GATE 2023

CIVIL ENGINEERING

Memory based Questions & Solutions

Exam held on 12th Feb, 2023 Forenoon Session

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SECTION - A GENERAL APTITUDE

Q.1 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 atleast A or B.

Ans. **(0.9)**

As it is independent evens so

$$P(A) \cap P(B) = P(A) \times P(B)$$

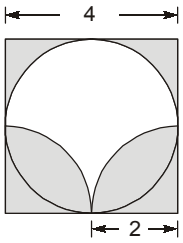
Given, $P(A) = 0.5$ and $P(B) = 0.8$

So, $P(\bar{A}) = 0.5$ and $P(\bar{B}) = 0.2$

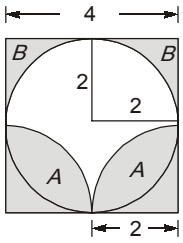
$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$
$$= 0.5 + 0.8 - 0.5 \times 0.8 = 0.9$$

End of Solution

Q.2 Find area of shaded region



Ans. **(8)**



Area of quadrant, $A = \frac{1}{4}\pi(2)^2 = \pi$

Area of sector, B = Area of square – Area of quadrant
$= 4 - \pi$

So, total shaded area $= 2A + 2B = 2 \times \pi + 2 \times (4 - \pi)$
$= 2\pi + 8 - 2\pi = 8$ unit^2

End of Solution

Q.3 If $a = 30!$, $b = 50!$, $c = 100!$ then arrange $\log_a c, \log_c a, \log_a b, \log_b a$

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

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

Ans. **(b)**

Given, $a = 30!$, $b = 50!$ and $c = 100!$

We know that $\log_n m = \dfrac{\log m}{\log n}$

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

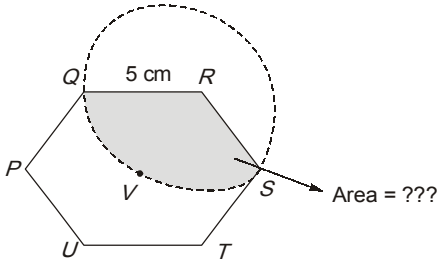
$\dfrac{\log 100!}{\log 30!}, \dfrac{\log 30!}{\log 100!}, \dfrac{\log 50!}{\log 30!}, \dfrac{\log 30!}{\log 50!}$

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

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

End of Solution

Q.4 PQRSTU 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?



(a) $\dfrac{25\pi}{3}$ (b) $\dfrac{20\pi}{3}$

(c) 6π (d) 7π

Ans. **(a)**

Interior angle sum = $(n - 2) \times 180°$

Each angle of regular Hexagon.

$$\frac{(n-2)\times 180°}{n} = 120°$$

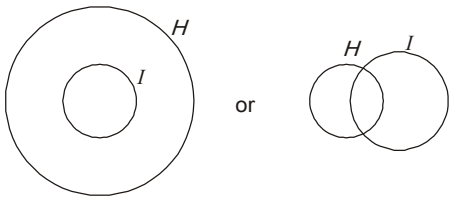
$$\text{Required area} = \frac{\theta}{360°} \times \pi \times 25 = \frac{25\pi}{3}$$

End of Solution

Q.5 Based on statement, "Some Humans are intelligent". What logical conclusion can be drawn with certainty?

(a) No Human is intelligent
(b) Some intelligent beings are human
(c) All human are intelligent
(d) No intelligent is human

Ans. **(b)**



Only option (b) is correct.

End of Solution

Q.6 I have not yet decided what will i do this evening. I _____ visit a friend.

(a) might (b) did not
(c) mite (d) would

Ans. **(a)**

End of Solution

Q.7 Eject : Insert : : Advance : _____.

(a) Loan (b) Retreat
(c) Progress (d) Advent

Ans. **(b)**

End of Solution

Q.8 The James Webb telescope, recently launched in space is giving human kind unprecedented access to the depths of time by giving imaging of very old stars formed almost 13 billion years ago. Astrophysicists and cosmetologists 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 weak or the strong interaction. This may justify the epithet 'dark' in dark matter.

Based on the above paragraph, which one is false?

(a) No other telescope has captured image of stars older than those captured by the James Webb telescope.
(b) If dark matter known to interact via the strong interaction, then the epithet 'dark' would be justified.
(c) The James Webb telescope could be of use in research on dark matter.
(d) People other than astrophysicists and cosmetologists may also believe in the existence of dark matter.

Ans. **(b)**

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SECTION - B TECHNICAL

Highway

Q.9 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 of the transition curve? (round off to nearest integer)

Ans. **(15)**

Given: $V = 15$ m/s

$R = 300$ m

Jerk, $C = 0.75$ m^3/s

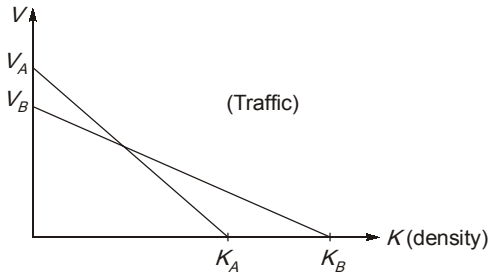
So, height of transition curve,

$$L_t = \frac{V^3}{RC} = \frac{15^3}{300 \times 0.75} = 15 \text{ m}$$

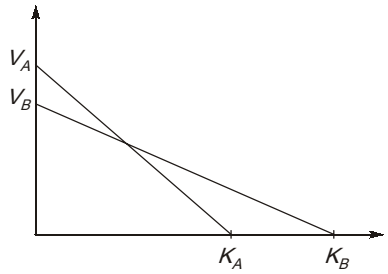
Note: We should also find out the length by formula given by IRC but terrain is not mentioned.

End of Solution

Q.10 Given capacitor of road A is C_A capacitor of road B is C_B, then, $\frac{C_A}{C_B} = ?$



Ans.



Now, capacity of road A,

$$q_{\max A} = \frac{1}{4} K_A V_A$$

Similarly, capacity of road B,

$$q_{\max B} = \frac{1}{4} K_B V_B$$

Now, $$\frac{C_A}{C_B} = \frac{\frac{1}{4} \times K_A \times V_A}{\frac{1}{4} \times K_B \times V_B} = \frac{K_A V_A}{K_B V_B}$$

End of Solution

Q.11 Two curves of gradients, g1 and g2 are merging such that g1 < g2 and g1 is not equal to g2 and not equal to zero...
(i) +g1 and +g2 are making sag vertical curve
(ii) - g1 and - g2 are making sag vertical curve
(iii) +g1 and - g2 are making crest vertical curve
Which of these statements is/are correct?

Ans. **(Statement (i) and (iii) are correct.)**
Condition for summit curve (crest vertical curve),
+ve to +ve; +ve to flat
(g1 > g2)
+ve to –ve; –ve to –ve
(g1 < g2)

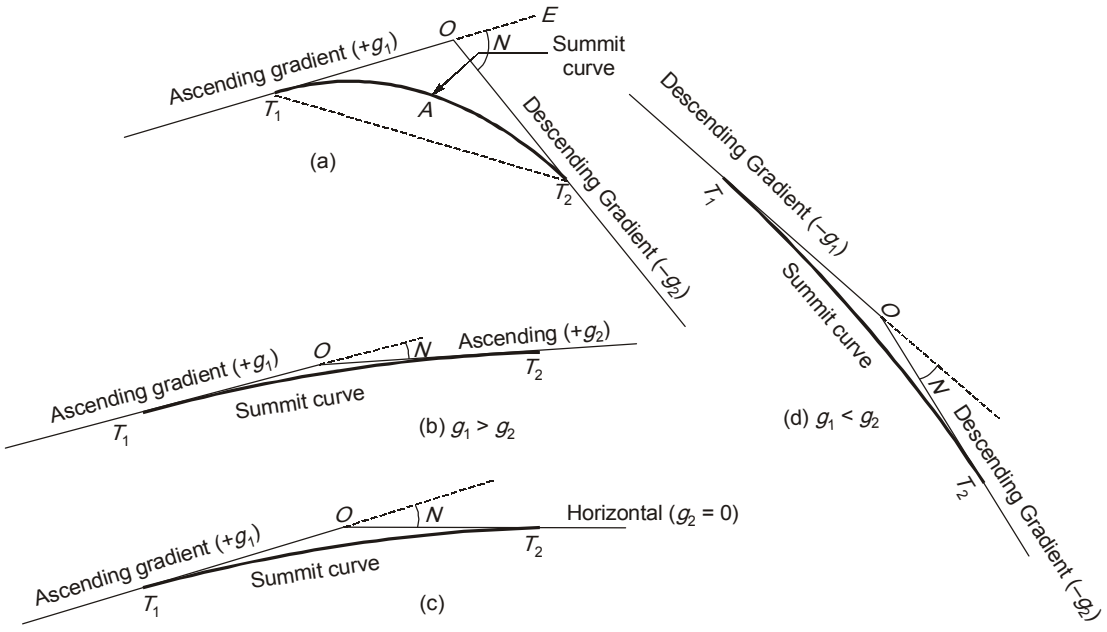
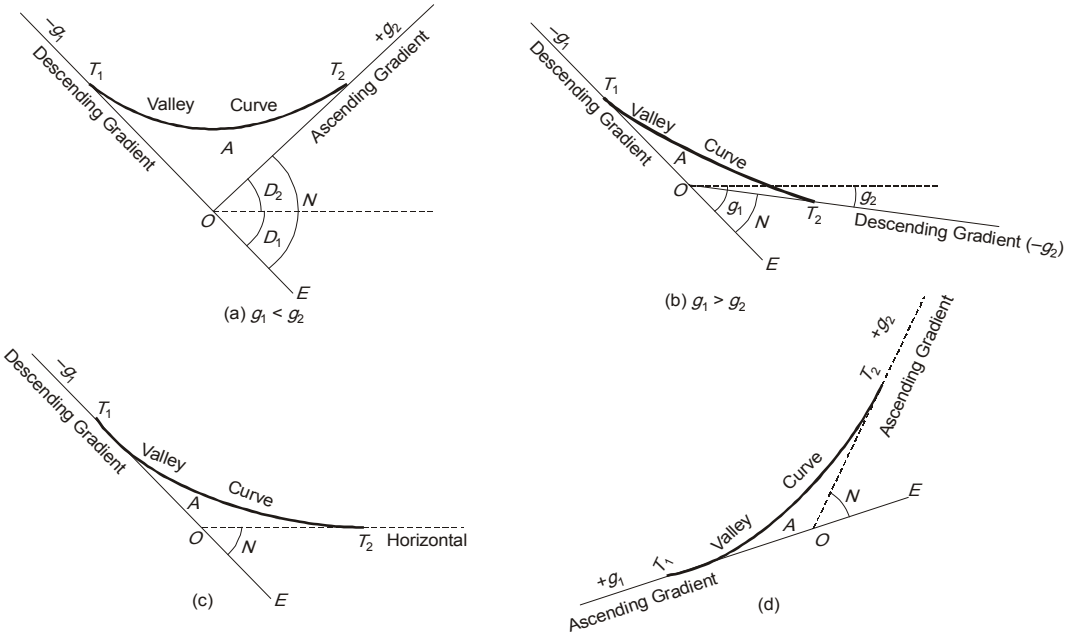


Fig. Summit curve, (showing deflection angle)

Condition for valley curve (sag vertical curve),
–ve to –ve; –ve to flat
(g1 > g2)
–ve to +ve; +ve to +ve

(g1 < g2)



End of Solution

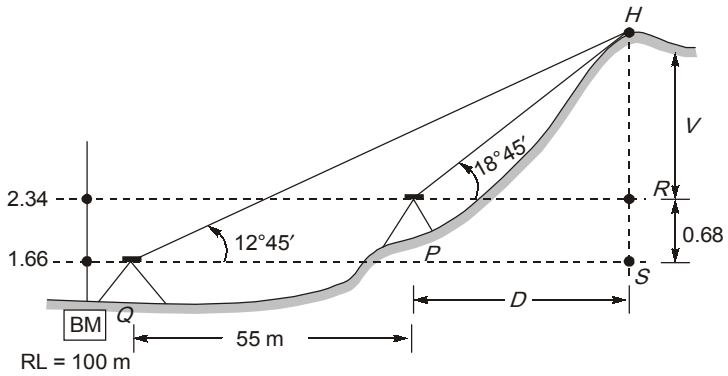
SURVEYING ENGINEERING

Q.12 To find the R.L of hilltop instrument readings were taken from *P* and *Q*. The distance between *P* and *Q* is 55 m and all the points lie in the same vertical plane.

Station	Vertical angle of top of hilllock	Staff reading on B.M	R.L of BM
P	18° 45′	2.340 m	100.000 m
Q	12° 45′	1.660 m	

The R.L. of hill top is _____ m.

Ans. (137.627)



Now, $\tan 12°45' = \dfrac{v + 0.68}{D + 55}$ ...(i)

Also, $\tan 18°45' = \frac{v}{D}$ ...(ii)

On solving (i) and (ii), weg get

$v = 35.287$ m

$D = 103.954$ m

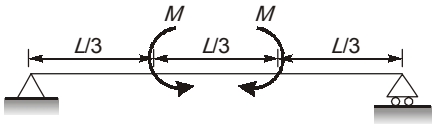
Now, R.L. of hill top = R.L. of BM + 2.34 + v

= 100 + 2.34 + 35.287 = 137.627 m

End of Solution

STRENGTH OF MATERIAL

Q.13 Consider the following beam subjected to moments as shown in figure.



Which of the following statement(s) is/are correct?

(a) Shear force is zero everywhere

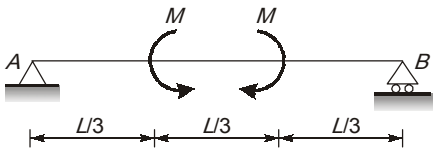
(b) Reaction is zero

(c) Bending moment is zero everywhere

(d) Deflection is zero

[MSQ]

Ans. **(a, b)**



$\Sigma F_y = 0$

$\therefore \quad V_A + V_B = 0$ ...(i)

$\Sigma M_A = 0$

$\Rightarrow \quad V_B \times L - M + M = 0$

$\therefore \quad V_B = 0$

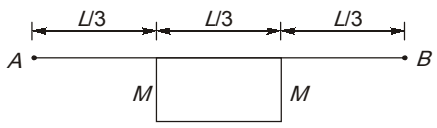
from equation (i), we get

$V_A = 0$

$\therefore$ shear force is zero everywhere in the beams,

and reactions are also zero.

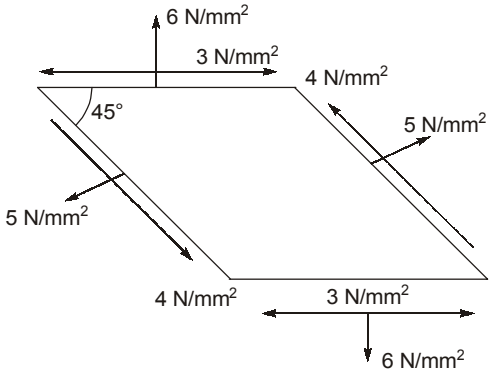
Bending moment diagram is shown below



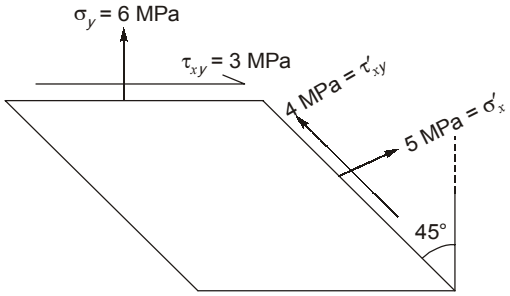
So, bending moment is not zero everywhere. Also deflection is not zero everywhere.

End of Solution

Q.14 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 principle stress (in N/mm^2 in integer) at the point is (Round off to nearest integer)



Ans. **(– 3)**



Now, $\sigma'_x = \sigma_x \cos^2\theta + \sigma_y \sin^2\theta + \tau_{xy} \sin 2\theta$ ...(i)

here $\theta = 45°$

$\sigma'_x = 5$ MPa

$\sigma_y = 6$ MPa

$\tau_{xy} = 3$ MPa

from eq. (i), we get, $\sigma_x = -2$ MPa

Now, $$\sigma_{1/2} = \frac{\sigma_x + \sigma_y}{2} \pm \frac{1}{2}\sqrt{(\sigma_y - \sigma_x)^2 + 4\tau xy^2}$$

$$= \frac{-2+6}{2} \pm \frac{1}{2}\sqrt{(6+2)^2 + 4\times 3^2}$$

$\sigma_1 = 7$ MPa

$\sigma_2 = -3$ MPa

End of Solution

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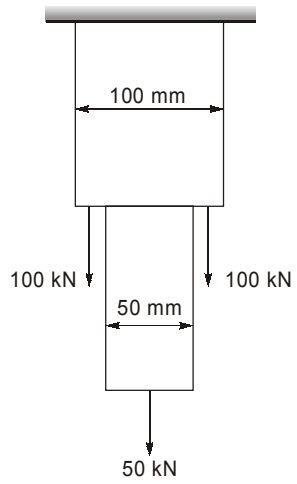
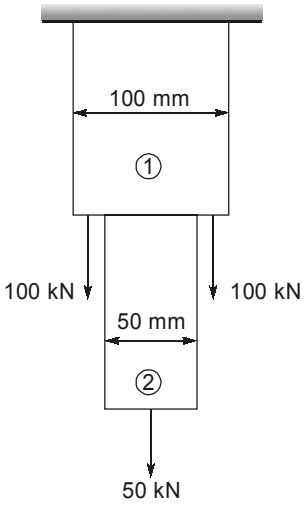
Q.15 A hanger is made of two bars of different sizes. Each bar has a square cross-section. The hanger is loaded by three-point loads in the mid vertical plane as shown in the figure. Ignore the self weight of the hanger. What is the maximum tensile stress in N/mm^2 anywhere in the hanger without considering stress concentration effects?



(a) 25.0
(b) 35.0
(c) 45.0
(d) 15.0

Ans. **(a)**



Stress in member (1),

$$(\sigma_1) = \frac{P_1}{A_1} = \frac{250 \times 10^3}{100 \times 100} = 25\ \text{N/mm}^2$$

Stress in m ember (2),

$$(\sigma_2) = \frac{P_2}{A_2} = \frac{50 \times 10^3}{50 \times 50} = 20\ \text{N/mm}^2$$

$\therefore$ $\sigma_{max} = 25\ \text{N/mm}^2$

End of Solution

GEOTECHNICAL + OCF

Q.16 A hydraulic jump occurs in a from wide horizontal, frictionless, rectangular channel, with a prejump depth of 0.2 m and post jump depth of 1.0 m. The value of g may be taken of 10 m/s^2. The value of specific force per meter width at the pre jump and post jump section is same and is equal to (in m^3/m).

Ans. **(3.02)**

Given, $y_1 = 0.2$ m, $y_2 = 1$ m

As we know

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

$$\Rightarrow \quad \frac{2q^2}{9.81} = 0.2 \times 1 (0.2 + 1)$$

$$\Rightarrow \quad q^2 = \frac{9.81}{2} \times 0.2 \times 1.2$$

$$q = 1.085 \text{ m}^3/\text{s/m}$$

Now, $\text{specific force} = \frac{Q^2}{Ag} + A\bar{y}$

$$= \frac{q^2 B^2}{B^2 y_1^2 g} + \frac{B y_1 y_1}{2}$$

$$= \left(\frac{1.085^2}{0.2^2 \times 9.81} + \frac{0.2^2}{2} \right) \times B = 0.32B = 3.02 \text{ B}$$

So, Specific force per unit width = 3.02 m^3/m

End of Solution

Q.17 Statements are given regarding the compaction curve. Select which of the following statements are INCORRECT?

(a) With increase in compactive effort, OMC decreases.

(b) With increase in compactive effort, $\gamma_{d,\max}$ increases.

(c) Peak of compaction curve, gives the value of $\gamma_{d,\max}$ and OMC.

(d) Compaction curve crosses zero-air void line.

Ans. **(d)**

Zero air void line do not cross compaction curve.

End of Solution

Q.18 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 (rounded off to the nearest integer)

Ans. **(35)**

Given, Normal stress, $\sigma_x = 50$ kPa

Shear stress, $\tau = 35$ kPa

$\tau = c + \sigma_n \tan\phi$

$\Rightarrow \quad 35 = 50 \tan\phi \qquad (\because C = 0$, sandy soil)

$\Rightarrow \quad \tan\phi = 0.7$

$\Rightarrow \quad \phi = 35°$

End of Solution

Q.19 The specific gravity of a soil is 2.60. The soil is 50% saturated with a water content of 15%. The void ratio of the soil is

(a) 0.87 (b) 1.28
(c) 0.78 (d) 0.35

Ans. **(0.78)**

Given: Specific gravity, $G = 2.6$

Saturation, $S = 0.5$

Water content, $w = 0.15$

As we know

$Se = Gw$

$\Rightarrow \quad 0.5 \times e = 2.6 \times 0.15$

$\Rightarrow \quad e = \dfrac{2.6 \times 0.15}{0.5} = 0.78$

End of Solution

Q.20 A group of 9 friction piles are arranged in a square grid maintaining equal spacing is all direction. Each piles is of diameter 300 mm and length 7 m. Assume that the soil is cohesionless with effective friction angle $\phi = 32°$. What is the centre to centre spacing of the piles (in m) for the piles group efficiency of 60%?

(a) 0.587 (b) 0.486
(c) 0.391 (d) 0.677

Ans. **(a)**

By converse – Labarre formula

$$\eta_g = \left[1 - \frac{\theta}{90}\left(\frac{m(n-1)+n(m-1)}{mn}\right)\right] \times 100$$

$$\Rightarrow \quad 0.6 = 1 - \frac{\theta}{90}\left(\frac{3\times 2 + 3\times 2}{3\times 3}\right)$$

$$\Rightarrow \quad \frac{\theta}{90}\left(\frac{6+6}{9}\right) = 0.4$$

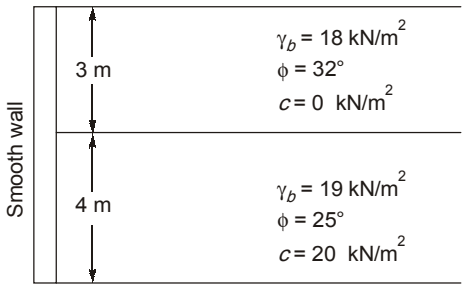
$$\Rightarrow \quad \theta = 27°$$

Now, $\tan\theta = \dfrac{d}{S}$ where d is diameter and S is spacing.

So, Spacing, $S = \dfrac{d}{\tan\theta} = \dfrac{0.3}{\tan 27°} = 0.587$

End of Solution

Q.21 A smooth vertical retaining wall supports lagesed soils is shown in figure. A/c to Rankine each pressure theory, the lateral active each pressure acting at the base of the wall is kPa.



Ans. **(27.29)**

Active earth pressure at base,

$$\therefore \quad \sigma = k_a(\gamma_z + q) - 2C\sqrt{ka}$$

where, $$k_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 25°}{1+\sin 25°} = 0.406$$

$$q = 18 \times 3 = 54 \text{ kN/m}^2$$
$$\gamma_z = 19 \times 4 = 76 \text{ kN/m}^2$$
$$C = 20 \text{ kN/m}^2 \quad [\because \text{Given}]$$

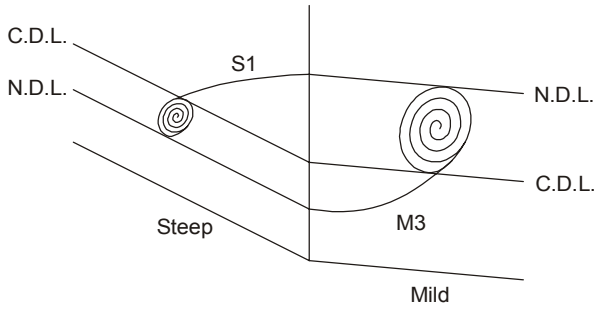
So, $$\sigma = 0.406 \times (76 + 54) - 2 \times 20 \times \sqrt{0.406}$$
$$= 27.29 \text{ kN/m}^2$$

End of Solution

Q.22 The supercritical stream enters the mild sloped (M) channel section, what would be the type of profile?

(a) M1 + M2 (b) M1
(c) M1 (d) M3

Ans. **(d)**



End of Solution

Q.23 Consider that force P is acting on the surface of a half-space (Boussineq's problem). The expression for the vertical stress (σ_z) at any point (r, z) is given as

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

where r is the radial distance and z is the depth with download direction taken as positive. At any given r, there is a variation of σ_z along is the locus of the maximum σ_z?

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

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

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

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

Ans. **(d)**

At given r

For maximum σ_z

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

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

$$\Rightarrow \quad \frac{d\sigma_z}{dz} = \frac{3P}{2\pi} \left[\frac{(r^2 + z^2)^{5/2} 3z^2 - z^3 \cdot \frac{5}{2} (r^2 + z^2)^{3/2} \cdot 2z}{(r^2 + z^2)^5} \right] = 0$$

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

$$\Rightarrow \quad 3r^2 + 3z^2 - 5z^2 = 0$$

$$\Rightarrow \quad 3r^2 = 2z^2$$

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

End of Solution

Q.24 A vertical trench is excavated in a clayey soil deposit having a surcharge load of 30 kPa. A fluid of unit-weight is 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, round off to two decimal).

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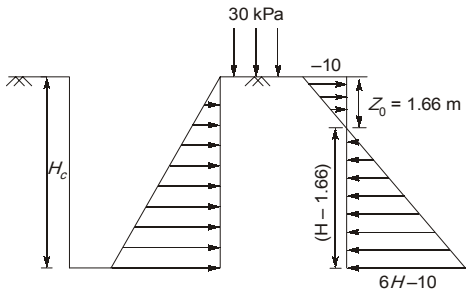
Ans. (3.33)



Now, active pressure at depth z,

$$\sigma_z = k_a\gamma z - 2C\sqrt{k_a} - 12z + kq$$

At $z = 0$

[$\because k = 1$ for $\phi = 0°$, $q = 30$ kN/m^2; $C = 20$ kN/m^2]

$$\sigma_z = -2 \times C + q = 2 \times 20 + 30$$
$$= -40 + 30$$
$$= -10 \text{ kN/m}^2$$

At z_0, $\sigma_z = 0$

$$18z_0 - 40 - 12z_0 + 30 = 0$$
$$\Rightarrow 6z_0 - 10 = 0$$
$$\Rightarrow z_0 = 1.66 \text{ m}$$

At depth H, $\sigma_H = k_a\gamma H - 2C\sqrt{k_a} - 12H + k_q$

So, $\sigma_H = 18H - 40 - 12H + 30$

$= 6H - 10$

For unsupported depth of excavation, total active thrust must be zero.

So, $\frac{1}{2} \times 10 \times 1.66 = \frac{1}{2} \times (H - 1.66) \times (6H - 10)$

$$\Rightarrow H = \frac{10}{3} = 3.33 \text{ m}$$

Alternatively:

$$\sigma_v = q + \gamma_z$$
$$= 30 + 18z$$

$$p_a = k_a\sigma_v - 2c\sqrt{k_a}$$

$$p_a = 30 + 18z - 2 \times 20 = 18z - 10$$

For critical depth, $p_a = 0$

$$18z_c - 10 = 0$$

$$z_c = \frac{10}{18}\text{m} = 0.556 \text{ m}$$

For the maximum depth of unsupported excavation, the active earth pressure force at that depth should be zero.

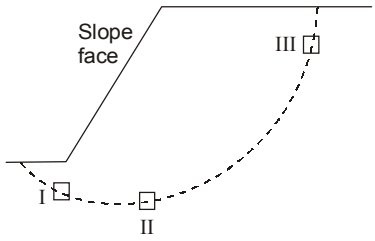
$$\therefore P_a = \frac{1}{2}(18H_c - 10)(H_c - 0.56) - \frac{1}{2}10 \times 0.56 - \frac{1}{2}\gamma_w H_c^2 = 0$$

$$H_c = 0, 3.33 \text{ m}$$

Therefore, the maximum depth of unsupported excavation is 3.33 m.

End of Solution

Q.25 Match **List-I** (Cross sectional element on failure surface) with **List-II** (Test to be perform for analysis) and select the correct answer using the codes given below the lists:



List-I	List-II
1. I	P. Triaxial compression
2. II	Q. Triaxial extension
3. III	R. Direct shear
	S. Vane shear

Ans.

$$I \rightarrow R, \quad II \rightarrow P, \; III \rightarrow S$$

End of Solution s

Q.26 A soil formation with average bulk density, γ_b = 19 kN/m^2, and ϕ = 25°, and C = 15 kPa, lies on a rock slope existing at 35°. The critical height of soil formation upto which it would be stable is _____.

Ans. **(5.03)**

For critical height of slope

$$C + \gamma H_C \cos^2\beta \tan\phi = \gamma H_C \sin\beta \cos\beta$$

So, $15 + 19 \times H_C \times \cos^2 35° \tan 25° = 19 \times H_C \times \sin 35° \cos 35°$

$$\Rightarrow \quad H_C = 5.03 \text{ m}$$

End of Solution

ENGINEERING MATHEMATICS

Q.27 $I = \int_{-1}^{1} \frac{1}{x^2} dx$ which of the following statement is true?

(a) $I = 2$
(b) The integral does not converge
(c) $I = 0$
(d) $I = -2$

Ans. **(b)**

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

So, $$I = \int_{-1}^{0} \frac{1}{x^2} dx + \int_{0}^{1} \frac{1}{x^2} dx$$

$$= \left(-\frac{1}{x}\right)_{-1}^{0} + \left(-\frac{1}{x}\right)_{0}^{1}$$

$\frac{1}{x}$ is not defined at $x = 0$

Therefore, the integral does not converge.

End of Solution

Q.28 In the differential equation $\frac{dy}{dx} + \alpha xy = 0$, α is a positive constant. $y = 1.0$ at $x = 0.0$ and $y = 0.8$ at $x = 1.0$, the value of α is _____.

Ans. **(0.446)**

Given, $\frac{dy}{dx} + \alpha xy = 0$

Using variable spareable method.

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

$$y = Ce^{\frac{-\alpha}{2}x^2}$$

By putting $y(0) = 1$
we get $C = 1$
By putting $y(1) = 0.8$

$$e^{\frac{-\alpha}{2}} = 0.8$$

$$\alpha = -2 \log 0.8 = 0.446$$

End of Solution

Q.29 $A = \begin{bmatrix} 1 & 2 & 3 \\ 3 & 2 & 1 \\ 3 & 1 & 2 \end{bmatrix}$ which of the following is/are true?

(a) Eigen values of A^T and A are same.
(b) Eigen vectors of A and A^T are same.
(c) Eigen value of A^{-1} is reciprocal of Eigen value of A.
(d) Eigen value of A^{-1} and A^T are same.

Ans. **(a, b, c)**

Using properties,
Eigen values of A^T and A are same.
Eigen vectors of A and A^T are same.
Eigen values of A^{-1} is reciprocal of Eigen value of A.
$\therefore$ Option (d) is not correct.

End of Solution

Q.30 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 3.14s. Each time step is 0.01s long. Then, the value of $(U_n - U_{n-1})$ is ____. (round off to three decimal).

Ans. **(– 0.182)**

Given differential equation

$$\frac{du}{dt} + 2tu^2 = 1$$

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

$$u_n = u_{n-1} + hf(t_n, u_n)$$

$$u_n - u_{n-1} = h[1 - 2t_n u_n^2]$$

Given, $h = 0.01,\ u_n = 1.75,\ t_n = 3.14$

Putting these value we get

$$= -0.182$$

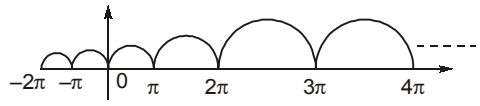
End of Solution

Q.31 $f(x) = e^x|\sin x|$

(a) Periodic
(b) Bounded
(c) Continuous
(d) Differentiable

Ans. **(c)**

Given: $f(x) = e^x|\sin x|$



By observing graph we can easily say given function is not periodic, not bounded and not differentiable.

End of Solution

Q.32 If $f(x) = px^4 + qx^5$; $\{-l, l\}$ and it's Fourier series expansion is

$$f(x) = a_0 + \sum_{n=1}^{\infty} b_n \cos\left(\frac{n\pi x}{l}\right) + \sum_{n=1}^{\infty} a_n \sin\left(\frac{n\pi x}{l}\right)$$

Then which statements is/are false?

(a) a_n depends upon p
(b) a_n depends on q
(c) b_n depends upon p
(d) b_n depends on q

Ans. (a, d)

$$b_n = \frac{1}{l}\int_{-l}^{l} f(x)\cos\frac{(n\pi x)}{l}dx$$

$$= \frac{1}{l}\int_{-l}^{l} px^4\cos\frac{(n\pi x)}{l}dx + 0$$

$$a_n = \frac{1}{l}\int_{-l}^{l} f(x)\sin\frac{(n\pi x)}{l}dx$$

$$= 0 + \frac{1}{l}\int_{-l}^{l} qx^5\sin\frac{(n\pi x)}{l}dx$$

End of Solution

RCC

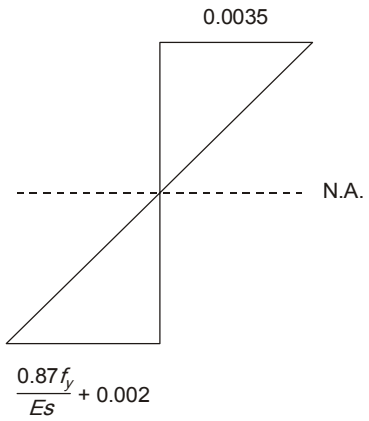
Q.33 A singly reinforced concrete beam of balanced section is made of M20 grade concrete and Fe415 grade steel bars. The magnitude of the maximum compressive strain in concrete and the steel bars at ultimate state under flexure as per IS 456 : 2000 are_____.

(a) 0.0035 and 0.0038 (b) 0.0020 and 0.0018

(c) 0.0020 and 0.0031 (d) 0.0035 and 0.004

Ans. (a)

In a balanced section, strain diagram under flexure is



So, strain in concrete = 0.0035

$$\text{Strain in steel} = \frac{0.87\times 415}{2\times 10^5} + 0.002 = 0.0038$$

End of Solution

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Q.34 Consider a doubly reinforced RCC beam with the option of using either Fe 250 plain bars or Fe 500 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 types (s) of the bars, the stress in the compression steel (F_{sc}) can reach the design strength (0.87 f_y) at the limit state of collapse?

(a) Fe 250 plain bars only.
(b) Neither Fe250 plain bars nor Fe500 deformed bars.
(c) Both Fe250 plain bars and Fe500 deformed bars.
(d) Fe 500 deformed bars only.

Ans. (a)

End of Solution

Q.35 Creep of concrete under compression is defined as the

(a) decrease in the magnitude of strain under constant stress
(b) increase in the magnitude of strain under constant stress
(c) decrease in the magnitude of stress under constant strain
(d) increase in the magnitude of strain under constant stress

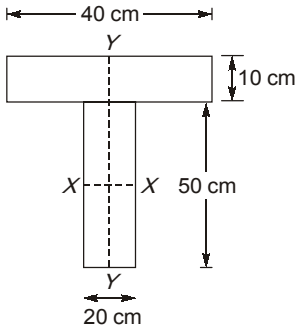
Ans. (b)

Increase in magnitude of strain under constant stress.

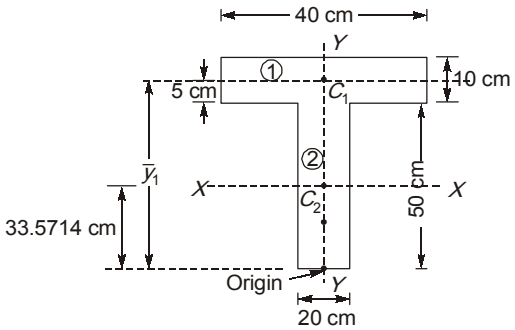
End of Solution

ENGINEERING MECHANICS

Q.36 The cross-section of a girder is as shown in 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)



$$A_1 = 40 \times 10 = 400 \text{ cm}^2$$
$$A_2 = 20 \times 50 = 1000 \text{ cm}^2$$
$$\bar{y}_1 = 50 + 5 = 55 \text{ cm}$$
$$\bar{y}_2 = \frac{50}{2} = 25 \text{ cm}$$

Centroid of composite shape, from bottom fibre,

$$\bar{y} = \frac{A_1\bar{y}_1 + A_2\bar{y}_2}{A_1 + A_2}$$
$$\bar{y} = \frac{(400\times 55) + (1000\times 25)}{400 + 1000}$$
$$\bar{y} = 33.5714 \text{ cm}$$
$$I_{xx} = \left[\frac{40\times 10^3}{12} + 400(\bar{y}_1 - \bar{y})^2\right] + \left[\frac{20\times 50^3}{12} + 1000(\bar{y} - \bar{y}_2)^2\right]$$
$$= \left[\frac{40\times 10^3}{12} + 400(55 - 33.5714)^2\right] + \left[\frac{20\times 50^3}{12} + 1000(33.5714 - 25)^2\right]$$
$$= 187007.2925 + 281802.2313$$
$$I_{xx} = 468809.5238 \text{ cm}^4 \simeq 468810 \text{ cm}^4$$

End of Solution

ENVIRONMENTAL ENGG.

Q.37 Identify the waterborne diseases caused by viral pathogens.

(a) Acute anterior poliomyelitis
(b) Infectious hepatitis
(c) Typhoid fever
(d) Cholera

Ans. **(a, b)**

End of Solution

Q.38 The composition of a Municipal solid waste is shown in table below. The moisture content of the MSW is 26%. The energy derived from the dry weight of the MSW is

Components	%Mass	Energy content [MJ/kg]
Food waste	20%	4.5
Paper	45%	16
Card board	5%	14
Plastic	10%	32
Other	20%	8

Ans. **(18.38)**

Energy content (as discarded basis):

$[0.2 \times 4.5 + 0.45 \times 16 + 0.05 \times 14 + 0.1 \times 32 + 0.2 \times 8] = 13.6$ MJ/kg

Energy content (on dry basis) for moisture content of 26%:

$$= \frac{13.6\ \text{MJ/kg} \times 100\%}{(100-26)\%} = 18.38\ \text{MJ/kg}$$

End of Solution

Q.39 The waste water inflow to an activated sludge plant is 0.5 m^3/s, and the plant is to be operated with a food to micro-organism ratio of 0.2 mg/mg-d. The concentration of influent biodegradable organic matter of the waste water to the plant (after primary settling) is 150 mg/L and the mixed liquor volatile suspended solid 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 required for the plant is _____ m^3. (in integer).

Ans. **(16200)**

Given: $Q = 0.5\ m^3/sec$

$$\frac{F}{M} = 0.2\ \text{mg/mg–d}$$

$$S_0 = 150\ \text{mg/L}$$

$$X = 2000\ \text{mg/L}$$

Now, $$\frac{F}{M} = \frac{Q_0 S_0}{V \cdot X}$$

$$0.2\,d^{-1} = \frac{0.5\frac{m^3}{sec.} \times 86400\frac{sec}{d} \times 150\frac{mg}{L}}{v \times 2000\frac{mg}{L}}$$

$$v = 16200\ m^3$$

End of Solution

Q.40 Which of the following is true about RDF (Refuse derived fuel)?

(a) RDF can be in powdered form

(b) HHV (High heat value) of unprocessed MSW is lesser than HHV of RDF

(c) RDF can't be used in conjunction with oil

(d) Inorganic fraction of MSW is mostly converted to RDF.

Ans. **(a, b, c)**

End of Solution

Q.41 Match the following:

(P)	Reverse osmosis	(I)	Ponding
(Q)	Trickling filter	(II)	Freundlich isotherm
(R)	Coagulation	(IIII)	Concentration polarization
(S)	Adsorption	(IV)	Charge neutralization

Ans.

P – III, Q – I, R – IV, S – II.

End of Solution

Q.42 Volume of tank = 280 m^3. Power is same

Case1: Temp = 15°C – μ = 1.139 N-s/m^2, G = 100 sec^{-1}

Case2: Temp = 5°C – μ = 1.518 N-s/m^2, G = ??

Determine % change in G.

Ans. **(13.38)**

$$G_1 = \sqrt{\frac{P}{\mu_1 \times V}} \quad ...(i)$$

$$G_2 = \sqrt{\frac{P}{\mu_2 \times V}} \quad ...(ii)$$

Divide (i) by (ii), we get

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

$$G_2^2 = \left[\frac{(100 s^{-1})^2 \times 1.139 \times 10^{-3}\ \text{N-s/m}^2}{1.518 \times 10^{-3}\ \text{N-s/m}^2}\right]^{1/2} = 86.62 S^{-1}$$

$$\% \text{ change in } G = \frac{G_1 - G_2}{G_1} \times 100 = \frac{100 - 86.62}{100} \times 100 = 13.38\%$$

End of Solution

FLUID MECHANICS

Q.43 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 % efficiency of the plates? (round off to one decimal)

(a) 66.7 (b) 88.9

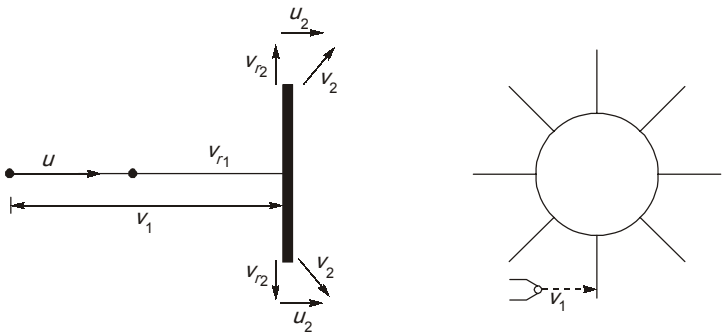
(c) 37.5 (d) 50.0

Ans. **(c)**

Given:

v_1 = 20 m/s

u = 15 m/s $\quad [u_1 = u_2 = u]$



$$\text{Efficiency, } \eta = \frac{\text{Work done per second}}{\text{Imput water power}}$$

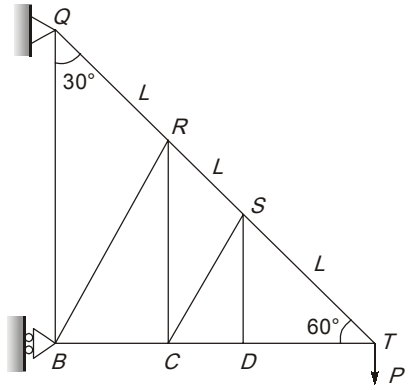
$$= \frac{F_x \cdot u}{\frac{1}{2}\dot{m}V_1^2} = \frac{\dot{m}[V_1 - u] \times u}{\frac{1}{2}\dot{m}V_1^2}$$

$$= \frac{[20-15]\times 15}{\frac{1}{2}\times(20)^2} = 0.375 \simeq 37.5\%$$

End of Solution

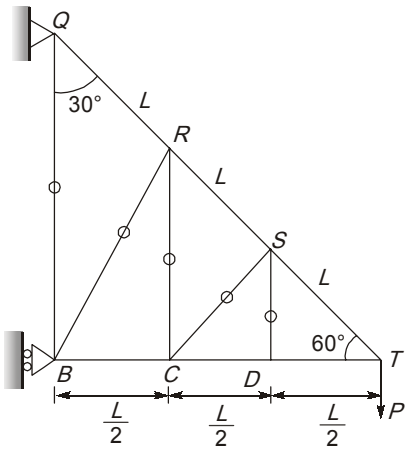
STRUCTUAL ANALYSIS

Q.44 Consider the pin jointed truss shown in figure (not to scale). All member have same axial rigidity, AE. Member QR, RS and ST have same length L. Angle QBT, RCT, SDT are all 90°. Angle of BQT, CRT, DST are all 30°. The joint T carries a vertical load P. The vertical deflection of joint T is $k\frac{PL}{AE}$. The value of k is ____.



(a) 9
(b) 1.5
(c) 4.5
(d) 13.6

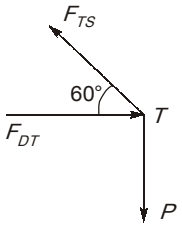
Ans. **(c)**



At joint T,

$$\Sigma F_y = 0$$

$$\Rightarrow \quad F_{TS}\sin 60^\circ = P$$



$$F_{TS} = \frac{2P}{\sqrt{3}}(T)$$

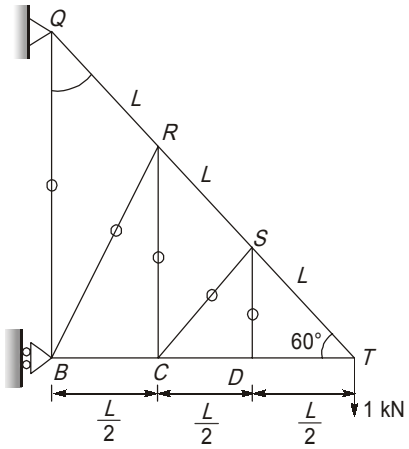
$$\Sigma F_x = 0$$

$$F_{TS}\cos 60^\circ = F_{DT}$$

$$F_{DT} = \frac{2P}{\sqrt{3}}\left(\frac{1}{2}\right) = \frac{P}{\sqrt{3}}(C)$$

$$F_{TS} = F_{SR} = F_{RQ} = \frac{2P}{\sqrt{3}}(T)$$

$$F_{DT} = F_{CD} = F_{BL} = \frac{P}{\sqrt{3}}(C)$$



Similarly,

$$k_{ST} = k_{SR} = k_{RQ} = \frac{2}{\sqrt{3}}(T)$$

$$k_{DT} = k_{CD} = k_{BC} = \frac{1}{\sqrt{3}}(T)$$

$$\therefore \quad \delta_{VT} = \Sigma\frac{PkL}{AE} = \frac{\left(\frac{2P}{\sqrt{3}}\right)\left(\frac{2}{\sqrt{3}}\right)L\times 3}{AE} + \frac{\left(\frac{P}{\sqrt{3}}\right)\left(\frac{1}{\sqrt{3}}\right)\frac{L}{2}\times 3}{AE}$$

$$\delta_{VT} = \frac{4PL}{AE} + \frac{PL}{2AE} = \frac{4.5PL}{AE}$$

$$\Rightarrow \quad k = 4.5$$

End of Solution

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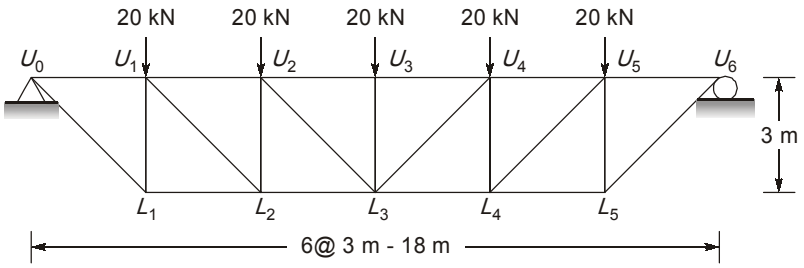
Q.45 An idealised bridge truss is shown in the figure. The force is member U_2L_3 is



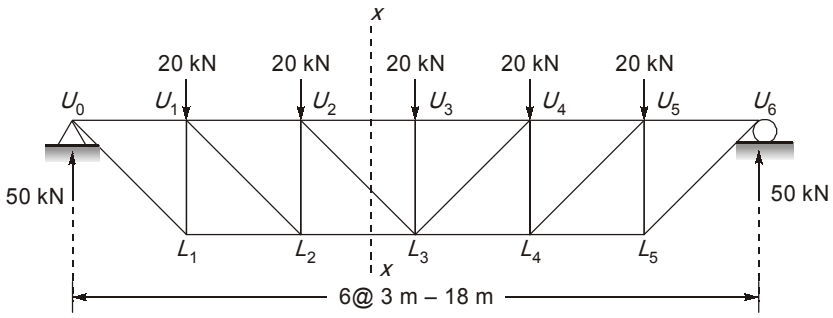
(a) #

(b) #

(c) $10\sqrt{2}$ kN (Compressive)

(d) $10\sqrt{2}$ kN (Tension)

Ans. **(d)**

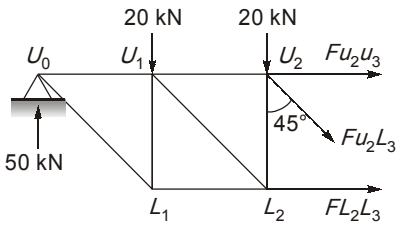


Reactions at supports:

Because of symmetry vertical reaction at supports

$$= \frac{100}{2} = 50 \text{ kN}$$

Applying method of sections and taking the section as shown in the figure above,



$$\Sigma F_y = 0$$

$$\Rightarrow Fu_2L_3\cos 45° + 20 + 20 - 50 = 0$$

$$F_{u2}L_3\cos 45° = 10$$

$$F_{u2}L_3 = 10\sqrt{2} \text{ kN (Tension)}$$

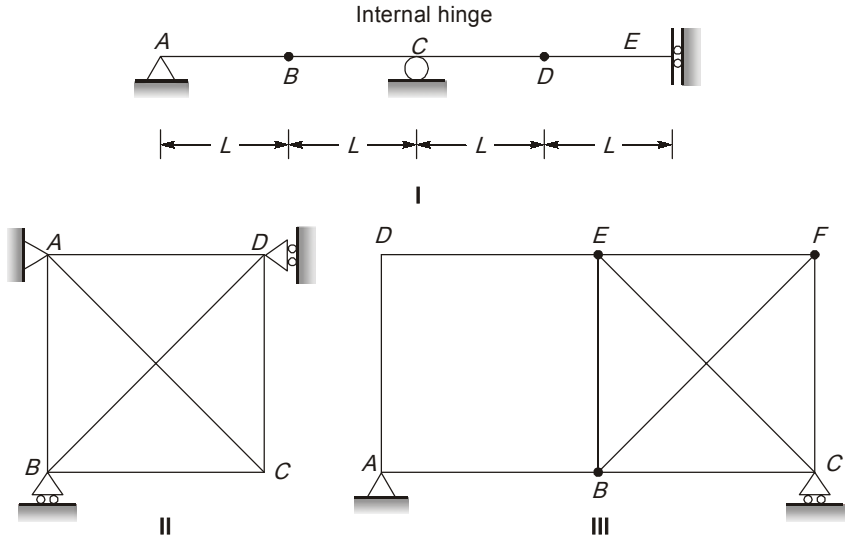
End of Solution

Q.46 Consider the following structures as shown below:

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

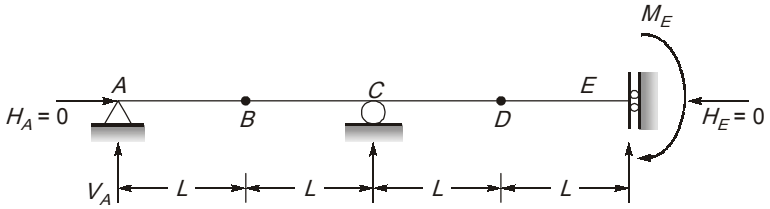
II. Pin jointed truss with hinge support at A and rollers at B and D.

III. Pin-jointed truss with hinge support at A and roller at C.



Which of the following structure is/are stable?

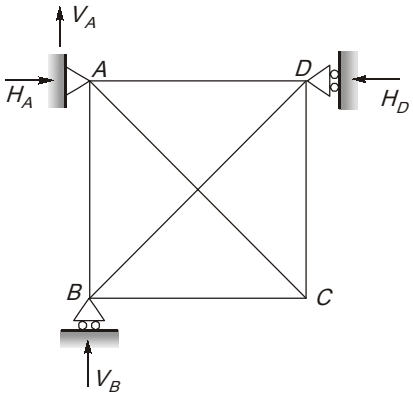
Ans.



$r = 3\ (V_A,\ V_C,\ M_E)$

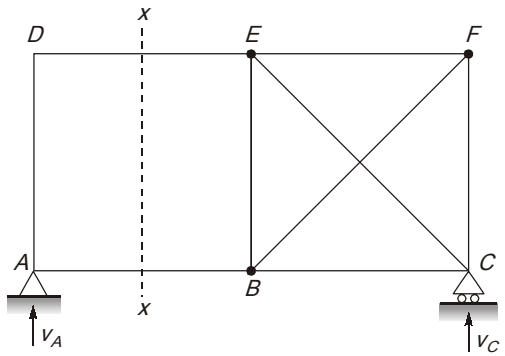
$s = 4\ (\Sigma F_y = 0,\ \Sigma M = 0,\ BM_B = 0,\ BM_D = 0)$

$D_s = r - s = 3 - 4 = -1$ $\Rightarrow$ negative implies unstable



Rigid body rotation is possible since all the four reactions are concurrent at *A*.

Unstable,



Shear force at x-x = Panel shear force = V_A

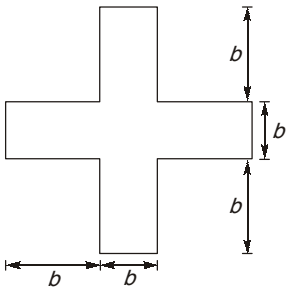
There is no member to resist panel shear force.

So unstable.

End of Solution

Design of Steel Structures

Q.47 Consider the horizontal axis passing through the centroid of the steel beam cross section shown in figure. What is the shape factor (rounded off to one decimal place) for the cross section?

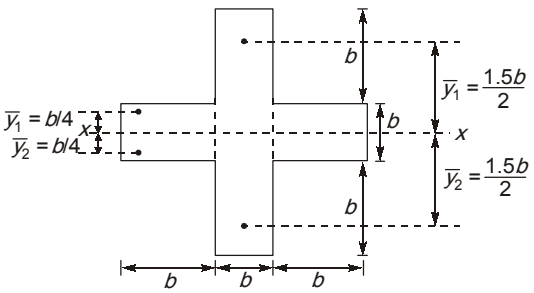


(a) 1.7 (b) 1.3

(c) 2.0 (d) 1.5

Ans. **(a)**

As we know,



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

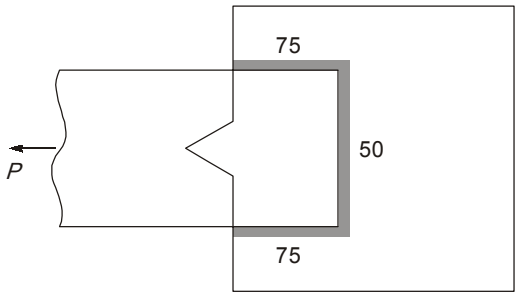
$$= (6 \times 1.5b)\left[\frac{1.5b}{2} + \frac{1.5b}{2}\right] + \left[2b \times \frac{b}{2}\right] \times \left[\frac{b}{4} + \frac{b}{4}\right] = 2.75b^3$$

$$z = \frac{I_{xx}}{y} = \frac{\left[\frac{b \times (3b)^3}{12} + \frac{2b \times b^3}{12}\right]}{1.5b} = \frac{29}{18}b^3$$

Shape factor, $\text{S.F.} = \frac{z_p}{z} = \frac{2.75b^3}{\frac{29}{18}b^3} = 1.7$

End of Solution

Q.48 Consider the following welded arrangement shown below. The welding is done at 90° and the size of the weld is 8 mm. If the permissible stress in the weld is 120 MPa, then the maximum load that can be safely transferred is



All dimensions in mm

Ans. **(134.4)**

Given: $S = 8$ mm, $\tau_{vw} = 120$ MPa, $L_w = 2 \times 75 + 50 = 200$ mm

The safe load is calculated as per WSM

$\therefore$ $\rho_{safe} = \tau_{vw} \times A_w$

$= \tau_{vw} \times L_w \times (0.7 \times s)$ $[\because t_t = 0.7s]$

$= 120 \times [2 \times 75 + 50] \times 0.7 \times 8 \times 10^{-3}$ kN $= 134.4$ kN

End of Solution

HYDROLOGY ENGG.

Q.49 The ordinates of a 1-hour unit hydrograph for a catchment are given below :

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

Using the principle of superposition a D-hr UH for a catchment was derived from the 1-hr UH. The ordinate of the D hr UH where obtained as 3 m^3/sec at t = 1 hr and 10 m^3/s at t = 2 hr., the value of 'D' (integer) is _____.

Ans. (3)

Time	1hr-UH	1hr UH lagged by 1 hr	1hr-UH lagged by 1 more hr	3 hr DRH	Ordinate of 3hr UH = Ordinate of 3hr DRH / 3cm
(1)	(2)	(3)	(4)	(5)	(6)
0	0	–	–	0	0
1	9	0	–	9	3
2	21	9	0	30	10
3	18	21	9	48	16
4	12	18	21	51	17
5	5	12	18	35	11.67
6	2	5	12	19	6.33
7	0	2	5	7	2.33
		0	2	2	0.67
			0	0	0

- Firstly lag the UH by 1 hr. By lagging 1 hr. We obtained a 2 hr UH of ordinate 4.5 m^3/sec. at 1 hr and 15 m^3/sec at 2 hr.
- So, further lag the UH by 1 more hr we obtained a 3 hr, UH of ordinates 3 m^3/sec at 1 hr and 10 m^3/sec at 2 hr. Therefore D = 3 hr.

End of Solution

Q.50 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 12h is _____ (round off to one decimal place).

Ans. (70)

Initial infiltration capacity, f_0 = 10 mm/h
Final infiltration capacity, f_c = 5 mm/h
Horton's Decay constant, k_h = 0.5/h

Now,
$$F_P = \int_0^T \left[f_c + [f_0 - f_c]e^{-k_h t}\right]dt$$
$$= \int_0^{12} \left(5 + (10-5)e^{-0.5t}\right)dt$$
$$= [5t]_0^{12} + \left[\frac{5e^{-0.5t}}{(-0.5)}\right]_0^{12}$$
$$= [5\times 12] + \left[-10e^{-0.5\times 12} - \left[-10e^{-0.5\times 0}\right]\right]$$
= 60 + [9.975]
= 69.97 mm ≃ 70 mm

Alternatively:

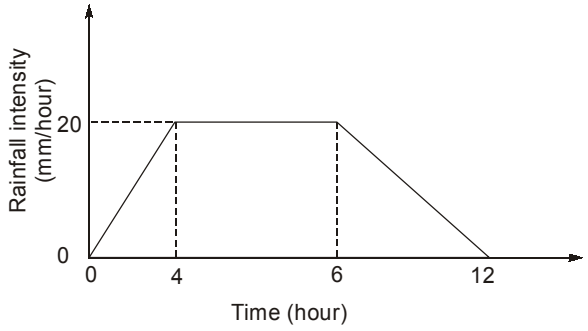
For large value of 't' comulative infiltration capacity is given by,

$$F_P = f_c t + \frac{(f_0 - f_c)}{k_h}$$

$$= (5 \times 12) + \frac{(10-5)}{0.5} = 70 \text{ mm}$$

End of Solution

Q.51 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 round off to two decimal) is _____.



Ans. **(3.6)**

Given: Time = 12 hr

Runoff, R = 100 mm

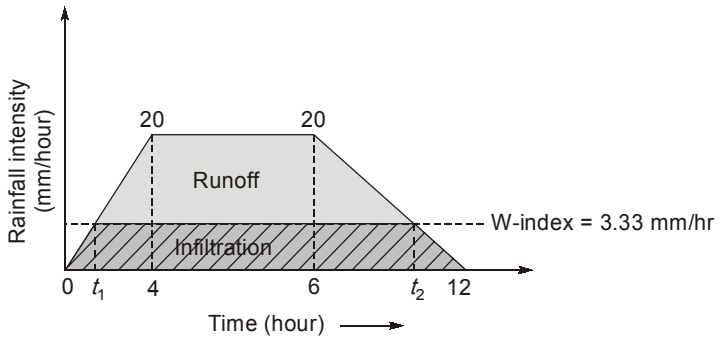
Total depth of precipitation,

$$P = \frac{1}{2}[20 \times 4] + 2 \times 20 + \frac{1}{2} \times 20 \times 6 = 140 \text{ mm}$$

$\therefore$ Total infiltration, $I = P - R$

$= 140 - 100 = 40$ mm

No, W-Index $= \frac{I}{t} = \frac{140-100}{12} = 3.33$ mm/hr



Now, $\frac{20}{4} = \frac{3.33}{t_1}$

$$\Rightarrow \quad t_1 = 0.67 \text{ hr}$$

Similarly, $$\frac{20}{6} = \frac{3.33}{t_2}$$

$$\Rightarrow \quad t_2 = 0.99 \text{ hr}$$

Now, $$\phi\text{-Index} = \frac{\text{Total infiltration in which rainfall excess occur}}{\text{Time period in rainfall which excess occur}}$$

$$= \frac{I - \text{infiltration in which no runoff}}{\text{Time excess}}$$

$$\phi\text{-Index} = \frac{140 - \left[\frac{1}{2}\times 3.33 \times 0.67 + \frac{1}{2}\times 3.33 \times 0.99\right]}{12 - 0.67 - 0.99}$$

$$= 3.6 \text{ mm/hr}$$

Check: Runoff = Area of hatched portion

$$= \frac{1}{2}\times(20-3.6)\times(4-0.67) + (20-3.6)\times 2 + \frac{1}{2}\times(20-3.6)\times(6-0.99)$$

$$= 100 \text{ mm} \quad \text{(Hence, OK)}$$

$\therefore$ ϕ-Index = 3.6 mm/hr

End of Solution

IRRIGATION

Q.52 A canal is used to irrigate area of 1000 ha for growing wheat. The time between first and last watering is 120 days, depth of water required is 35 cm. Intense watering is required for 30 days and depth of water required is 12 cm. Neglecting all other losses, calculate the minimum discharge required in the canal in m^3/sec.

Ans. **(0.46)**

Given: Area : 1000 ha

Total depth of water, Δ_2 = 35 cm

Total time period, B_2 = 120 days

Kor depth, Δ_1 = 12 cm

Kor period, B_1 = 30 days

(i) Kor duty, $\Delta_1 = \frac{8.64 \times B_1}{\Delta_1} = \frac{8.64 \times 30}{0.12} = 2160 \text{ ha}/m^3/\text{sec}$

Corresponding discharge $= \frac{\text{Area}}{\text{Duty}} = \frac{1000}{2160} = 0.46 m^3/\text{sec}$

(ii) Overall duty, $\Delta_2 = \frac{8.64 \times B_2}{\Delta_2} = \frac{8.64 \times 120}{0.35} = 2962.28 \text{ ha}/m^3/\text{sec}$

Corresponding discharge $= \frac{\text{Area}}{\text{Duty}} = \frac{1000}{2962.28} = 0.34\ m^3/sec$

Minimum discharge required will be maximum of the above two.

$\therefore \quad Q_{req.} = 0.46\ m^3/sec$

End of Solution

CONSTRUCTION MATERIAL

Q.53 Choose the correct statement regarding the water-cement ratio of concrete

(a) With increase in water cement ratio, the workability increases and compressive strength decreases.

(b) With increase in water cement ratio, the workability decreases and compressive strength increases.

(c) With increase in water cement ratio, both workability and compressive strength decreases.

(d) With increase in water cement ratio, both workability and compressive strength increases.

Ans. **(a)**

■■■■