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GATE 2020

Civil Engineering

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Questions and Solutions

Date of Exam : 09/02/2020 (Afternoon)

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SECTION A : GENERAL APTITUDE

- Q.1** Select the word that fits the analogy:
Partial : Impartial : : Popular : _____
(a) Impopular (b) Dispopular
(c) Mispopular (d) Unpopular

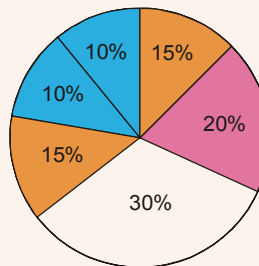
Ans. (d)
Partial and Impartial are opposite, in the same way popular and unpopular are opposite words.

End of Solution

- Q.2** The monthly distribution of 9 Watt LED bulbs sold by two firms X and Y from January to June 2018 is shown in the pie-chart and the corresponding table. If the total number of LED bulbs sold by two firms during April-June 2018 is 50000, then the number of LED bulbs sold by the firm Y during April-June 2018 is _____.

Months	Ratio of LED bulbs sold by two firms X : Y
January	7 : 8
February	2 : 3
March	2 : 1
April	3 : 2
May	1 : 4
June	9 : 11

January	15%
February	20%
March	30%
April	15%
May	10%
June	10%



- (a) 11250 (b) 9750
(c) 8250 (d) 8750

Ans. (*)
LED bulbs sold

By
$$Y_{\text{April}} = \frac{2}{5} \times 15 = 6\% \quad \dots(A)$$

$$Y_{\text{May}} = \frac{4}{5} \times 10 = 8\%$$

$$Y_{\text{June}} = \frac{10}{20} \times 11 = 5.5\%$$

LED bulb sold by Y during April-June

$$A + B + C = (6 + 8 + 5.5)\% = 19.5\%$$

Total LED bulb sold by X and Y 35% this value = 50000

So, LED bulb sold by Y (April to June)

$$\frac{50000}{35} \times 19.5 = 27857.142$$

[As 35% of total = 50000]

$$\text{Total} = \frac{50000}{0.35} = 142857.142$$

$$Y \text{ (April- June)} = 19.5\% \text{ of total } 0.195 \times 142857.14 = 2785.142$$

No option is matching.

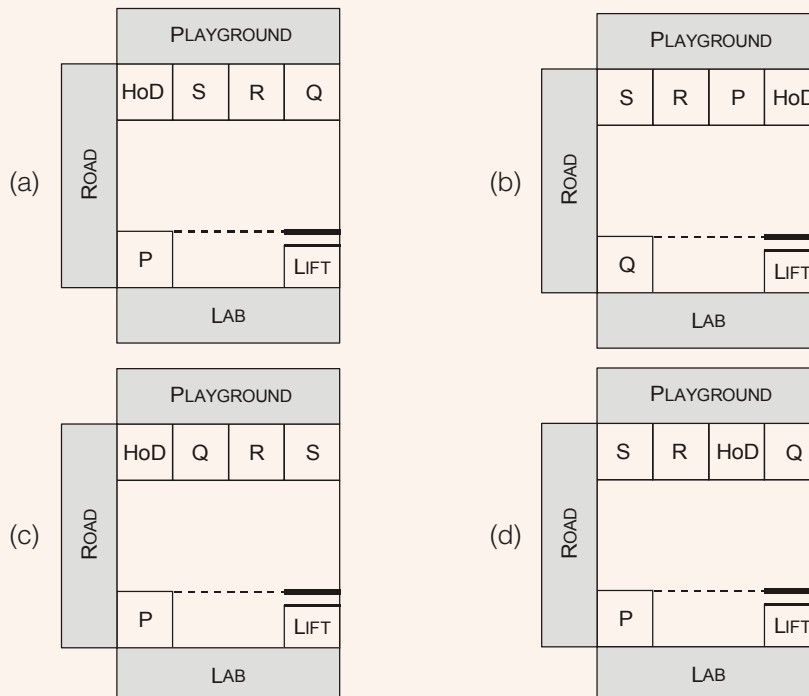
Mistake in paper was that examiner intended to give total as 50000 and the options were placed accordingly as 19.5% of 50000 = 9750 which is (d).

But this will be wrong as total is NOT 50000 as per language. So correct answer is 27857.142.

Which matches with none of options.

End of Solution

- Q.3** After the inauguration of the new building, the head of department (HOD) collated faculty preferences for office space. P wanted a room adjacent to the lab. Q wanted to be close to the lift. R wanted a view of the playground and S wanted a corner office. Assuming that everyone was satisfied, which among the following shows a possible allocation?



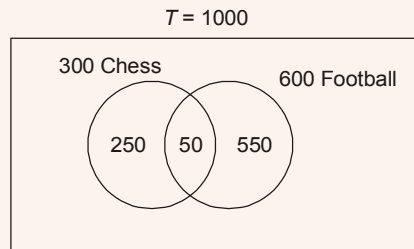
Ans. (d)

End of Solution

Q.4 In a school of 1000 students, 300 students play chess and 600 students play football. If 50 students play both chess and football, the number of students who play neither is _____.

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

Ans. (a)



Total number of students playing sports = 850

Total number of students not playing sports = $1000 - 850 = 150$

End of Solution

Q.5 Select the most appropriate word that can replace the underlined word without changing the meaning of the sentence:

Now-a-days, most children have a tendency to belittle the legitimate concerns of their parents.

- (a) Applaud (b) Begrudge
(c) Disparage (d) Reduce

Ans. (c)

Belittle means to undervalue/ underestimate some as unimportant. Disparage fits in the most appropriate manner.

End of Solution

Q.6 For the year 2019, which of the previous year's calendar can be used?

- (a) 2011 (b) 2013
(c) 2012 (d) 2014

Ans. (b)

Year	Number of odd days
2013	1
2014	1
2015	1
2016	2
2017	1
2018	1
Total	7

Number of odd days in 2019 = 1, so 2013 calendar is same as 2019.

End of Solution

- Q.7** If $f(x) = x^2$ for each $x \in (-\infty, \infty)$, then $\frac{f(f(f(x)))}{f(x)}$ is equal to _____.
- (a) $f(x)$ (b) $(f(x))^4$
(c) $(f(x))^2$ (d) $(f(x))^3$

Ans. (d)

$$f(x) = x^2$$
$$f(f(f(x))) = f(f(x^2)) = f(x^4) = (x^4)^2 = x^8$$

So,
$$\frac{f(f(f(x)))}{f(x)} = \frac{x^8}{x^2} = x^6 = (x^2)^3 = (f(x))^3$$

End of Solution

- Q.8** Rescue teams deployed _____ disaster hit areas combat _____ a lot of difficulties to save the people.
- (a) with, at (b) to, to
(c) with, with (d) in, with

Ans. (d)

End of Solution

- Q.9** Nominal interest rate is defined as the amount paid by the borrower to the lender for using the borrowed amount for a specific period of time. Real interest rate calculated on the basis of actual value (inflation-adjusted), is approximately equal to the difference between nominal rate and expected rate of inflation in the economy. Which of the following assertions is best supported by the above information?
- (a) Under low inflation, real interest rate is low and borrowers get benefited.
(b) Under high inflation, real interest rate is low and borrowers get benefited.
(c) Under low inflation, real interest rate is high and borrowers get benefited.
(d) Under high inflation, real interest rate is low and lenders get benefited.

Ans. (b)

End of Solution

- Q.10** The ratio of 'the sum of the odd positive integers from 1 to 100' to 'the sum of the even positive integers from 150 to 200' is _____.
- (a) 50 : 91 (b) 1 : 1
(c) 1 : 2 (d) 45 : 95

Ans. (a)

$$\frac{\text{Sum of odd numbers from 1 to 100}}{\text{Sum of even numbers from 150 to 200}} = \frac{50^2}{175 \times 26} = \frac{50 \times 50}{175 \times 26} = \frac{2500}{4550}$$

$$\text{Ratio} = 50 : 91$$

From 1 to 100 = 50 odd number

From 150 to 200 = 26 even number

End of Solution

SECTION B : TECHNICAL

Q.1 For an axle load of 15 tonne on a road, the Vehicle Damage Factor (round off to two decimal places), in terms of the standard axle load of 8 tonne, is _____.

Ans. (12.35)

Axle load = 15 T
Standard axle load = 8 T

$$VDF = \left[\frac{15}{8} \right]^4 = 12.35$$

End of Solution

Q.2 Muskingum method is used in
(a) hydrologic channel routing (b) hydraulic channel routing
(c) hydrologic reservoir routing (d) hydraulic reservoir routing

Ans. (a)

End of Solution

Q.3 The traffic starts discharging from an approach at an intersection with the signal turning green. The constant headway considered from the fourth or fifth headway position is referred to as
(a) saturation headway (b) effective headway
(c) discharge headway (d) intersection headway

Ans. (a)

End of Solution

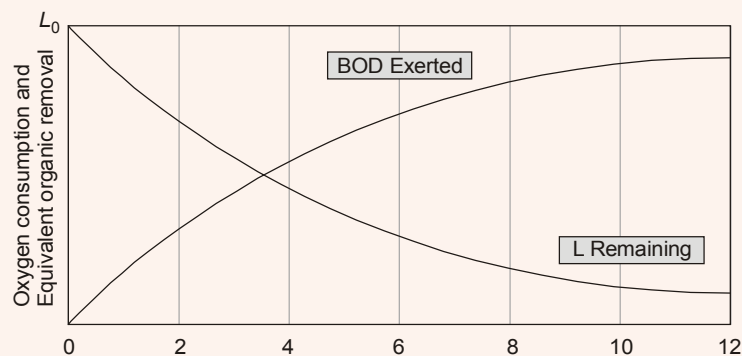
Q.4 Soil deposit formed due to transportation by wind is termed as
(a) lacustrine deposit (b) alluvial deposit
(c) estuarine deposit (d) aeolian deposit

Ans. (d)

Soil deposited by wind is Aeolian soil.

End of Solution

Q.5 The relationship between oxygen consumption and equivalent biodegradable organic removal (i.e. BOD) in a closed container with respect to time is shown in the figure.



Integrating it,

$$\ln(-5 + 6x)^{1/6} = -\ln(9 + 6y)^{1/6} + \ln C^{1/6}$$

$$\frac{1}{6} \ln(-5 + 6x) \cdot (9 + 6y) = \frac{1}{6} \ln C$$

Take antilog,

$$(-5 + 6x)(9 + 6y) = \text{constant}$$

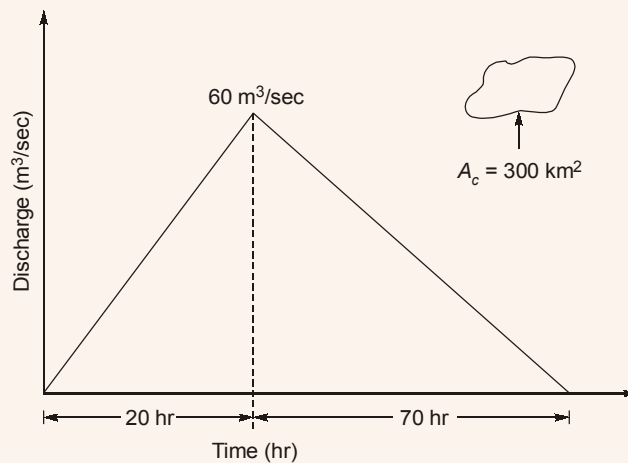
$$u \cdot v = \text{constant}$$

End of Solution

Q.8 A triangular direct runoff hydrograph due to a storm has a time base of 90 hours. The peak flow of 60 m³/s occurs at 20 hours from the start of the storm. The area of catchment is 300 km². The rainfall excess of the storm (in cm), is

- (a) 5.40 (b) 2.00
(c) 3.24 (d) 6.48

Ans. (c)



$$\Rightarrow \left[\frac{\frac{1}{2} \times 60 \text{ m}^3/\text{s} \times 90 \times 3600 \text{ s}}{300 \times 10^6 \text{ m}^2} \times 100 \right] \text{ cm} = \text{Rainfall excess}$$

$$\therefore \text{Rainfall excess} = 3.24 \text{ cm}$$

End of Solution

Q.9 24-h traffic count at a road section was observed to be 1000 vehicles on a Tuesday in the month of July. If daily adjustment factor for Tuesday is 1.121 and monthly adjustment factor for July is 0.913, the Annual Average Daily Traffic (in veh/day, round off to the nearest integer) is _____.

Ans. (1023)

$$\begin{aligned}
 T_{24} &= 1000 \text{ veh (Tuesday)} \\
 \text{DAF} &= 1.121 \\
 \text{AADT} &= ? \\
 \text{MAF} &= 0.913 \\
 T_{\text{week}} &= T_{24} \times \text{DAF} \\
 &= 1000 \times 1.121 = 1121 \\
 \text{AADT} &= \text{MAF} \times \text{ADT} = (0.913 \times 1121) \\
 &= 1023.473 \\
 &= 1023 \text{ VPD}
 \end{aligned}$$

End of Solution

Q.10 Velocity distribution in a boundary layer is given by $\frac{u}{U_{\infty}} = \sin\left(\frac{\pi y}{2\delta}\right)$, where u is the velocity at vertical coordinate y , U_{∞} is the free stream velocity and δ is the boundary layer thickness. The values of U_{∞} and δ are 0.3 m/s and 1.0 m, respectively. The velocity gradient $\left(\frac{\partial u}{\partial y}\right)$ (in s^{-1} , round off to two decimal places) at $y=0$, is _____.

Ans. (0.47)

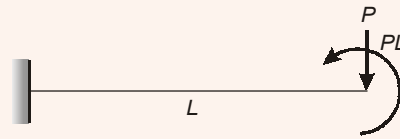
$$\begin{aligned}
 \text{Given : } \quad \frac{u}{U_{\infty}} &= \sin\left(\frac{\pi \cdot y}{2 \cdot \delta}\right) \\
 U_{\infty} &= 0.3 \text{ m/s} \\
 \delta &= 1 \text{ m} \\
 \frac{du}{dy} &= \frac{d}{dy} U_{\infty} \cdot \sin\left(\frac{\pi \cdot y}{2 \cdot \delta}\right) \\
 &= \frac{U_{\infty} \cdot \pi}{2\delta} \cos\left(\frac{\pi \cdot y}{2 \cdot \delta}\right)
 \end{aligned}$$

At $y = 0$ and $\delta = 1$

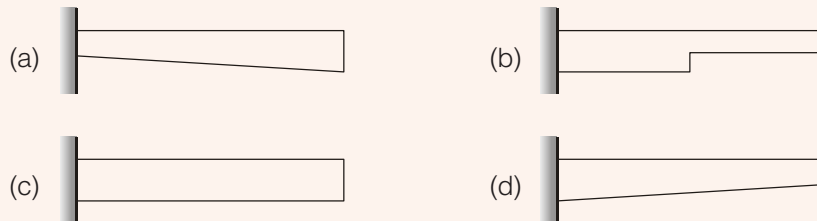
$$\begin{aligned}
 \left.\frac{du}{dy}\right|_{y=0} &= \frac{0.3\pi}{2(1)} \cos\left(\frac{\pi \cdot 0}{2 \cdot 1}\right) \\
 &= 0.47 \text{ s}^{-1}
 \end{aligned}$$

End of Solution

Q.11 A weightless cantilever beam of span L is loaded as shown in the figure. For the entire span of the beam, the material properties are identical and the cross-section is rectangular with constant width.



From the flexure-critical perspective, the most economical longitudinal profile of the beam to carry the given loads amongst the options given below, is

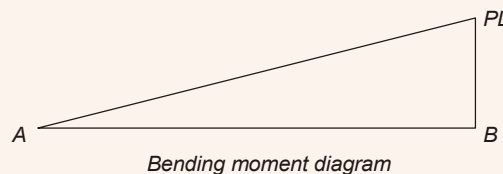


Ans. (a)

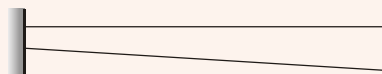


$$(-PL) + (PL) + (-M_A) = 0$$

$$M_A = 0$$



For most economical,
Maximum cross-section is given where maximum bending moment occurs.



So, option (a) is correct.

End of Solution

Q.12 Two identically sized primary settling tanks receive water for Type-I settling (discrete particles in dilute suspension) under laminar flow conditions. The surface overflow rate (SOR) maintained in the two tanks are $30 \text{ m}^3/\text{m}^2 \cdot \text{d}$ and $15 \text{ m}^3/\text{m}^2 \cdot \text{d}$. The lowest diameters of the particles, which shall be settled out completely under SORs of $30 \text{ m}^3/\text{m}^2 \cdot \text{d}$ are designated as d_{30} and d_{15} respectively. The ratio $\frac{d_{30}}{d_{15}}$ (round off to two decimal places), is _____.

Ans. (1.41)

For type-I setting, Stokes law is applicable.

$$V_s \propto d^2$$

$$\frac{d_{30}^2}{d_{15}^2} = \frac{30}{15} = 2$$

$$\frac{d_{30}}{d_{15}} = \sqrt{2} = 1.41$$

End of Solution**Q.13** As per **IS 456:2000**, the pH value of water for concrete mix shall NOT be less than

- (a) 6.0 (b) 5.0
(c) 4.5 (d) 5.5

Ans. (a)

1. Minimum pH value of water for concrete = 6.0

As per IS code provision no. 5.4.2, the pH value of water shall not less than 6.0.

End of Solution**Q.14** Superpassage is a canal cross-drainage structure in which

- (a) canal water flows under pressure below a natural stream
(b) natural stream water flows under pressure below a canal
(c) canal water flows with free surface below a natural stream
(d) natural stream water flows with free surface below a canal

Ans. (c)**End of Solution****Q.15** A soil has dry weight of 15.5 kN/m^3 , specific gravity of 2.65 and degree of saturation of 72%. Considering the unit weight of water as 10 kN/m^3 , the water content of the soil (in %, round off to two decimal places) is _____.**Ans. (19.28)**

$$\gamma_d = 15.5 \text{ kN/m}^3, \quad G = 2.65, \quad S = 72\%$$

$$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.65 \times 10}{1+e} = 15.5$$

$$e = 0.7096$$

$$w = \frac{Se}{G} = \frac{0.72 \times 0.7096}{2.65} = 0.1928$$

$$w = 19.28\%$$

End of Solution

Q.16 The maximum applied load on a cylindrical concrete specimen of diameter 150 mm and length 300 mm tested as per the split tensile strength test guidelines of **IS 5816 : 1999** is 157 kN. The split tensile strength (in MPa, round off to one decimal place) of the specimen is _____.

Ans. (2.2)

$$P = 157 \text{ kN}$$

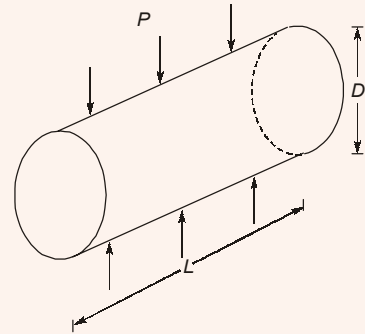
$$D = 150 \text{ mm}$$

$$L = 300 \text{ mm}$$

In split tensile strength test, split tensile strength of concrete

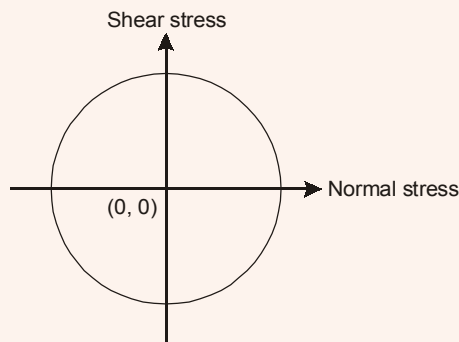
$$f_{et} = \frac{2P}{\pi DL} = \frac{2 \times 157000}{\pi \times 150 \times 300}$$

$$= 2.22 \text{ N/mm}^2$$



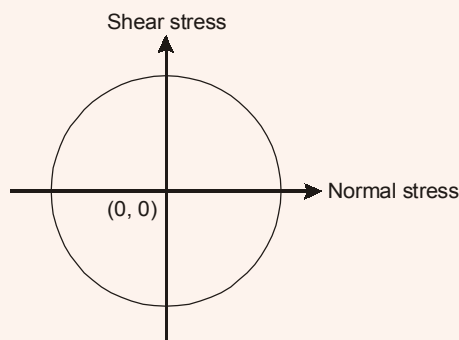
End of Solution

Q.17 The state of stress represented by Mohr's circle shown in the figure is



- (a) hydrostatic stress (b) uniaxial tension
(c) biaxial tension of equal magnitude (d) pure shear

Ans. (d)



In pure shear condition, Mohr's circle has its center at origin.

End of Solution

- Q.18** The ratio of the plastic moment capacity of a beam section to its yield moment capacity is termed as
- (a) aspect ratio (b) load factor
(c) shape factor (d) slenderness ratio

Ans. (c)

$$\text{Ratio of } \frac{M_p}{M_y} = \text{Shape factor}$$

End of Solution

- Q.19** A sample of 500 g dry sand, when poured into a 2 litre capacity cylinder which is partially filled with water, displaces 188 cm³ of water. The density of water is 1 g/cm³. The specific gravity of the sand is
- (a) 2.55 (b) 2.72
(c) 2.66 (d) 2.52

Ans. (c)

$$W_s = 500 \text{ gm}$$
$$V_s = 188 \text{ cc}$$

$$\gamma_s = \frac{W_s}{V_s}$$

$$G_s = \frac{\gamma_s}{\gamma_w} = \frac{500 / 188}{1} = 2.66$$

End of Solution

- Q.20** The value of $\lim_{x \rightarrow \infty} \frac{\sqrt{9x^2 + 2020}}{x + 7}$ is
- (a) 1 (b) 3
(c) $\frac{7}{9}$ (d) Indeterminable

Ans. (b)

$$\lim_{x \rightarrow \infty} \frac{3x \sqrt{1 + \frac{2020}{x^2}}}{x \left(1 + \frac{7}{x}\right)} = 3$$

End of Solution

Q.21 The ordinary differential equation $\frac{d^2u}{dx^2} - 2x^2u + \sin x = 0$ is

- (a) linear and homogeneous (b) nonlinear and homogeneous
(c) nonlinear and nonhomogeneous (d) linear and nonhomogeneous

Ans. (d)

Its solution is of the type $u = f(x)$, i.e., dependent variable is u .
Hence, given equation is Linear & Non-Homogeneous.

End of Solution

Q.22 A gas contains two types of suspended particle having average sizes of 2 μm and 50 μm . Amongst the options given below, the most suitable pollution control strategy for removal of these particles is

- (a) electrostatic precipitator followed by cyclonic separator
(b) bag filter followed by electrostatic precipitator
(c) settling chamber followed by bag filter
(d) electrostatic precipitator followed by venturi scrubber

Ans. (c)

End of Solution

Q.23 The integral

$$\int_0^1 (5x^3 + 4x^2 + 3x + 2) dx$$

is estimated numerically using three alternative methods namely the rectangular, trapezoidal and Simpson's rules with a common step size. In this context, which one of the following statement is TRUE?

- (a) Simpson's rule as well as rectangular rule of estimation will give non zero error.
(b) Only Simpson's rule of estimation will give zero error.
(c) Simpson's rule, rectangular rule as well as trapezoidal rule of estimation will give non-zero error.
(d) Only the rectangular rule of estimation will given zero error.

Ans. (b)

Because integral is a polynomial of 3rd degree so Simpson's rule will give error free answer.

End of Solution

Q.24 A fair (unbiased) coin is tossed 15 times. The probability of getting exactly 8 Heads (round off to three decimal places), is _____.

Ans. (0.196)

$$P(H) = \frac{1}{2}$$

$$P(T) = \frac{1}{2}$$

$$\begin{aligned} \text{Probability of getting exactly 8 heads out of 15 trial} &= {}^{15}C_8 \left[\frac{1}{2}\right]^8 \times \left[\frac{1}{2}\right]^{15-8} \\ &= 0.196 \end{aligned}$$

End of Solution

Q.25 The following partial differential equation is defined for $u : u(x, y)$

$$\frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial x^2}; y \geq 0; x_1 \leq x \leq x_2$$

The set of auxiliary conditions necessary to solve the equation uniquely, is

- (a) one initial condition and two boundary conditions
- (b) three initial conditions
- (c) two initial conditions and one boundary condition
- (d) three boundary conditions

Ans. (a)

$$\text{Given: DE is } \frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial x^2}; y \geq 0; x_1 \leq x \leq x_2$$

$\therefore y$ is given as ≥ 0 so we take it as time.

Hence, above equation is nothing but one-D heat equation which requires one initial condition and two boundary condition.

End of Solution

Q.26 A hydraulic jump occurs, in a triangular (V-shaped) channel with side slopes 1:1 (vertical to horizontal). The sequent depths are 0.5 m and 1.5 m. The flow rate (in m^3/s , round off to two decimal places) in the channel is _____.

Ans. (1.73)

$$A = \frac{1}{2} \times 2Y \times Y = Y^2$$

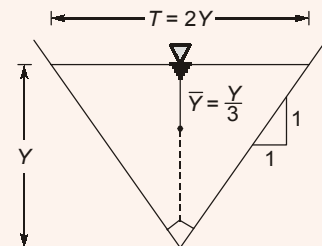
$$\bar{Y} = \frac{Y}{3}$$

For a horizontal and frictionless channel

$$\text{Specific Force (F)} = A\bar{Y} + \frac{Q^2}{Ag} = \text{Constant}$$

$$\Rightarrow Y^2 \left(\frac{Y}{3}\right) + \frac{Q^2}{(Y^2)g} = \text{Constant}$$

$$\Rightarrow \frac{Y^3}{3} + \frac{Q^2}{gY^2} = \text{Constant}$$



If Y_1 and Y_2 are conjugate depths

$$\frac{Y_1^3}{3} + \frac{Q^2}{gY_1^2} = \frac{Y_2^3}{3} + \frac{Q^2}{gY_2}$$

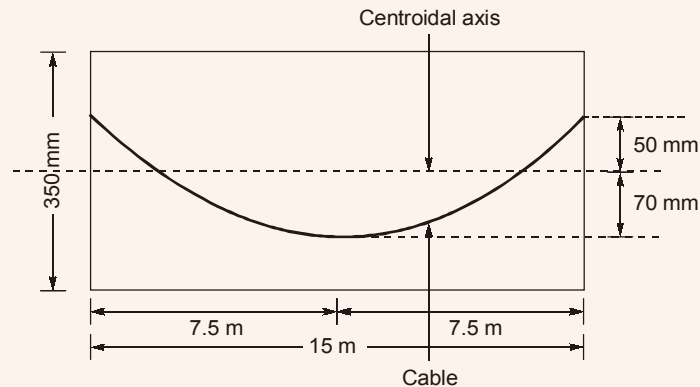
$$\Rightarrow \frac{0.5^3}{3} + \frac{Q^2}{g \times 0.5^2} = \frac{1.5^3}{3} + \frac{Q^2}{g \times 1.5^2}$$

$$\Rightarrow \frac{1.5^3}{3} - \frac{0.5^3}{3} = \frac{Q^2}{g} \left(\frac{1}{0.5^2} - \frac{1}{1.5^2} \right)$$

$$Q = 1.728 \text{ m}^3/\text{sec}$$

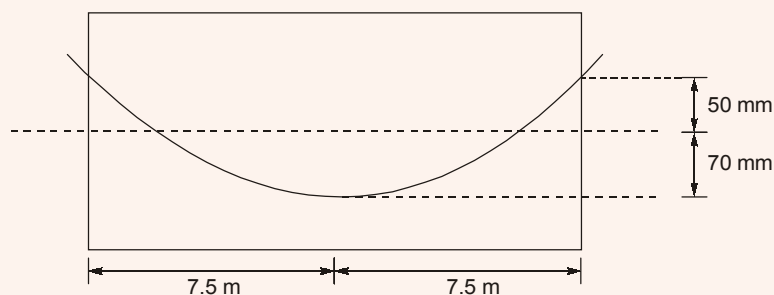
End of Solution

- Q.27** A concrete beam of span 15 m, 150 mm wide and 350 mm deep is prestressed with a parabolic cable as shown in the figure (not drawn to the scale). Coefficient of friction for the cable is 0.35, and coefficient of wave effect is 0.0015 per metre.



If the cable is tensioned from one end only, the percentage loss (round off to one decimal place) in the cable force due to friction, is _____.

Ans. (4.49)



Jacking from one end

$$x = L = 15 \text{ m}$$

Wobble correction factor, $K = 0.0015$

Coefficient of friction = $0.35 = \mu$

$P =$ Not given

$\rho_0 =$ Unknown

Change of gradient, $\alpha = \tan \alpha = \frac{8h}{L} = \frac{8 \times 120}{15000} = 0.064$

% loss of stress in steel due to friction

$$= \frac{\rho_0(Kx + \mu\alpha)}{\rho_0} \times 100$$

$$= (0.0015 \times 15 + 0.35 \times 0.064) \times 100$$

$$= 4.49\%$$

End of Solution

Q.28 The Fourier series to represent $x - x^2$ for $-\pi \leq x \leq \pi$ is given by

$$x - x^2 = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos nx + \sum_{n=1}^{\infty} b_n \sin nx$$

The value of a_0 (round off to two decimal places), is _____.

Ans. (-6.58)

$$a_0 = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) dx = \frac{1}{\pi} \int_{-\pi}^{\pi} (x - x^2) dx = \frac{-1}{\pi} \int_0^{\pi} 2x^2 dx$$

$$= -\frac{1}{\pi} \left(\frac{2x^3}{3} \right)_0^{\pi} = -\frac{2}{3\pi} [\pi^3] = \frac{-2\pi^2}{3} = -6.58$$

End of Solution

Q.29 The diameter and height of a right circular cylinder are 3 cm and 4 cm, respectively. The absolute error in each of these two measurements is 0.2 cm. The absolute error in the computed volume (in cm^3 , round off to three decimal places), is _____.

Ans. (5.18)

Let diameter, $x = 3$ and height $= y = 4$ and error $= \pm 0.2$

$$V = \pi \left(\frac{x}{2} \right)^2 y = \frac{\pi x^2 y}{4}$$

$\therefore V = f(x, y)$

So, $dV = \left(\frac{\partial V}{\partial x} \right) dx + \left(\frac{\partial V}{\partial y} \right) dy$

i.e., $dV = \left(\frac{1}{2} \pi xy \right) dx + \left(\frac{\pi x^2}{4} \right) dy$

$$= \frac{1}{2} \pi \times 3 \times 4 \times (0.2) + \frac{\pi}{4} \times (3)^2 \times (0.2) = 1.65\pi$$

$$= 1.65 \times 3.14 = 5.18 \text{ (approx)}$$

i.e., absolute error $= | 5.18 | = 5.18$

End of Solution

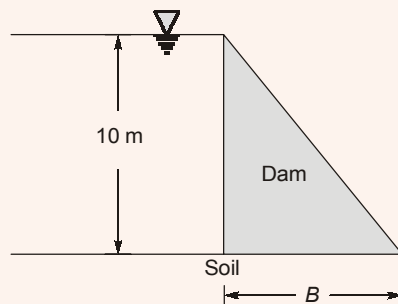
Q.30 The ion product of water (pK_w) is 14. If a rain water sample has a pH of 5.6, the concentration of OH^- in the sample (in 10^{-9} mol/litre, round off to one decimal place), is _____.

Ans. (3.98)

$$\begin{aligned} \text{pH} + \text{pOH} &= 14 \\ \text{pOH} &= 14 - 5.6 = 8.4 \\ -\log [\text{OH}^-] &= 8.4 \\ [\text{OH}^-] &= 10^{-8.4} \text{ moles/l} \\ &= 10^{-8.4+9} \times 10^{-9} \text{ moles/l} \\ &= 3.98 \times 10^{-9} \text{ moles/l} \end{aligned}$$

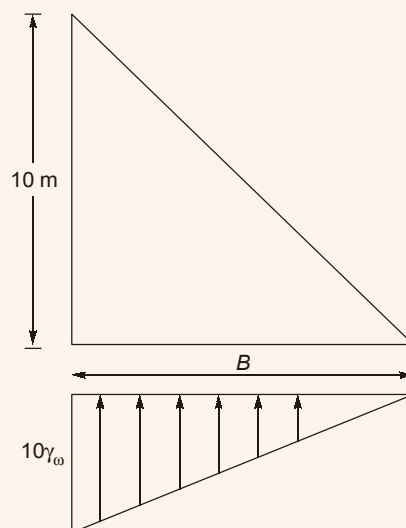
End of Solution

Q.31 A concrete dam holds 10 m of static water as shown in the figure (not drawn to the scale). The uplift assumed to vary linearly from full hydrostatic head at the heel, to zero at the toe of dam. The coefficient of friction between the dam and foundation soil is 0.45. Specific weights of concrete and water are 24 kN/m^3 and 9.81 kN/m^3 , respectively.



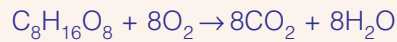
For NO sliding condition, the required minimum base width B (in m, round off to two decimal places) is _____.

Ans. (15.873 m)



Ans. (0.256)

$C_8H_{16}O_8$ of conc. 10^{-3} moles/l required O_2 (in gm/l)



1 mole 8 mole

1 mole of $C_8H_{16}O_8$ requires 8 moles of O_2 for its decomposition

$$240 \text{ gm} = 128 \text{ gm}$$

or 10^{-3} moles = 8×10^{-3} moles

$$= 8 \times 10^{-3} \times 32$$

$$= 0.256 \text{ gm/l}$$

End of Solution

Q.34 A constant head permeability test was conducted on a soil specimen under a hydraulic gradient of 2.5. The soil specimen has specific gravity of 2.65 and saturated water content of 20%. If the coefficient of permeability of the soil is 0.1 cm/s, the seepage velocity (in cm/s, round off to two decimal places) through the soil specimen is _____.

Ans. (0.72)

$$\text{Void ratio, } e = \frac{wG}{s} = \frac{0.2 \times 2.65}{1} = 0.53$$

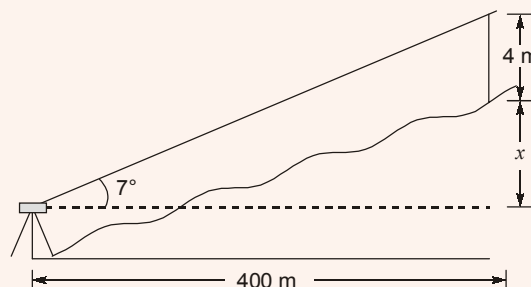
$$\text{Porosity, } n = \frac{e}{1+e} = 0.3464$$

$$\begin{aligned} \text{Seepage velocity, } V_s &= \frac{v}{n} = \frac{Ki}{n} \\ &= \frac{0.1 \times 2.5}{0.3464} = 0.72 \text{ cm/sec} \end{aligned}$$

End of Solution

Q.35 A theodolite is set up at station A. The RL of instrument axis is 212.250 m. The angle of elevation to the top of a 4 m long staff, held vertical at station B, is 7° . The horizontal distance between station A and B is 400 m. Neglecting the errors due to curvature of earth and refraction, the RL (in m, round off to three decimal places) of station B is _____.

Ans. (257.363)



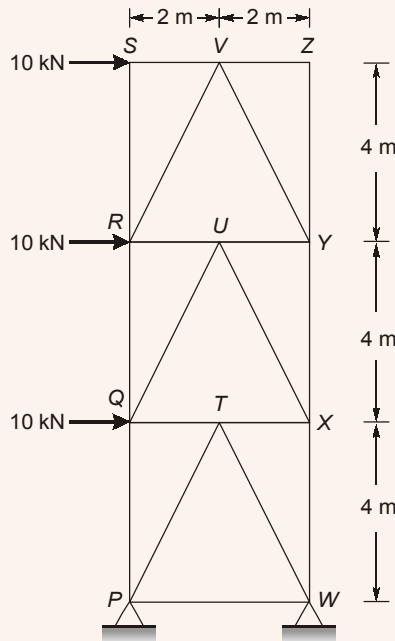
$$V = 400 \tan 7^\circ = 49.113$$

$$x = (49.113 - 4) = 45.113$$

$$RL_B = 212.25 + 45.113 = 257.363 \text{ m}$$

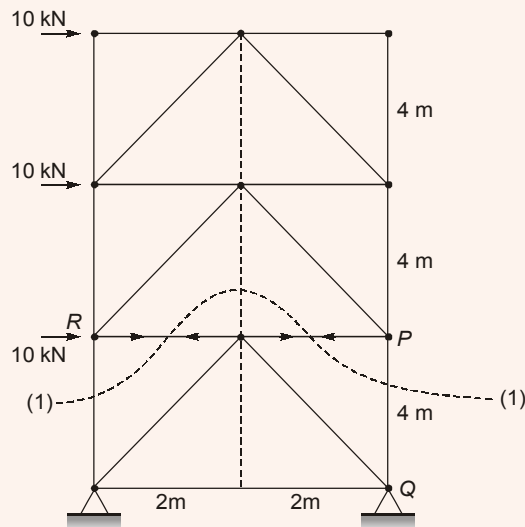
End of Solution

Q.36 The plane truss has hinge supports at P and W and is subjected to the horizontal forces as shown in the figure (not drawn to the scale).

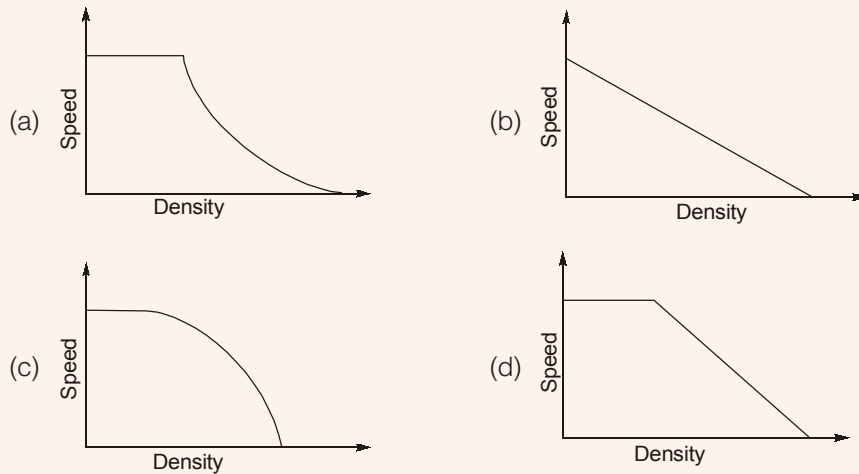


Representing the tensile force with '+' sign and the compressive force with '-' sign, the force in member XW (in kN, round off to the nearest integer), is _____.

Ans. (-30 kN)
Force in PQ



The correct representation of speed-density relationship of the traffic on this highway is



Ans. (a)

End of Solution

Q.39 Alkalinity of water, in equivalent/litre (eq/litre), is given by

$$\{ \text{HCO}_3^- \} + 2 \{ \text{CO}_3^{2-} \} + \{ \text{OH}^- \} - \{ \text{H}^+ \}$$

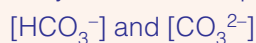
where, { } represents concentration in mol/litre. For a water sample, the concentration of $\text{HCO}_3^- = 2 \times 10^{-3}$ mol/litre, $\text{CO}_3^{2-} = 3.04 \times 10^{-4}$ mol/litre and the pH of water = 9.0.

The atomic weights are : Ca = 40; C = 12; and O = 16. If the concentration of OH^- and H^+ are NEGLECTED, the alkalinity of the water sample (in mg/litre as CaCO_3), is

- (a) 65.2 (b) 50.0
(c) 100.0 (d) 130.4

Ans. (d)

Alkalinity of water sample is due to presence of



$$\begin{aligned} \text{Total alkalinity} &= 1 \text{ mole of } [\text{HCO}_3^-] + 2 \text{ mole of } [\text{CO}_3^{2-}] \text{ in terms of } \text{CaCO}_3 \\ &= (2 \times 10^{-3} \times 50 + 2 \times 3.04 \times 10^{-4} \times 50) \times 10^3 \text{ mg/l} \\ &= 130.4 \text{ mg/l as } \text{CaCO}_3 \end{aligned}$$

End of Solution

Q.40 Group-I gives a list of test methods for evaluating properties of aggregates. Group-II gives the list of properties to be evaluated.

Group-I : Test Methods	Group-II: Properties
P. Soundness test	1. Strength
Q. Crushing test	2. Resistance to weathering
R. Los Angeles abrasion test	3. Adhesion
S. Stripping value test	4. Hardness

The correct match of test methods under Group-I to properties under Group-II, is

- (a) P-4, Q-1, R-2, S-3
(b) P-2, Q-4, R-3, S-1
(c) P-2, Q-1, R-4, S-3
(d) P-3, Q-4, R-1, S-2

Ans. (c)

End of Solution

Q.41 A waste to energy plant burns dry solid waste of composition : Carbon = 35%, Oxygen = 26%, Hydrogen = 10%, Sulphur = 6%, Nitrogen = 3% and Inerts = 20%. Burning rate is 1000 tonnes/d. Oxygen in air by weight is 23%. Assume complete conversion of Carbon to CO_2 , Hydrogen to H_2O , Sulphur to SO_2 and Nitrogen to NO_2 . Given Atomic weights : H = 1, C = 12, N = 14, O = 16, S = 32. The stoichiometric (theoretical) amount of air (in tonnes/d, round off to the nearest integer) required for complete burning of this waste, is _____.

Ans. (6957)

Let MSW be 100 gm

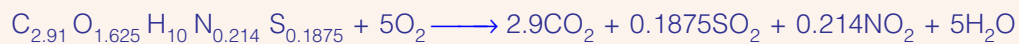
The proportion of C = 35 gm = 2.91 moles

O = 26 gm = 1.625 moles

H = 10 gm = 10 moles

N = 3 gm = 0.214 moles

S = 6 gm = 0.1875 moles



From reaction

1 mole MSW requires 5 mole O_2 for combustion

80 gm of MSW compound reacts with 160 gm of O_2 for combustion

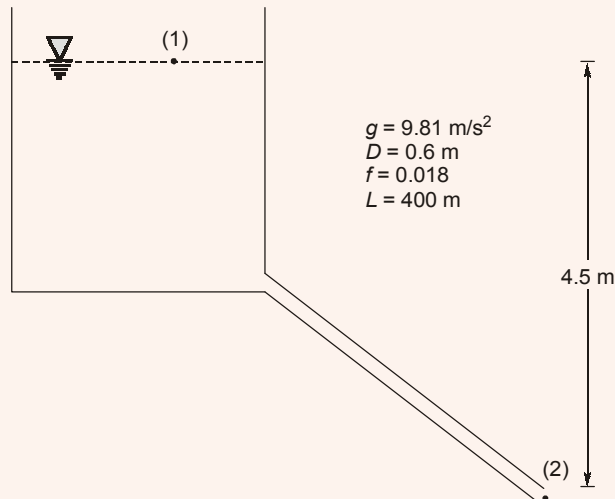
$$800 \text{ tonne/day} \times \frac{160}{80} = 1600 \text{ t/d}$$

$$\text{Air requires } \frac{1600}{0.23} = 6956.5 \text{ t/d} \approx 6957 \text{ t/d}$$

End of Solution

Q.42 A cast iron pipe of diameter 600 mm and length 400 m carries water from a tank and discharges freely into air at a point 4.5 m below the water surface in the tank. The friction factor of the pipe is 0.018. Consider acceleration due to gravity as 9.81 m/s^2 . The velocity of the flow in pipe (in m/s, round off to two decimal places) is _____.

Ans. (2.56)



Apply energy equation between (1) and (2)

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_f$$

$$4.5 = \frac{f \cdot L \cdot V^2}{2gD} + 0.5 \frac{V^2}{2g} + \frac{V^2}{2g}$$

$$4.5 = \frac{(0.018)(400) \cdot V^2}{2(9.81)(0.6)} + \frac{1.5V^2}{2g}$$

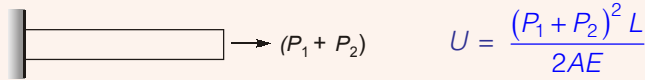
$$4.5 = \frac{12V^2}{2g} + \frac{1.5V^2}{2g}$$

$$V^2 = 6.54$$

$$V = 2.557 \text{ m/s} \simeq 2.56 \text{ m/s}$$

End of Solution

Q.43 Joints I, J, K, L, Q and M of the frame shown in the figure (not drawn to the scale) are pins. Continuous members IQ and IJ are connected through a pin at N. Continuous members JM and KQ are connected through a pin at P. The frame has hinge supports at joints R and S. The loads acting at joints I, J and K are along the negative Y direction and the loads acting at joints I, M are along the positive X direction.



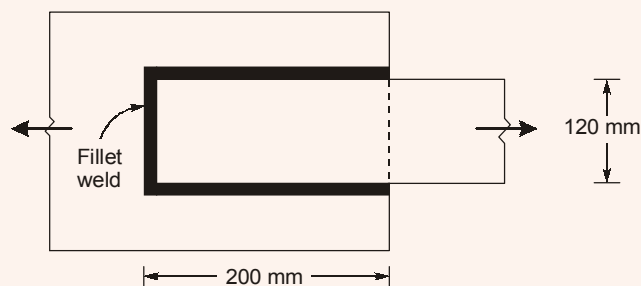
$$U = \frac{(P_1 + P_2)^2 L}{2AE}$$

$$(P_1 + P_2)^2 > P_1^2 + P_2^2$$

$$U > U_1 + U_2$$

End of Solution

- Q.46** Two steel plates are lap jointed in a workshop using 6 mm thick fillet weld as shown in the figure (not drawn to the scale). The ultimate strength of the weld is 410 MPa.

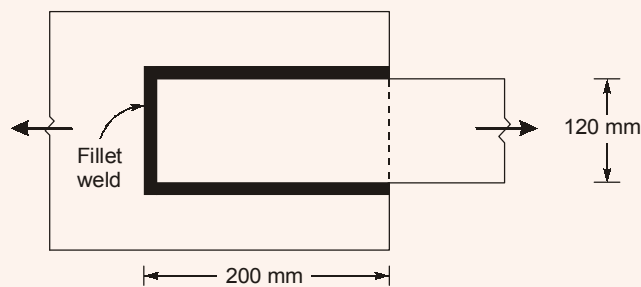


As per Limit State Design is **IS 800 : 2007**, the design capacity (in kN, round off to three decimal places) of the welded connection, is _____.

Ans. (413.586)

Design capacity of welded connection

$$P_s = f_b \times l_{\text{eff}} \times t_t$$



$$P = \frac{410}{\sqrt{3} \times 1.25} \times 520 \times 0.7 \times 6$$

$$= \frac{716352}{\sqrt{3}} = 413586 \text{ N}$$

$$= 413.586 \text{ kN}$$

End of Solution

- Q.47** For the hottest month of the year at the proposed airport site, the monthly mean of the average daily temperature is 39°C. The monthly mean of the maximum daily temperature is 48°C for the same month of the year. From the given information, the calculated Airport Reference Temperature (in°C), is
- (a) 42 (b) 39
(c) 36 (d) 48

Ans. (a)

$$T_a = 39^\circ\text{C}$$

$$T_m = 48^\circ\text{C}$$

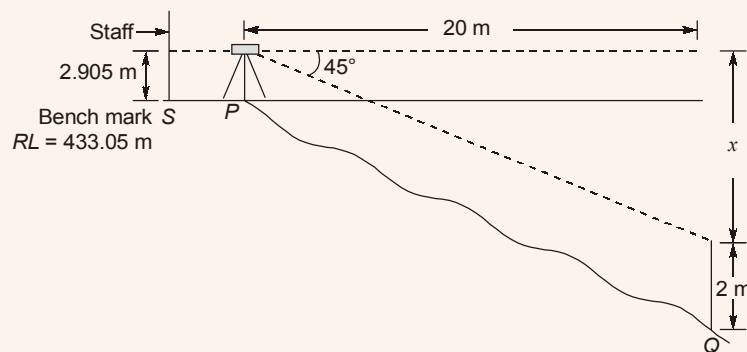
$$\text{ATR} = T_a + \left(\frac{T_m - T_a}{3} \right)$$

$$= 39 + \left(\frac{48 - 39}{3} \right) = 42^\circ\text{C}$$

End of Solution

- Q.48** A theodolite was set up at a station P. The angle of depression to a vane 2 m above the foot of a staff held at another station Q was 45°. The horizontal distance between stations P and Q is 20 m. The staff reading at a benchmark S of RL 433.050 m is 2.905 m. Neglecting the errors due to curvature and refraction, the RL of the station Q (in m), is
- (a) 431.050 (b) 435.955
(c) 413.050 (d) 413.955

Ans. (d)



$$\frac{x}{20} = \tan 45^\circ$$

$$x = 20 \text{ m}$$

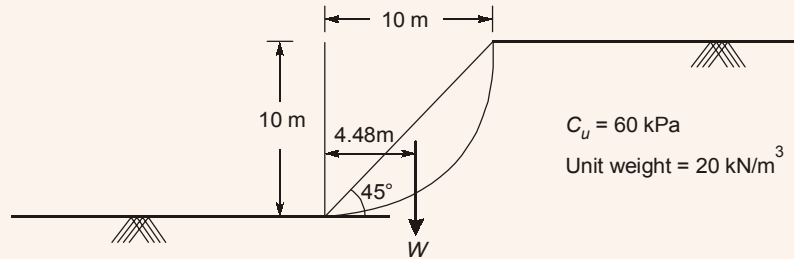
$$\text{RL of } Q = 433.05 + 2.905 - x - 2$$

$$= 433.05 + 2.905 - 20 - 2$$

$$= 413.955 \text{ m}$$

End of Solution

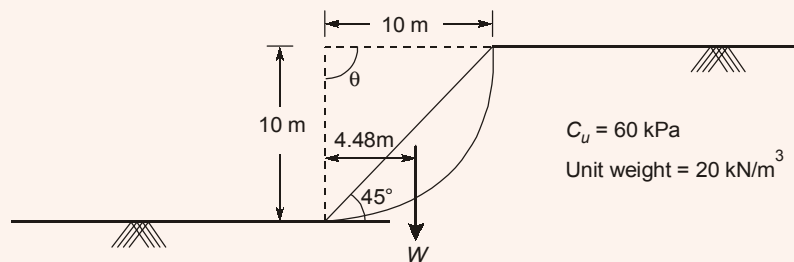
- Q.49** A 10 m high slope of dry clay soil (unit weight = 20 kN/m³), with a slope angle of 45° and the circular slip surface, is shown in the figure (not drawn to the scale). The weight of the slip wedge is denoted by W. The undrained unit cohesion (c_u) is 60 kPa.



The factor of safety of the slope against slip failure, is

- (a) 0.58 (b) 1.84
(c) 1.57 (d) 1.67

Ans. (*)



Consider unit length of slope

$$\text{Area of circular arc} = \frac{\theta}{360} \times \pi r^2 - \text{Area of } \Delta$$

$$= \frac{90}{360} \times \pi \times 10^2 - \frac{1}{2} \times 10 \times 10 = 28.54 \text{ m}^2$$

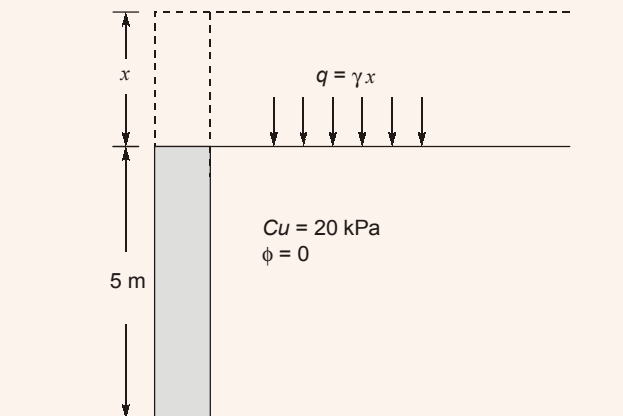
$$\begin{aligned} \text{Height of wedge} &= \text{Volume} \times \gamma = (\text{Area} \times 1) \times \gamma \\ &= 28.54 \times 1 \times 20 = 570.8 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{FOS} &= \frac{M_R}{M_0} = \frac{[c \times (r\theta)] \times r}{W \times x} = \frac{60 \times 10 \times \frac{\pi}{2} \times 10}{570.8 \times 4.48} \\ &= 3.68 \end{aligned}$$

End of Solution

Q.50 A 5 m high vertical wall has a saturated clay backfill. The saturation unit weight and cohesion of clay are 18 kN/m^3 and 20 kPa , respectively. The angle of internal friction of clay is zero. In order to prevent development of tension zone, the height of the wall is required to be increased. Dry sand is used as backfill above the clay for the increased portion of the wall. The unit weight and angle of internal friction of sand are 16 kN/m^3 and 30° , respectively. Assume that the back of the wall is smooth and top of the backfill is horizontal. To prevent the development of tension zone, the minimum height (in m, round off to one decimal place) by which the wall has to be raised, is _____.

Ans. (2.5)



To prevent tension crack,

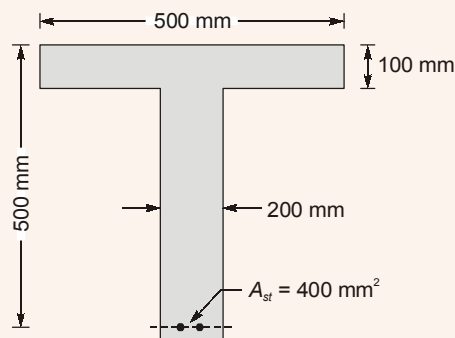
$$q = \frac{2c}{\sqrt{k_a}} = \frac{2 \times 20}{1} = 40$$

$$q = \gamma_d x = 40$$

$$x = \frac{40}{16} = 2.5 \text{ m}$$

End of Solution

Q.51 The cross-section of the reinforced concrete beam having an effective depth of 500 mm is shown in the figure (not drawn to the scale). The grades of concrete and steel used are M35 and Fe550, respectively. The area of tension reinforcement is 400 mm^2 . It is given that corresponding to 0.2% proof stress, the material safety factor is 1.15 and the yield strain of Fe550 steel is 0.0044.



As per IS 456:2000, the limiting depth (in mm, round off to the nearest integer) of the neutral axis measured from the extreme compression fiber, is _____.

Ans. (221.52)

For a RCC T-Beam
(For limiting depth of neutral axis)

Considering $d = 500 \text{ mm}$

$$\frac{0.0035}{x_{u,lim}} = \frac{0.0044}{d - x_{u,lim}}$$

$$d - x_{u,lim} = \frac{0.0044}{0.0035} \times x_{u,lim}$$

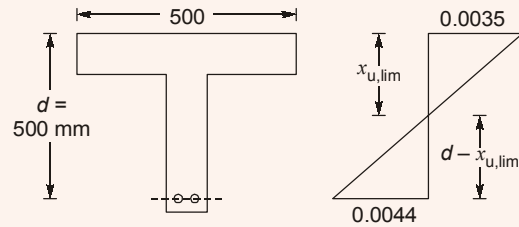
$$35 \times 500 = 35x_{u,lim} + 44x_{u,lim}$$

$$= 79x_{u,lim}$$

$$x_{u,lim} = \frac{35 \times 500}{79} = 221.52 \text{ mm}$$

Limiting depth of neutral axis

$$x_{0,lim} = 221.52 \text{ mm}$$



End of Solution

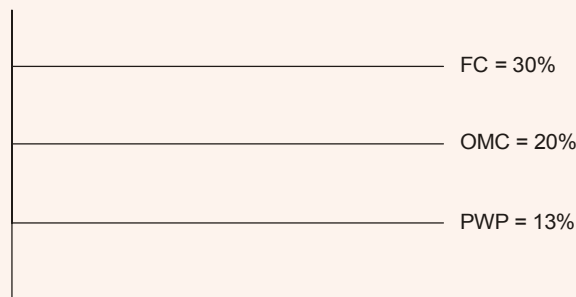
Q.52 Crops are grown in a field having soil, which has field capacity of 30% and permanent wilting point of 13%. The effective depth of root zone is 80 cm. Irrigation water is supplied when the average soil moisture drops to 20%. Consider density of the soil as 1500 kg/m^3 and density of water as 1000 kg/m^3 . If the daily consumptive use of water for the crops is 2 mm, the frequency of irrigating the crops (in days), is

- (a) 7 (b) 13
(c) 10 (d) 11

Ans. (*)

$$FC = 30\%$$

$$PWP = 13\%$$



$$d_w = \frac{\gamma_d}{\gamma_w} \cdot d \times (FC - OMC)$$

$$\theta_R = \frac{(PL/2)L}{6EI}$$

$$\theta_R = \frac{PL^2}{12EI}$$

End of Solution

Q.54 An ordinary differential equation is given below

$$6 \frac{d^2y}{dx^2} + \frac{dy}{dx} - y = 0$$

The general solution of the above equation (with constant C_1 and C_2), is

- (a) $y(x) = C_1 e^{-\frac{x}{3}} + C_2 x e^{\frac{x}{2}}$ (b) $y(x) = C_1 e^{-\frac{x}{3}} + C_2 e^{\frac{x}{2}}$
 (c) $y(x) = C_1 x e^{-\frac{x}{3}} + C_2 e^{\frac{x}{2}}$ (d) $y(x) = C_1 e^{\frac{x}{3}} + C_2 e^{-\frac{x}{2}}$

Ans. (d)

$$\frac{6d^2y}{dx^2} + \frac{dy}{dx} - y = 0$$

$$(6D^2 + D - 1)y = 0$$

$$6D^2 + 3D - 2D - 1 = 0$$

$$3D(2D + 1) - 1(2D + 1) = 0$$

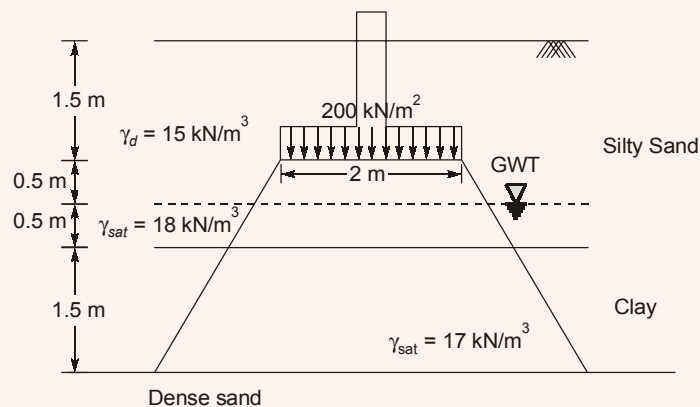
$$(2D + 1)(3D - 1) = 0$$

$$D = \frac{-1}{2}, D = \frac{1}{3}$$

$$y = C_1 e^{x/3} + C_2 e^{-x/2}$$

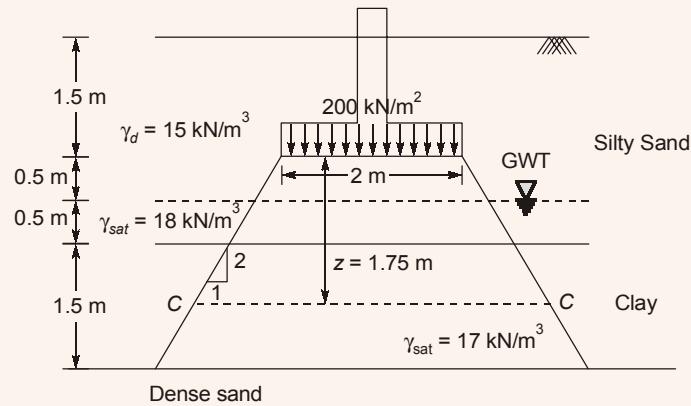
End of Solution

Q.55 A footing of size 2 m × 2 m transferring a pressure of 200 kN/m², is placed at a depth of 1.5 m below the ground as shown in the figure (not drawn to the scale). The clay stratum is normally consolidated. The clay has specific gravity of 2.65 and compression index of 0.3



Considering 2 : 1 (vertical to horizontal) method of load distribution and $\gamma_w = 10 \text{ kN/m}^3$, the primary consolidation settlement (in mm, round off to two decimal places) of the clay stratum is _____.

Ans. (74.27)



For clay layer,

$$\gamma_{sat} = \left(\frac{G + e}{1 + e} \right) \gamma_w \Rightarrow \left(\frac{2.65 + e}{1 + e} \right) 10 = 17 \text{ kN/m}^3$$

$$e_0 = 1.357$$

1. $H_0 = 1.5 \text{ m}$

2.
$$(\bar{\sigma}_0)_{c-c} = [2\gamma_d + 0.5\gamma_{sat} + 0.75\gamma_{sat}] - 1.25\gamma_w$$

$$= (2 \times 15 + 0.5 \times 18 + 0.75 \times 17) - 1.25 \times 10$$

$$= 39.25 \text{ kN/m}^2$$

3.
$$\Delta\bar{\sigma} = \frac{\text{Force}}{\text{Area}} = \frac{qB^2}{(B + 2nZ)^2} = \frac{200 \times 2 \times 2}{\left(2 + 2 \times \frac{1}{2} \times 1.75 \right)^2} = 56.88 \text{ kN/m}^2$$

4.
$$\Delta H = \frac{H_0 C_c}{1 + e_0} \log \left(\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0} \right)$$

$$= \frac{1.5 \times 0.3}{1 + 1.357} \log \left(\frac{39.25 + 56.88}{39.25} \right)$$

$$= 74.27 \text{ mm}$$

End of Solution

