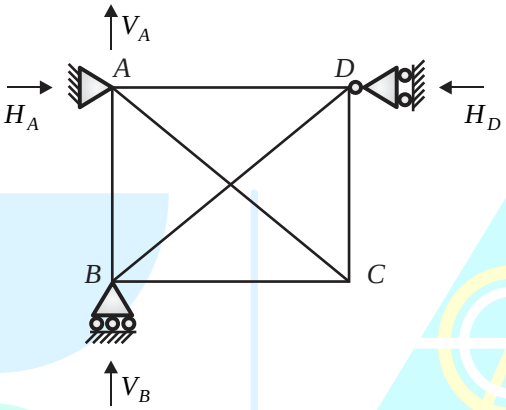
Sol. I.



$D_s = r - s = 3-4 = -1$

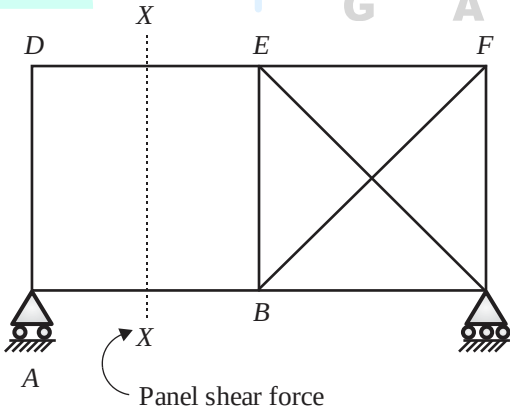
D_s is negative so Structure is unstable

II.



(4 reactions are concurrent so unstable)

III.



(Unstable)

Hence, the correct options are (A), (B) & (C).

Question 27

Identify the waterborne diseases caused by viral pathogens:

(A) Acute anterior poliomyelitis
(B) Cholera
(C) Infectious hepatitis
(D) Typhoid fever

Ans. **(A), (C)**

Sol. Hepatitis is caused due to virus.
Bacterial : Cholera, Typhoid fever.
Hence, the correct options are (A) & (C).

Question 28

Which of the following statements is/are TRUE for the Refuse-Derived Fuel (RDF) in the context of Municipal Solid Waste (MSW) management?

(A) Higher Heating Value (HHV) of the unprocessed MSW is higher than the HHV of RDF processed from the same MSW
(B) RDF can be made in the powdered form
(C) Inorganic fraction of MSW is mostly converted to RDF
(D) RDF cannot be used in conjunction with oil

Ans. (B)

Question 29

The probabilities of occurrences of two independent events A and B are 0.5 and 0.8, respectively. What is the probability of occurrence of at least A or B (rounded off to one decimal place)? _____

Ans. 0.9 (0.9 to 0.9)

Sol. **Given :** $P(A)=0.5$ and $P(B)=0.8$

P (at least A (or) B) $=1-P(\text{None of } A \text{and } B)$

$$=1-P(\bar{A})P(\bar{B})=1-(0.5)(0.2)=1-0.10=0.9$$

Hence, the correct answer is 0.9.

Question 30

In the differential equation $\frac{dy}{dx}+\alpha xy=0$, α is a positive constant. If y = 1.0 at x = 0.0, and y = 0.8 at x = 1.0, the value of α is_____ (rounded off to three decimal places).

Ans. 0.446 (0.445 to 0.447)

Sol. $\frac{dy}{dx}=-\alpha xy$ $\qquad y(0)=1$

$\frac{dy}{y}=-\alpha x dx$ $\qquad y(1)=0.8$

$\int\frac{dy}{y}=\int-\alpha x dx$

$\ln y=-\alpha\frac{x^2}{2}+c$ $\qquad \ldots(i)$

$y(0)=1 \qquad \ln 1=0+c \qquad c=0$

$\ln y=-\alpha\frac{x^2}{2}$ $\qquad \ldots(ii)$

$y(1)=0.8 \qquad \ln(0.8)=\frac{-\alpha}{2}$

$-\alpha = 2\ln(0.8)$

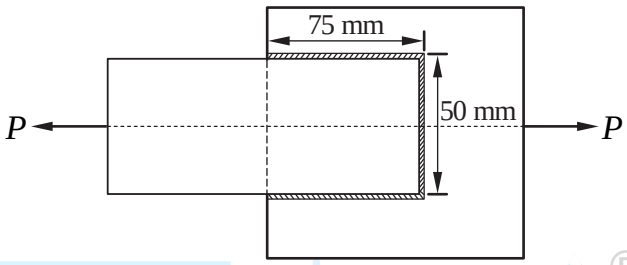
$-\alpha = \ln(0.8)^2$

$\alpha = -\ln(0.8)^2 = 0.446$

Hence, the correct answer is 0.446.

Question 31

Consider the fillet-welded lap joint shown in the figure (not to scale). The length of the weld shown is the effective length. The welded surfaces meet at right angle. The weld size is 8 mm, and the permissible stress in the weld is 120 MPa. What is the safe load P (in kN, rounded off to one decimal place) that can be transmitted by this welded joint?



Ans. 134.4(134.0 to 136.0)

Sol. **Given :** Weld size (S) = 8 mm

Permissible stress $(\sigma_{ps}) = 120$ MPa

$P_{safe} = K \times S \times l_{eff} \times \sigma_{ps}$

$= 0.7 \times 8 \times (75+75+50) \times 120 = 134.40$ kN

Hence, the correct answer is 134.4.

Question 32

A drained direct shear test was carried out on a sandy soil. Under a normal stress of 50 kPa, the test specimen failed at a shear stress of 35 kPa. The angle of internal friction of the sample is _____ degree (round off to the nearest integer).

Ans. 35 (35 to 35)

Sol. **Given :** In drain shear test :

Normal stress $\sigma_n = 50$ kPa, Shear stress, $\tau_f = 35$ kPa, Cohesion, $C = 0$ (Sand)

$\phi = ?$

We know that, $\tau_f = \sigma_n \tan\phi + C$

$\tau_f = \sigma_n \tan\phi$

$\frac{35}{50} = \tan\phi$

$\phi = \tan^{-1}\left(\frac{35}{50}\right) = 34.99$

Hence, the correct answer is 35.

Question 33

A canal supplies water to an area growing wheat over 100 hectares. The duration between the first and last watering is 120 days, and the total depth of water required by the crop is 35 cm. The most intense watering is required over a period of 30 days and requires a total depth of water equal to 12 cm. Assuming precipitation to be negligible and neglecting all losses, the minimum discharge (in m^3/s, rounded off to three decimal places) in the canal to satisfy the crop requirement is _____.

Ans. 0.046 (0.045 to 0.047)

Sol. **Given :** A = 100 ha, $B_1 = 120$ days, $\Delta_1 = 35\,\text{cm}$, $B_2 = 30$ days, $\Delta_2 = 12\,\text{cm}$

$$Q = \frac{A}{D}\,\frac{\text{ha}}{\text{ha/cumec}}$$

$$D = 864 \times \frac{B}{\Delta}$$

$$D_1 = 864 \times \frac{120}{35} = 2962.28\,\frac{\text{ha}}{\text{cumec}}$$

$$D_2 = 864 \times \frac{30}{12} = 2160\,\frac{\text{ha}}{\text{cumec}}$$

$$Q_1 = \frac{100}{2962.28} = 0.03375\,\text{m}^3/\text{s}$$

$$Q_2 = \frac{100}{2160} = 0.04629\,\text{m}^3/\text{s}$$

Hence, the correct answer is 0.046.

Question 34

The ordinates of a one-hour unit hydrograph for a catchment are given below:

t (hour)	0	1	2	3	4	5	6	7
Q (m^3/s)	0	9	21	18	12	5	2	0

Using the principle of superposition, a D-hour unit hydrograph for the catchment was derived from this one-hour unit hydrograph. The ordinates of the D-hour unit hydrograph were obtained as 3 m^3/s at t = 1 hour and 10 m^3/s at t = 2 hour. The value of D (in integer) is _____.

Ans. 3 (3 to 3)

Sol.

Time (t)	0	1	2	3	4	5	6	7		
Discharge (Q) 1st hr UH	0	9	21	18	12	5	2	0		
2nd hr UH	-	0	9	21	18	12	5	2	0	
3rd hr UH	-	-	0	9	21	18	12	5	2	0

From table clearly visible D = 3 hr or 3-hr UH is 3 m^3/sec

Hence, the correct answer is 3.

Question 35

For a horizontal curve, the radius of a circular curve is obtained as 300 m with the design speed as 15 m/s. If the allowable jerk is 0.75 m/s^3, what is the minimum length (in m, in integer) of the transition curve? _____.

Ans. 15 (15 to 15)

Sol. **Given :** Radius, $R = 300\,\text{m}$, Design speed, $V = 15\,\text{m/sec}$ and Allowable jerk, $C = 0.75\,\text{m/s}^3$.

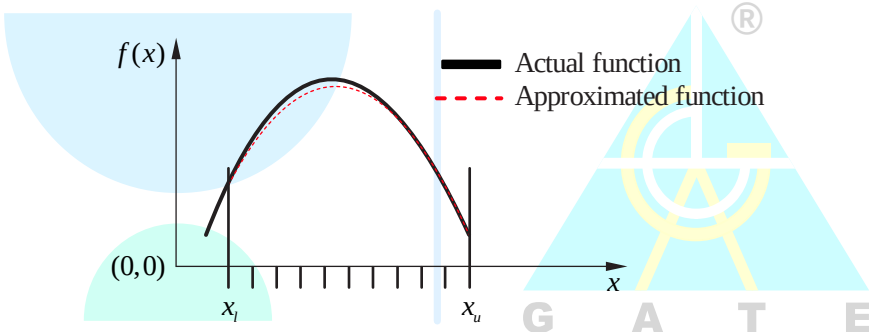
Minimum length of transition curve, $L = \dfrac{V^3}{CR} = \dfrac{(15)^3}{0.75 \times 300} = 15\,\text{m}$

Hence, the correct answer is 15.

Q.36 to Q.65 Carry Two Marks Each

Question 36

A function $f(x)$, that is smooth and convex-shaped between interval (x_l, x_u) is shown in the figure. This function is observed at odd number of regularly spaced points. If the area under the function is computed numerically, then _____.



(A) the numerical value of the area obtained using the trapezoidal rule will be less than the actual

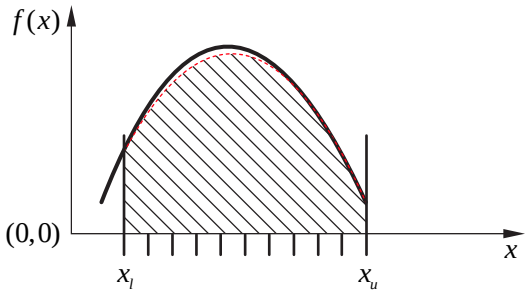
(B) the numerical value of the area obtained using the trapezoidal rule will be more than the actual

(C) the numerical value of the area obtained using the trapezoidal rule will be exactly equal to the actual

(D) with the given details, the numerical value of area cannot be obtained using trapezoidal rule

Ans. (A)

Sol. Approximated function has under estimation so numerical value of the area obtained using trapezoidal rule will be less than the actual.



Hence, the correct option is (A).

Question 37

Consider a doubly reinforced RCC beam with the option of using either Fe250 plain bars or Fe500 deformed bars in the compression zone. The modulus of elasticity of steel is 2×10^5 N/mm^2. As per IS456:2000, in which type(s) of the bars, the stress in the compression steel $\left(f_{sc}\right)$ can reach the design strength $\left(0.87 f_y\right)$ at the limit state of collapse?

(A) Fe250 plain bars only
(B) Fe500 deformed bars only
(C) Both Fe250 plain bars and Fe500 deformed bars
(D) Neither Fe250 plain bars nor Fe500 deformed bars

Ans. (A)

Sol. **For Fe250 :**

$$\varepsilon = \frac{0.87 f_y}{E_s} = 0.87 \times 250 / 2 \times 10^5 = 0.001087$$

So, In this case the stress in the compression steel (f_{sc}) can reach the design strength ($0.87\ f_y$)

For Fe500 :

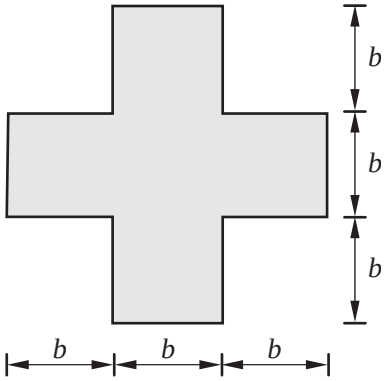
$$\text{Strain} = 0.002 + \frac{0.87 \times 500}{2 \times 10^5} = 0.00417$$

In this case $f_{sc} < 0.87\ f_y$, So, the stress in the compression steel (f_{sc}) can't be reached to the design strength ($0.87\ f_y$).

Hence, the correct option is (A).

Question 38

Consider the horizontal axis passing through the centroid of the steel beam cross- section shown in the figure. What is the shape factor (rounded off to one decimal place) for the cross-section?

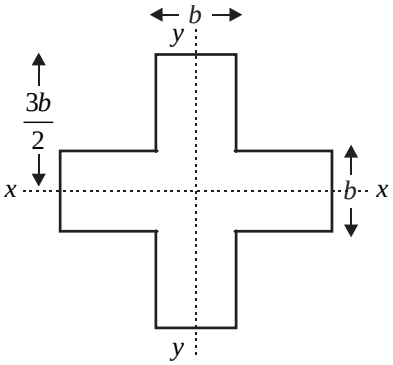


(A) 1.5
(B) 1.7
(C) 1.3
(D) 2.0

Ans. (B)

Sol. $Z_e = \frac{I}{Y_{max}}, Y_{max} = \frac{3b}{2}$

$$I_{xx}=\frac{3b\times b^3}{12}+2\times\left[\frac{b\times b^3}{12}\times(b\times b)\times b^2\right]=b^4\left[\frac{1}{4}+2\left[\frac{1}{12}+b\right]\right]=\frac{29b^4}{12}$$



$$Z_e=\frac{29b^4}{12}\times\frac{2}{36}=\frac{29}{18}b^3$$

$$Z_P=\frac{A}{2}[\bar{y}_1+\bar{y}_2]$$

$$A=3b\times b+2\times b^2=5b^2$$

$$\bar{y}_1=\frac{\left(3b\times\frac{b}{2}\right)\times\frac{b}{4}+b^2\times b}{3b\times\frac{b}{2}\times b^2}=\frac{b\left[\frac{3}{8}+1\right]}{\left[\frac{3}{2}+1\right]}$$

$$\bar{y}_1=\frac{11}{20}b$$

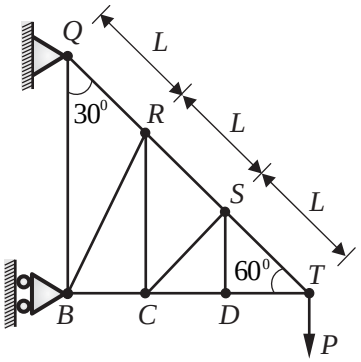
$$Z_p=\frac{A}{2}(\bar{y}_1+\bar{y}_2)=\frac{5b^2}{2}\left(\frac{11}{20}\times b+\frac{11}{20}\times b\right)=\frac{11}{4}b^3$$

$$S.F=\frac{\frac{11}{4}b^3}{\frac{29}{18}b^3}=\frac{11\times18}{4\times29}=1.706=1.71$$

Hence, the correct option is (B).

Question 39

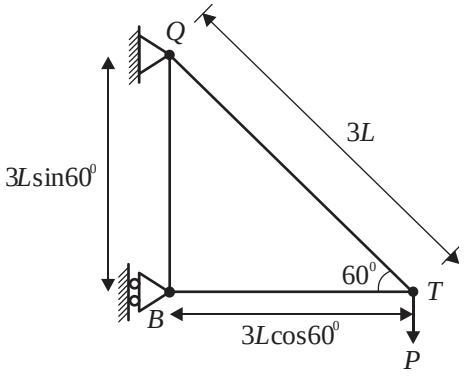
Consider the pin-jointed truss shown in the figure (not to scale). All members have the same axial rigidity, AE. Members QR, RS, and ST have the same length *L*. Angles QBT, RCT, SDT are all 90°. Angles BQT, CRT, DST are all 30°. The joint T carries a vertical load P. The vertical deflection of joint *T* is $k\frac{PL}{AE}$. What is the value of *k*?



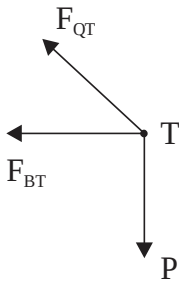
(A) 1.5
(B) 4.5
(C) 3.0
(D) 9.0

Ans. (B)

Sol.



FBD of Joint T :



$\Sigma M_B = 0, \quad R \times 3L \sin 60^0 + P \times 3L \cos 60^0 = 0$

Considering joint T,

$\Sigma f_y = 0, \quad F_{TQ} \sin 60^0 = P, F_{TQ} = \dfrac{2P}{\sqrt{3}} = 1.1547\,\text{P}$

$\Sigma f_x = 0, \quad F_{BT} = -F_{TQ} \cos 60° = -0.577P$

Vertical deflection at joint T,

$$\Delta V_T = \sum \frac{NnL}{AE} = \frac{(-0.577P) \times (-0.577) \times 1.5L}{AE} + \frac{(1.1547P)(1.1547) \times 3L}{AE} = \frac{4.5PL}{AE}$$

$\therefore \quad K = 4.5$

Hence, the correct option is (B).

Question 40

With reference to the compaction test conducted on soils, which of the following is INCORRECT?

(A) Peak point of the compaction curve gives the maximum dry unit weight and optimum moisture content

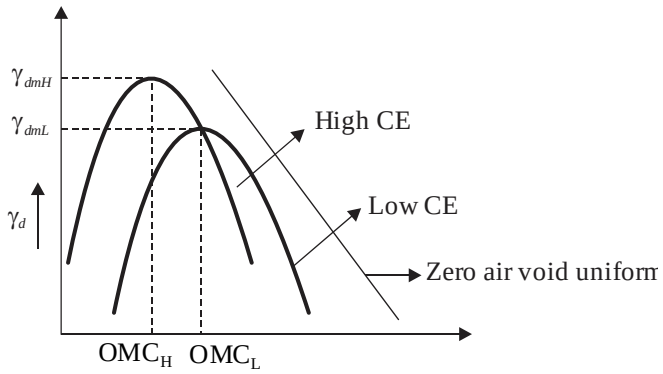
(B) With increase in the compaction effort, the maximum dry unit weight increases

(C) With increase in the compaction effort, the optimum moisture content decreases

(D) Compaction curve crosses the zero-air-voids curve

Ans. (D)

Sol.



Hence, the correct option is (D).

Question 41

Consider that a force P is acting on the surface of a half-space (Boussinesq's problem). The expression for the vertical stress (σ_z) at any point (r, z), within the half-space is given as,

$$\sigma_z = \frac{3P}{2\pi}\frac{z^3}{\left(r^2+z^2\right)^{\frac{5}{2}}}$$

where, r is the radial distance, and z is the depth with downward direction taken as positive. At any given r, there is a variation of (σ_z) along z, and at a specific z, the value of (σ_z) will be maximum. What is the locus of the maximum (σ_z)?

(A) $z^2 = \frac{3}{2}r^2$

(B) $z^3 = \frac{3}{2}r^2$

(C) $z^2 = \frac{5}{2}r^2$

(D) $z^3 = \frac{5}{2}r^2$

Ans. (A)

Sol. **Given :** $\sigma_z = \frac{3p}{2\pi}\cdot\frac{z^3}{\left(r^2+z^2\right)^{\frac{5}{2}}}$

For maximum σ_z,

$$\frac{\partial\sigma_z}{dz} = 0$$

$$\frac{3P}{2\pi}\left[\frac{\left(r^2+z^2\right)^{5/2}3z^2 - z^3\frac{5}{2}\left(r^2+z^2\right)^{3/2}\times 2z}{\left(r^2+z^2\right)^5}\right] = 0$$

$$\left(r^2+z^2\right)^{3/2} z^2\left[3\left(r^2+z^2\right)-5z^2\right] = 0$$

$$3r^2+3z^2-5z^2 = 0$$

$$3r^2 = 2z^2$$

$$z^2 = \frac{3}{2}r^2$$

Hence, the correct option is (A).

Question 42

A square footing of size 2.5 m × 2.5 m is placed 1.0 m below the ground surface on a cohesionless homogeneous soil stratum. Considering that the groundwater table is located at the base of the footing, the unit weights of soil above and below the groundwater table are 18 kN/m^3 and 20 kN/m^3, respectively, and the bearing capacity factor N_q is 58, the net ultimate bearing capacity of the soil is estimated as 1706 kPa (unit weight of water = 10 kN/m^3).

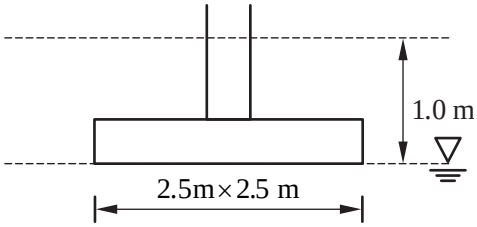
Earlier, a plate load test was carried out with a circular plate of 30 cm diameter in the same foundation pit during a dry season, when the water table was located beyond the plate influence zone. Using Terzaghi's bearing capacity formulation, what is the ultimate bearing capacity (in kPa) of the plate?

(A) 110.16 (B) 61.20

(C) 204.00 (D) 163.20

Ans. (A)

Sol. **Given :** $\gamma_t = 18\,\text{kN/m}^3$, $\gamma_{sat} = 20\,\text{kN/m}^3$, $q_{nu} = 1706\,\text{kPa}$, $\gamma_w = 10\,\text{kN/m}^3$ and $N_q = 58$



From plate load test :

Diameter of plate, (d) = 30 cm

$$q_{nu} = 0 + q\left(N_q - 1\right) + 0.4B\gamma N_\gamma$$

$$q_{nu} = 18\times1\times\left(58-1\right) + 0.4\times2.5\times\left(20-10\right)\times N_\gamma$$

$$N_\gamma = \frac{\left(1706 - 18\times57\right)}{\left(0.4\times2.5\times10\right)} \Rightarrow N_\gamma = 68$$

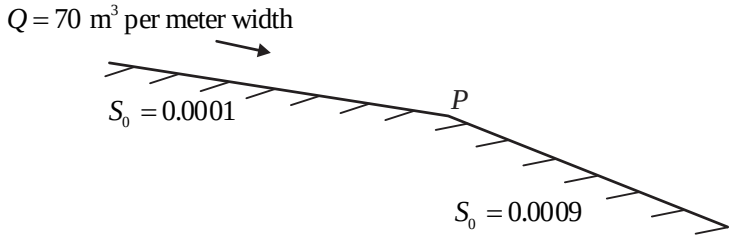
$$q_{u\,plate} = 0.3\times d\times\gamma_t\times N_\gamma$$

$$q_{u\,plate} = 0.3\times0.3\times18\times68 = 110.16\ \text{kPa}$$

Hence, the correct option is (A).

Question 43

A very wide rectangular channel carries a discharge (Q) of 70 m^3/s per meter width. Its bed slope changes from 0.0001 to 0.0009 at a point P, as shown in the figure (not to scale). The Manning's roughness coefficient of the channel is 0.01. What water surface profile(s) exist(s) near the point P?

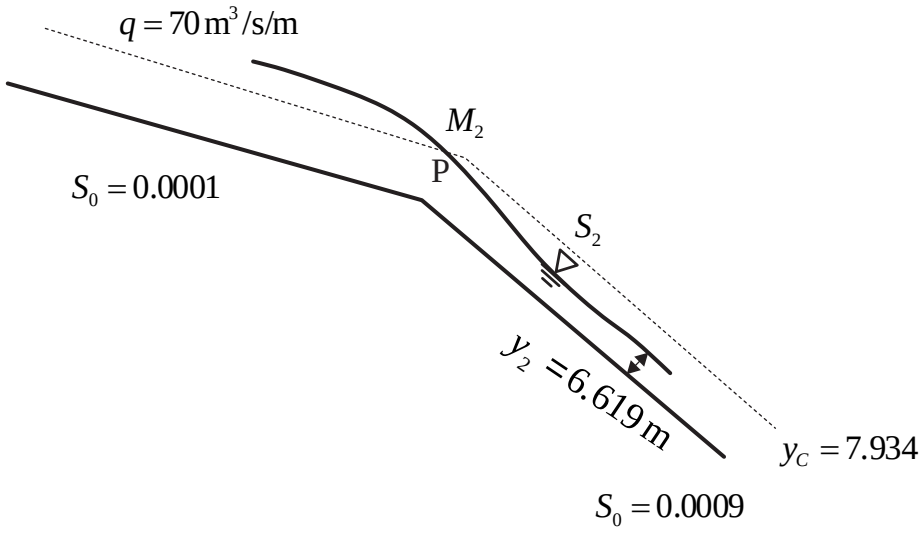


(A) M_2 and S_2 (B) M_2 only

(C) S_2 only (D) S_2 and hydraulic jump

Ans. (A)

Sol. **Given :** $\eta = 0.01$



Critical depth, $y_c = \left(\frac{q^2}{g}\right)^{1/3} = \left(\frac{70^2}{9.81}\right)^{1/3} = 7.934$ m

For normal depth of flow for wide rectangular channel.

S = 0.001

$$Q = \left(\frac{1}{\eta} R^{2/3} \sqrt{S}\right) \times A$$

$$R = \frac{A}{P} = \frac{\beta y}{B + 2y} = y$$

$$Q = \frac{1}{\eta}(y)^{2/3} \sqrt{S} \times By$$

$$q = \frac{1}{\eta} y^{5/3} \sqrt{S}$$

$$y_1 = \left(\frac{q\eta}{\sqrt{S}}\right)^{3/5} \left(\frac{70 \times 0.01}{\sqrt{0.0001}}\right)^{3/5} = 12.796\,m > y_c \text{ (Mild slope)}$$

$$y_2 = 6.619\,m < y_c \text{ (Steep slope)}$$

The profile derived as M_2 and S_2.

Hence, the correct option is (A).

Question 44

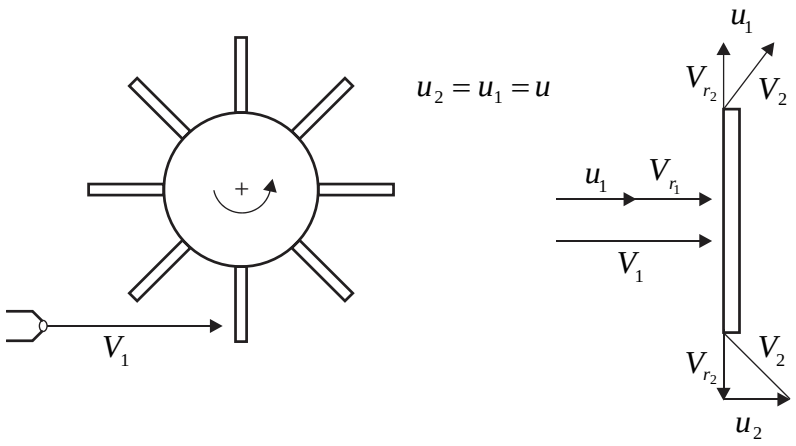
A jet of water having a velocity of 20 m/s strikes a series of plates fixed radially on a wheel revolving in the same direction as the jet at 15 m/s. What is the percentage efficiency of the plates? (round off to one decimal place)

(A) 37.5 (B) 66.7

(C) 50.0 (D) 88.9

Ans. **(A)**

Sol.



$$\text{Efficiency } (\eta) = \frac{\text{Work done per sec}}{\text{Input work power}}$$

$$= \frac{F_x u}{\frac{1}{2}\dot{m}V_1^2} = \frac{\dot{m}(V_1 - u).u}{\frac{1}{2}\dot{m}V_1^2} = \frac{(20-15)15}{\frac{1}{2}(20)^2}$$

$$= 0.375 \text{ or } 37.5\%$$

Hence, the correct option is (A).

Question 45

In the following table, identify the correct set of associations between the entries in Column-1 and Column-2.

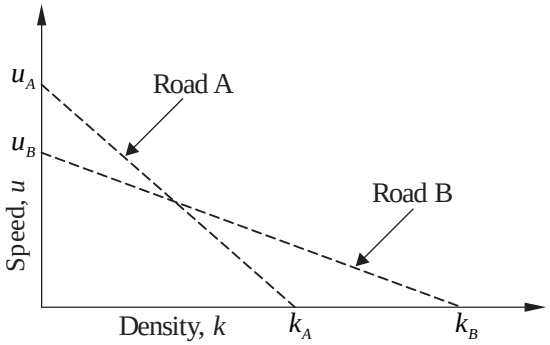
Column – 1		Column – 2	
P:	Reverse Osmosis	I:	Ponding
Q:	Trickling Filter	II:	Freundlich Isotherm
R:	Coagulation	III:	Concentration Polarization
S:	Adsorption	IV:	Charge Neutralization

(A) P-II, Q-I, S-III
(B) Q-III, R-II, S-IV
(C) P-IV, R-I, S-II
(D) P-III, Q-I, R-IV

Ans. (D)

Question 46

A plot of speed-density relationship (linear) of two roads (Road A and Road B) is shown in the figure.



If the capacity of Road A is C_A and the capacity of Road B is C_B, what is $\frac{C_A}{C_B}$?

(A) $\frac{k_A}{k_B}$

(B) $\frac{u_A}{u_B}$

(C) $\frac{k_A u_A}{k_B u_B}$

(D) $\frac{k_A u_B}{k_B u_A}$

Ans. (C)

Sol. Capacity of road A, $C_A = \frac{1}{4} K_A u_A$

Capacity of road B, $C_B = \frac{1}{4} K_B u_B$

Now, $$\frac{C_A}{C_B} = \frac{\frac{1}{4} K_A u_A}{\frac{1}{4} K_B u_B} = \frac{K_A u_A}{K_B u_B}$$

Hence, the correct option is (C).

Question 47

For the matrix $[A] = \begin{bmatrix} 1 & 2 & 3 \\ 3 & 2 & 1 \\ 3 & 1 & 2 \end{bmatrix}$, which of the following statements is/are TRUE?

(A) The eigenvalues of $[A]$ are same as the eigenvalues of $[A]$

(B) The eigenvalues of $[A]^{-1}$ are the reciprocals of the eigenvalues of $[A]$

(C) The eigenvectors of $[A]$ are same as the eigenvectors of $[A]$

(D) The eigenvectors of $[A]^{-1}$ are same as the eigenvectors of $[A]$

Ans. (A), (B), (D)

Sol. Characteristics equation of A and A^T are same.

$\therefore$ Characteristics roots of A and A^T are same.

$$AX = \lambda X$$

$$A^{-1}AX = A^{-1}\lambda X$$

$$IX = A^{-1}\lambda X$$

$$X = \lambda A^{-1} X$$

$$\frac{1}{\lambda} X \rightarrow A^{-1} X$$

$\therefore$ $\frac{1}{\lambda}$ is Eigen value of A^{-1}.

Hence, the correct options are (A), (B) & (C).

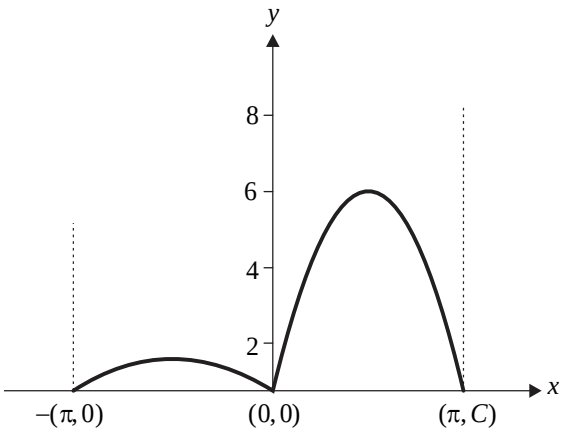
Question 48

For the function $f(x)=e^{x}|\sin x|; x\in\mathbb{R}$, which of the following statements is/are TRUE?

(A) The function is continuous at all x
(B) The function is differentiable at all x
(C) The function is periodic
(D) The function is bounded

Ans. (A)

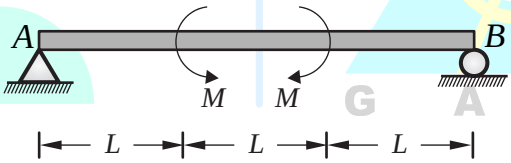
Sol.



Hence, the correct option is (A).

Question 49

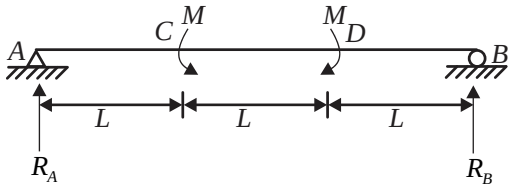
Consider the beam shown in the figure (not to scale), on a hinge support at end A and a roller support at end B. The beam has a constant flexural rigidity, and is subjected to the external moments of magnitude M at one-third spans, as shown in the figure. Which of the following statements is/are TRUE?



(A) Support reactions are zero
(B) Shear force is zero everywhere
(C) Bending moment is zero everywhere
(D) Deflection is zero everywhere

Ans. (A) & (B)

Sol.



Equilibrium equations :

$\sum M_A \circlearrowright = 0$

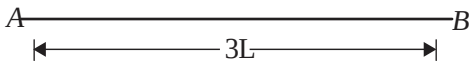
$\Rightarrow \quad -M+M-R_B\times(3L)=0$

$\Rightarrow \quad R_B=0$

$\sum F_V=0, \quad R_A+R_B=0$

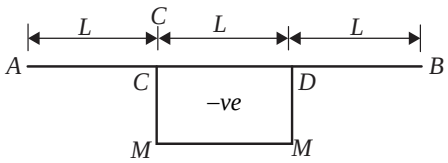
$\Rightarrow \qquad R_A = 0$

SFD



No shear force throughout the span.

BMD



Here, bending moment and deflection is not zero everywhere.

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

Question 50

Which of the following statements is/are TRUE in relation to the Maximum Mixing Depth (or Height) 'D_{max}' in the atmosphere?

(A) D_{max} is always equal to the height of the layer of unstable air

(B) Ventilation coefficient depends on D_{max}

(C) A smaller D_{max} will have a smaller air pollution potential if other meteorological conditions remain same

(D) Vertical dispersion of pollutants occurs up to D_{max}

Ans. (B) & (D)

Sol. The depth of mixing layer in which vertical movement of pollutants are possible is called maximum mixing depth.

An air parcel at temperature rises and cools. The level where its temperature becomes equal to surrounding air gives the maximum mixing depth value.

Also, ventilation coefficient = MMD × Average wind speed

High value of ventilation coefficient leads to low air pollution potential.

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

Question 51

Which of the following options match the test reporting conventions with the given material tests in the table?

Test reporting convection	Material test
(P) Reported as ratio	(I) Solubility of bitumen
(Q) Reported as percentage	(II) Softening point of bitumen
(R) Reported in temperature	(III) Los Angeles abrasion test
(S) Reported in Length	(IV) Flash point of bitumen
	(V) Ductility of bitumen
	(VI) Specific gravity of bitumen

(A) (P) - (VI); (Q) - (I); (R) - (II); (S) - (VII)
(B) (P) - (VI); (Q) - (III); (R) - (IV); (S) - (V)
(C) (P) - (VI); (Q) - (I); (R) - (II); (S) - (V)
(D) (P) - (VI); (Q) - (III); (R) - (IV); (S) - (VII)

Ans. (B) & (C)

Question 52

The differential equation, $\frac{du}{dt}+2tu^2=1$

is solved by employing a backward difference scheme within the finite difference framework. The value of u at the $(n-1)^{th}$ time-step, for some n, is 1.75. The corresponding time (t) is 3.14 s. Each time step is 0.01 s long. Then, the value of (u_n-u_{n-1}) is_____.(round off to three decimal places).

Ans. – 0.151 (– 0.152 to – 0.149)

Sol. **Given :** $h = 0.01$, $u_{n-1}=1.75$, $t_{n-1}=3.14$

$$\frac{du}{dt}=f(t,u)=(1-2tu^2)$$

From Euler's backward method,

$$u_n=u_{n-1}+hf(t_n,u_n)$$
$$u_n=u_{n-1}+h(1-2t_nu_n^2)$$
$$u_n=1.75+0.01(1-2\times3.15\times u_n^2)$$
$$u_n=1.75+0.01-0.63u_n^2$$
$$0.63u_n^2+u_n-1.76=0$$

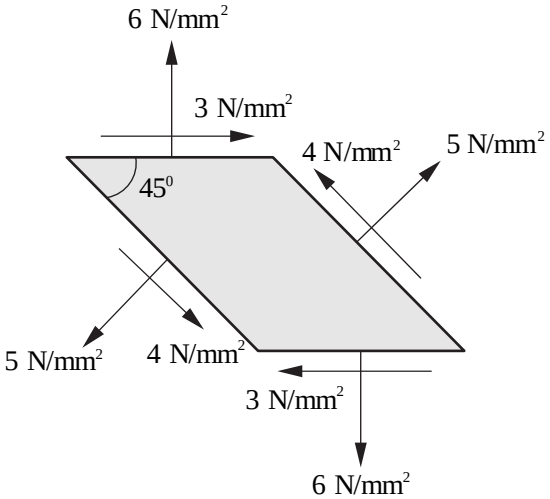
By solving, $u_n=1.599$, $u_{n-1}=1.75$

So, $u_n-u_{n-1}=1.599-1.75=-0.151$

Hence, the correct answer is – 0.151.

Question 53

The infinitesimal element shown in the figure (not to scale) represents the state of stress at a point in a body. What is the magnitude of the maximum principal stress (in N/mm^2, in integer) at the point?



Ans. **7 (7 to 7)**

Sol. **Method-1 :**

Given : $\sigma_y = 6$ MPa, $\tau_{xy} = 3$ MPa,

$$\sigma_{45} = \sigma_X^2 \cos^2 45^0 + \sigma_y^2 \sin^2 45^0 + 2\tau_{XY} \sin 45^0 . \cos 45^0$$

$$5 = \sigma_X \times \frac{1}{2} + 6 \times \frac{1}{2} + 2 \times 3 \times \frac{1}{2}$$

$$5 = \frac{\sigma_X}{2} + 3 + 3$$

$$\sigma_X = -2 \text{ MPa}$$

$$\sigma_{p_1} / \sigma_{p_2} = \frac{\sigma_X + \sigma_Y}{2} \pm \sqrt{\left(\frac{\sigma_X - \sigma_Y}{2}\right)^2 + \tau_{XY}^2}$$

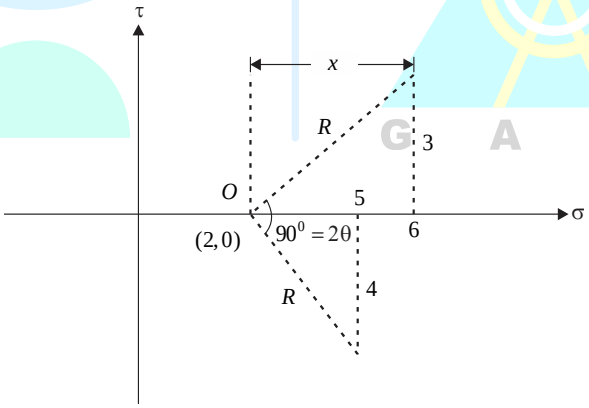
$$= \frac{-2+6}{2} \pm \sqrt{\left(\frac{-2-6}{2}\right)^2 + 3^2} = 2 \pm \sqrt{16+9}$$

$$= 2 \pm 5 \Rightarrow -3 \& 7 \text{ MPa}$$

So, maximum principle stress = 7 MPa

Hence, the correct answer is 7.

Method-2 : (Mohr Circle)



$$R = \sqrt{x^2 + 3^2} = \sqrt{(x-1)^2 + 4^2}$$

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

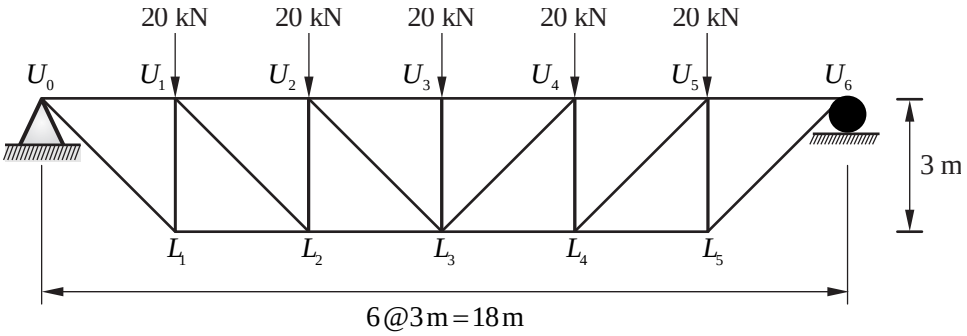
$$x = 4$$

$$\sigma_{max} = 2 + R = 2 + \sqrt{x^2 + 3^2} = 2 + \sqrt{4^2 + 3^2} = 7 \text{ MPa}$$

Hence, the correct answer is 7.

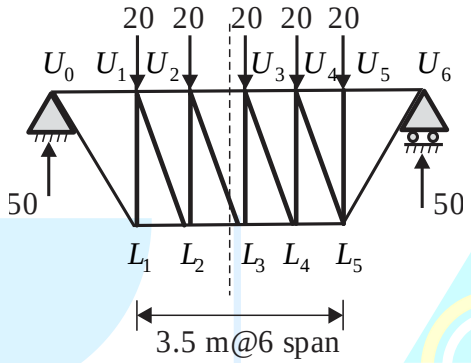
Question 54

An idealised bridge truss is shown in the figure. The force in Member U_2L_3 is _____ kN (round off to one decimal place).

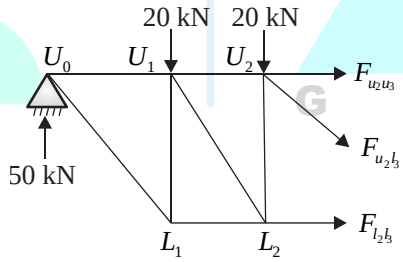


Ans. 14.1 (13.5 to 14.5)

Sol. Vertical reaction at supports $=\frac{100}{2}=50\text{ kN}\left(\text{Due to symmetry of structure}\right)$



By using method section:



$$\sum V=0$$

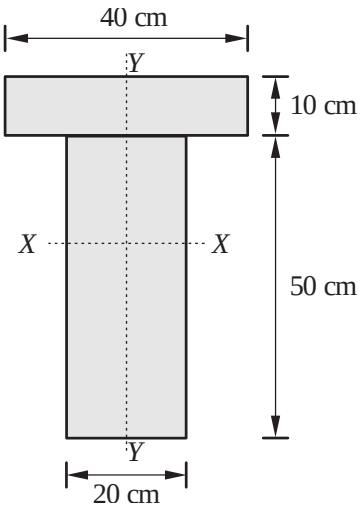
$$F_{u_2l_3}\cos 45°+20+20-50=0$$

$$F_{u_2l_3}=10\sqrt{2}=14.14\text{ kN}$$

Hence, the correct answer is 14.14.

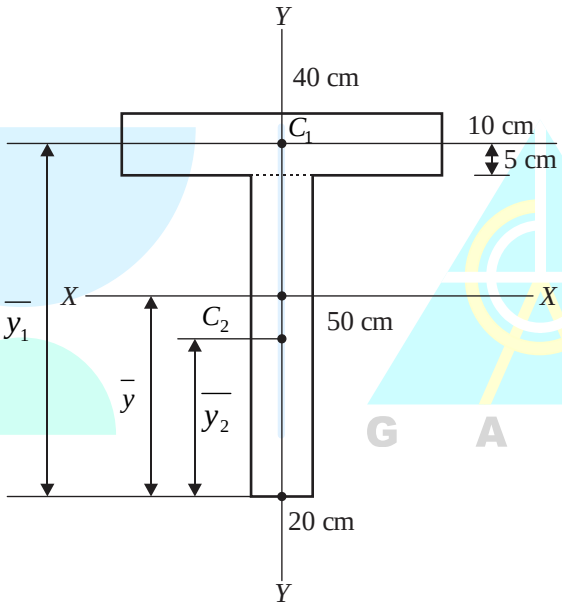
Question 55

The cross-section of a girder is shown in the figure (not to scale). The section is symmetric about a vertical axis (Y-Y). The moment of inertia of the section about the horizontal axis (X-X) passing through the centroid is_____cm^4 (round off to nearest integer).



Ans. 468810 (464000 to 472000)

Sol.



$$A_1 = 40\times10 = 400\,\text{cm}^2$$

$$A_2 = 20\times50 = 1000\,\text{cm}^2$$

$$\bar{y}_1 = 50+5 = 55\,\text{cm}$$

$$\bar{y}_2 = \frac{50}{2} = 25\,\text{cm}$$

Centroid of composite shape from bottom fibre:-

$$\bar{y} = \frac{A_1\bar{y}_1 + A_2\bar{y}_2}{A_1+A_2} = \frac{(400\times55)+(1000\times25)}{400+1000} = 33.5714\,\text{cm}$$

$$I_{xx} = \left[40\times\frac{10^3}{12} + 400(\bar{y}_1-\bar{y}_2)^2\right] + \left[20\times\frac{50^3}{12} + 1000(\bar{y}-\bar{y}_2)^2\right]$$

$$I_{xx}=\left[40\times\frac{10^3}{12}+400(55-33.5714)^2\right]+\left[20\times\frac{50^3}{12}+1000(33.5714-25)^2\right]$$

$$I_{xx}=187007.29+281802.23$$

$$I_{xx}=468809.52\,\text{cm}^4\cong 468810\ \text{cm}^4$$

Hence, the correct answer is 468810.

Question 56

A soil having the average properties, bulk unit weight = 19 kN/m^3; angle of internal friction = 25^o and cohesion = 15 kPa, is being formed on a rock slope existing at an inclination of 35^o with the horizontal. The critical height (in m) of the soil formation up to which it would be stable without any failure is _____ (round off to one decimal place).

[Assume the soil is being formed parallel to the rock bedding plane and there is no ground water effect.]

Ans. 5.0 (4.8 to 5.2)

Sol. **Given :** Bulk unit weight $(\gamma)=18\,\text{kN/m}^2$, Angle of internal friction $(\phi)=25°$

Cohesion (C) = 15 kPa and $\beta=35°$ and For critical height, FOS =1.

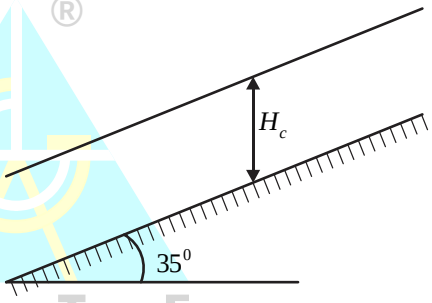
For C-ϕ soil,

$$\text{FOS}=\frac{C+\gamma H_c+\cos^2 i.\tan\phi}{\gamma z\sin i.\cos i}=1$$

$$1=\frac{15+19\times H_c\cos^2 35^0\tan 25^0}{19H_c\sin 35^0\times\cos 35^0}$$

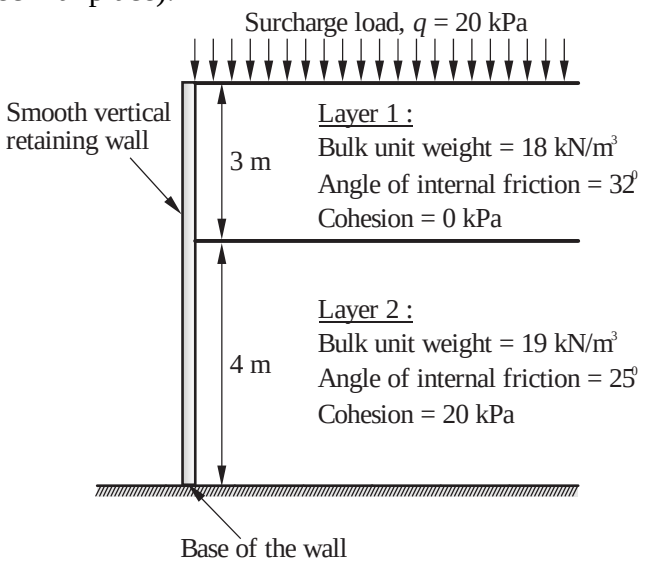
$$H_c=5.03\text{m}$$

Hence, the correct answer is 5.0.



Question 57

A smooth vertical retaining wall supporting layered soils is shown in figure. According to Rankine's earth pressure theory, the lateral active earth pressure acting at the base of the wall is _____ kPa (round off to one decimal place).



Ans. 35.4 (35.0 to 37.0)

Sol. **Given :** Surcharge load $(q) = 20\ \text{kN/m}^2$

From layer 1 : $\gamma_b = 18\,\text{kN/m}^3,\ C = 0\ \text{kPa},\ \phi = 32°$

$$\therefore \quad K_{a_1} = \frac{1-\sin 32°}{1+\sin 32°} = 0.307$$

From layer 2 : $\gamma_b = 19\,\text{kN/m}^3,\ C = 20\ \text{kPa},\ \phi = 25°$

$$\therefore \quad K_{a_2} = \frac{1-\sin 25^0}{1+\sin 25^0} = 0.4058$$

Active earth pressure at the base of the wall (P_a)

$$= (20+18\times 3+19\times 4)\times 0.4058 - 2\times 20\sqrt{0.4058} = 35.39\ \text{kPa}$$

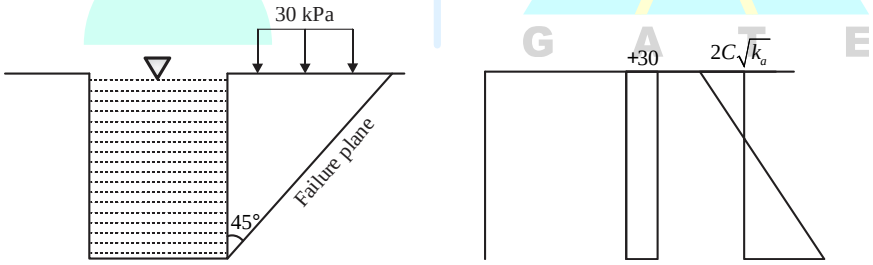
Hence, the correct answer is 35.4.

Question 58

A vertical trench is excavated in a clayey soil deposit having a surcharge load of 30 kPa. A fluid of unit weight 12 kN/m^3 is poured in the trench to prevent collapse as the excavation proceeds. Assume that the fluid is not seeping through the soil deposit. If the undrained cohesion of the clay deposit is 20 kPa and saturated unit weight is 18 kN/m^3, what is the maximum depth of unsupported excavation (in m, rounded off to two decimal places)? _____.

Ans. 3.33 (3.30 to 3.35)

Sol. $\gamma_{sub} = 18-12 = 6\ \text{kN/m}^3$



$$P = \sigma_v K_a - 2C\sqrt{K_a}$$

$$P = (30+\gamma_{sub} z)\times 1 - 2C\sqrt{1}$$

When P = 0, $\quad 30+6z-2\times 20 = 0$

$$6z = 10$$

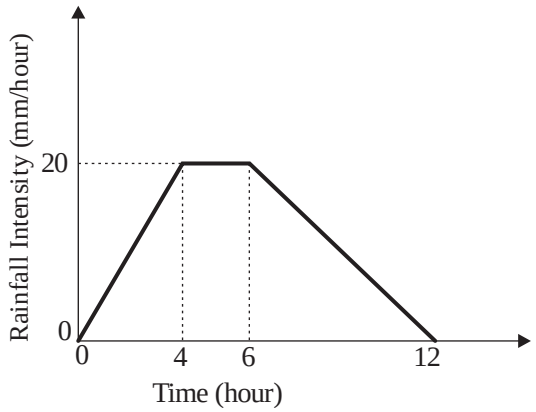
$$z = \frac{10}{6}\text{m}$$

So, maximum depth of unsupported excavation = $2\times\frac{10}{6} = 3.33$

Hence, the correct answer is 3.33.

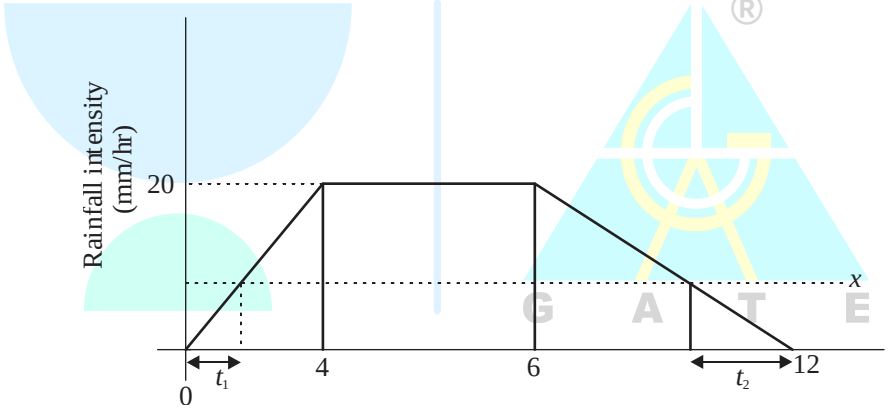
Question 59

A 12-hour storm occurs over a catchment and results in a direct runoff depth of 100 mm. The time-distribution of the rainfall intensity is shown in the figure (not to scale). The ϕ-index of the storm is (in mm, rounded off to two decimal places) _____.



Ans. 3.60 (3.59 to 3.61) or (39.9 to 40.1)

Sol.



W-Index: $P=\frac{1}{2}\times4\times20+(2\times20)+\frac{1}{2}\times20\times6=40+40+60=140$ mm

Total infiltration = 140 -100 = 40 mm

From figure, $\frac{x}{t_1}=\frac{20}{4}$

$$t_1=\frac{x}{5}$$

Also, $\frac{x}{t_2}=\frac{20}{6}$

$$t_2=\frac{3x}{10}$$

Total infiltration $\Rightarrow\frac{1}{2}\times\frac{x}{5}\times x+\frac{1}{2}\times\frac{3x}{10}\times x+\left(12-\frac{5x}{10}\right)\times x=40$

$$\Rightarrow \frac{x^2}{10}+\frac{3x^2}{20}+12x-\frac{5x^2}{10}=40$$

$$\Rightarrow \frac{-5x^2}{20}+12x=40$$

$$\Rightarrow x^2-48x+160=0$$

By solving, $x=3.6, 44.39$

So, $\phi-$index of the storm $=3.6$ mm/hr

Hence, the correct answer is 3.6.

Question 60

A hydraulic jump occurs in a 1.0 m wide horizontal, frictionless, rectangular channel, with a pre-jump depth of 0.2 m and a post-jump depth of 1.0 m. The value of g may be taken as 10 m/s^2. The values of the specific force at the pre-jump and post-jump sections are same and are equal to (in m^3, rounded off to two decimal places) _____.

Ans. 0.62 (0.60 to 0.64)

Sol. For hydraulic jump specific force is constant

$$\frac{Q^2}{gA_1}+A_1\bar{Z}_1=\frac{Q^2}{gA_2}+A_2\bar{Z}_2$$

$$\frac{Q^2}{10\times0.2\times1}+(0.2\times1)\times0.1=\frac{Q^2}{10\times1\times1}+(1\times1)\times0.5$$

$$\frac{Q^2}{10}\left(\frac{1}{0.2}-1\right)=(0.5-0.02)$$

$$Q^2=1.2$$

$$\text{Specific Force}=\frac{Q^2}{gA_1}+A_1\bar{Z}_1=\frac{1.2}{10\times0.2\times1}+(0.2\times1)0.1$$

$$\text{Specific Force}=0.62\,\text{m}^3$$

Hence, the correct answer is 0.62.

Question 61

In Horton's equation fitted to the infiltration data for a soil, the initial infiltration capacity is 10 mm/h; final infiltration capacity is 5 mm/h; and the exponential decay constant is 0.5 /h. Assuming that the infiltration takes place at capacity rates, the total infiltration depth (in mm) from a uniform storm of duration 12 h is _____. (round off to one decimal place)

Ans. 70 (69.7 to 70.1)

Sol. **Given :** Initial Infiltration $(f_0)=10$ mm/hr, Final infiltration $(f_c)=5$ mm/hr

Duration (t) =12 hr, Horton's decay constant (k) = 0.5 per hr.

$$f(t)=\int_0^t f_t\,dt=\int_0^t\left(f_c+(f_0-f_c)e^{-kt}\right)dt$$

$$f(12)=\int_0^{12}\left(5+(10-5)e^{-0.5t}\right)dt$$

$$=(5\times12)+\left[-10e^{-0.5\times12}-\left(-10e^{-0.5\times0}\right)\right]=70\text{ mm}$$

Hence, the correct answer is 70.

Question 62

The composition and energy content of a representative solid waste sample are given in the table. If the moisture content of the waste is 26%, the energy content of the solid waste on dry-weight basis is _____ MJ/kg (round off to one decimal place).

Component	Percent by mass	Energy content as-discarded basis (MJ/kg)
Food waste	20	4.5
Paper	45	16.0
Cardboard	5	14.0
Plastics	10	32.0
Others	20	8.0

Ans. 18.4 (18 to 19)

Sol. **Given :** Moisture content of waste = 26%

Solid content = 100 – 26 = 74%

Component	% Mass	EC (MJ/kg)	Energy content (Discarded basis)
Food waste	20	4.5	20×4.5
Paper	45	16	45×16
Card board	5	14	5×14
Plastic	10	32	10×32
Others	20	8	20×8
			$\Sigma EC=13.60$ MJ

EC on dry basis = $\dfrac{13.60}{0.74}=18.37\text{ MJ}\approx18.4\text{MJ/kg}$

Hence, the correct answer is 18.4.

Question 63

A flocculator tank has a volume of 2800 m^3. The temperature of water in the tank is 15°C, and the average velocity gradient maintained in the tank is 100/s. The temperature of water is reduced to 5°C, but all other operating conditions including the power input are maintained as the same. The decrease in the average velocity gradient (in %) due to the reduction in water temperature is (round off to nearest integer).

[Consider dynamic viscosity of water at 15°C and 5°C as 1.139×10^{-3} N-s/m^2 and 1.518×10^{-3} N-s/m^2, respectively]

Ans. 13 (12 to 15)

Sol. **Given :** Volume of flocculation tank (V) = 2800 m^3

Initial temperature (T_1) = 15°C

Reduced temperature (T_2) = 5°C

$$G_{1,15°C} = \sqrt{\frac{P}{\mu_1 \times V}} \qquad ...(i)$$

$$G_{2,5°C} = \sqrt{\frac{P}{\mu_2 \times V}} \qquad ...(ii)$$

From equation (i) and (ii), we get

$$\frac{G_1^2}{G_2^2} = \frac{\mu_2}{\mu_1}$$

$$G_2^2 = \frac{(100\,s^{-1}) \times 1.139 \times 10^{-3}}{1.518 \times 10^{-3}}$$

$$G_2^2 = 86.62 \text{ sec}^{-1}$$

Decrease in velocity gradient = $\frac{G_1 - G_2}{G_1} \times 100 = \frac{100 - 86.62}{100} \times 100 = 13.38\%$

Hence, the correct answer is 13.38.

Question 64

The wastewater inflow to an activated sludge plant is 0.5 m^3/s, and the plant is to be operated with a food to microorganism ratio of 0.2 mg/mg-d. The concentration of influent biodegradable organic matter of the wastewater to the plant (after primary settling) is 150 mg/L, and the mixed liquor volatile suspended solids concentration to be maintained in the plant is 2000 mg/L. Assuming that complete removal of biodegradable organic matter in the tank, the volume of aeration tank (in m^3, in integer) required for the plant is _____.

Ans. **16200 (16200 to 16200)**

Sol. **Given :** Wastewater inflow $(Q_0) = 0.5\ m^3/s$

Food to micro-organism ratio $\left(\frac{F}{M}\right) = 0.2d^{-1}$

$S_0 = 150\ mg/l$, MLVSS$(X) = 2000\,mg/l$

$V = ?$

We know that, $\frac{F}{M} = \frac{Q_0 S_0}{VX}$

$$0.2 = \frac{0.5\ m^3/s \times 86400 \times 150\,mg/l}{V \times 2000\ mg/l}$$

$$V = 16200\,m^3$$

Hence, the correct answer is 16200.

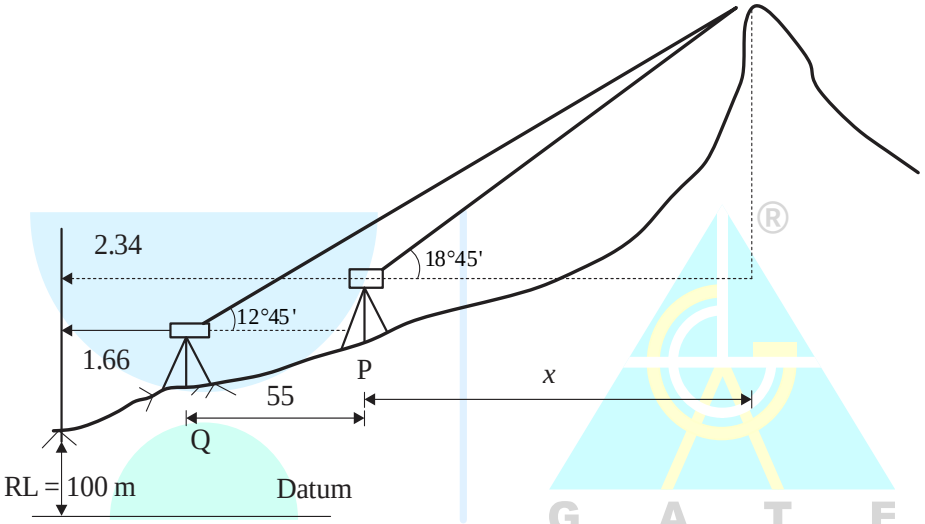
Question 65

Trigonometric levelling was carried out from two stations P and Q to find the reduced level (R. L.) of the top of hillock, as shown in the table. The distance between Stations P and Q is 55 m. Assume Stations P and Q, and the hillock are in the same vertical plane. The R. L. of the top of the hillock (in m) is _____. (round off to three decimal places).

Station	Vertical angle of the top of hillock	Staff reading on benchmark	R.L. of benchmark
P	18°45'	2.340 m	100.000 m
Q	12°45'	1.660 m	

Ans. 137.682 (137.500 to 137.700)

Sol.



When reading taking from P,

RL of hillock = $HI_P + x\tan 18°45' = 100 + 2.34 + x\tan 18°45'$ ...(i)

When reading taking from Q,

RL of hillock $= HI_Q + (x+55)\tan 12°45' = 100 + 1.66 + (x+55)\tan 12°45'$ ...(ii)

By Equating equation (i) and (ii),

$$100 + 2.34 + x\tan 18°45' = 100 + 1.66 + (x+55)\tan 12°45'$$

$$2.34 + 0.339x = 1.66 + 12.445 + 0.226x$$

$\therefore$ $x = 104.115$

$\therefore$ RL of the top of the hillock

$$= 100 + 2.34 + 104.115\tan 18°45' = 137.682\text{ m}$$

Hence, the correct answer is 137.682.

❑❑❑