BYJU'S EXAM PREP

GATE 2022

Civil Engineering

Shift-1

Questions with Detailed Solution

1. You should _____ when to say _____.

A. no / no B. no / know

C. know / know D. know / no

[MCQ: 1 Mark]

Ans. (D)

Sol.

You should **know** when to say **no**.

2. Two straight lines pass through the origin $(x_0, y_0) = (0, 0)$. One of them passes through the point $(x_2, y_2) = (1,3)$ and the other passes through the point $(x_2, y_2) = (1, 2)$.

What is the area enclosed between the straight lines in the interval [0,1] on the x-axis?

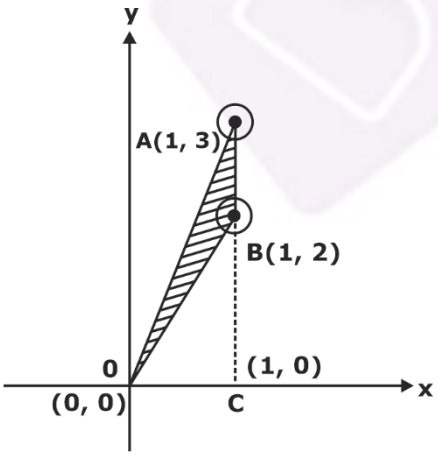
A. 0.5 B. 1.0

C. 1.5 D. 2.0

[MCQ: 1 Mark]

Ans. (A)

Sol.



Area enclosed = Area of the shaded region

= Area of ΔDAB

$= \frac{1}{2} \times \text{base} \times \text{height}$

$= \frac{1}{2} \times AB \times OC$

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

= 0.5 sq. units

3. If

p : q = 1 : 2

q : r = 4 : 3

r : s = 4 : 5

and u is 50% more than s, what is the ratio p : u?

A. 2: 15 B. 16: 15

C. 1 : 5 D. 16 : 45

[MCQ: 1 Mark]

Ans. (D)

Sol. Given:

p:q = 1:2, q:r = 4:3, r:s = 4:5

or, $\frac{r}{s} = \frac{12}{15}, \frac{q}{r} = \frac{16}{12}$ and $\frac{p}{q} = \frac{8}{16}$

Let, p = 8k, q = 16k, r = 12 k and s = 15 k

$u = \left(1 + \frac{50}{100}\right)s$

= 1.5 s

= 1.5 × 15 k = 22.5 k

p:u = 8 k : 22.5 k

= 16 : 45

4. Given the statements:

- P is the sister of Q.
- Q is the husband of R.
- R is the mother of S.

- T is the husband of P.

Based on the above information, T is _____ of S.

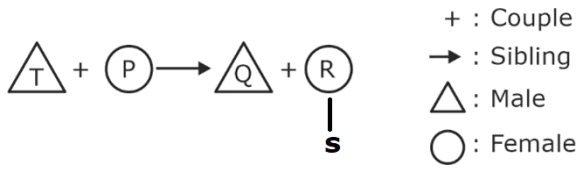
A. the grandfather B. an uncle

C. the father D. a brother

[MCQ: 1 Mark]

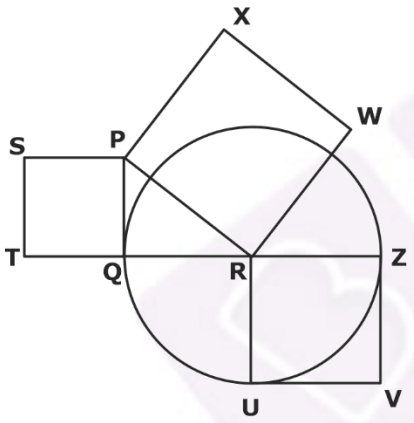
Ans. (B)

Sol. The family tree is as shown below:



T is the uncle of S

5. In the following diagram, the point R is the center of the circle. The lines PQ and ZV are tangential to the circle. The relation among the areas of the squares, PXWR, RUVZ and SPQT is



A. Area of SPQT = Area of RUVZ = Area of PXWR

B. Area of SPQT = Area of PXWR - Area of RUVZ

C. Area of PXWR = Area of SPQT - Area of RUVZ

D. Area of PXWR = Area of RUVZ- Area of SPQT

[MCQ: 1 Mark]

Ans. (B)

Sol. Area of square SPQT = PQ^2 …(1)

Area of square PXWR = PR^2 …(2)

Area of square RUVZ = $RZ^2 = QR^2$ [RZ = QR = radius] …(3)

In ΔPQR, ∠PQR = 90° as PQ is tangent to the circle

$PR^2 = PQ^2 + QR^2$ …(4)

From (1), (2), (3) and (4) we can write.

Area of square PXWR = Area of square SPQT + Area of square RUVZ

⇒ Area of square SPQT = Area of square PXWR - Area of square RUVZ

6. Healthy eating is a critical component of healthy ageing. When should one start eating healthy? It turns out that it is never too early. For example, babies who start eating healthy in the first year are more likely to have better overall health as they get older.

Which one of the following is the CORRECT logical inference based on the information in the above passage?

A. Healthy eating is important for those with good health conditions, but not for others

B. Eating healthy can be started at any age, earlier the better

C. Eating healthy and better overall health are more correlated at a young age, but not older age

D. Healthy eating is more important for adults than kids

[MCQ: 2 Marks]

Ans. (B)

Sol. The conclusion is that eating healthy and better overall health are more co-related at a young age but not older age.

7. P invested ₹ 5000 per month for 6 months of a year and Q invested ₹ x per month for 8 months of the year in a partnership business. The profit is shared in proportion to the total investment made in that year.
If at the end of that investment year, Q receives $\frac{4}{9}$ of the total profit, what is the value of x (in ₹)?

A. 2500 B. 3000
C. 4687 D. 8437

[MCQ: 2 Marks]

Ans. (B)

Sol. The ratio of the profits = 5000 × 6: 8x

$$= \frac{15000}{4x}$$

$$\% \text{ share of the profit of } Q = \frac{4x}{4x+15000}$$

From the question

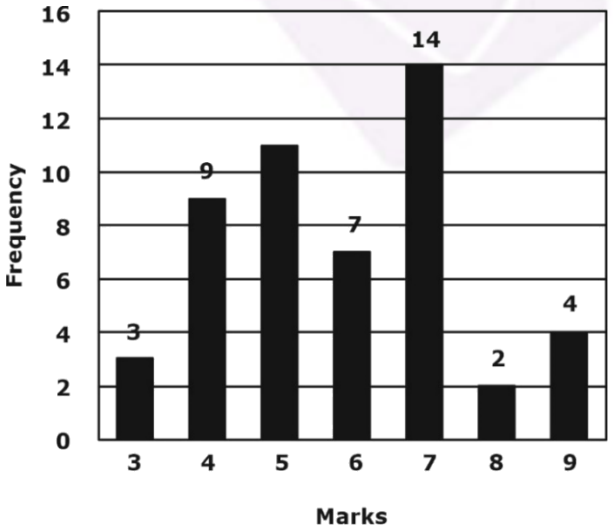
$$\frac{4x}{4x+15000} = \frac{4}{9}$$

$\Rightarrow 9x = 4x + 15000$

$\Rightarrow 5x = 15000$

$$\boxed{x = 3000}$$

8.



The above frequency chart shows the frequency distribution of marks obtained by a set of students in an exam.

From the data presented above, which one of the following is CORRECT?

A. mean > mode > median

B. mode > median > mean

C. mode > mean > median

D. median > mode > mean

[MCQ: 2 Marks]

Ans. (B)

Sol.

$$\text{Mean} = \frac{\sum f_i x_i}{\sum f_i}$$

$$= \frac{3\times3+9\times4+11\times5+7\times6+14\times7+2\times8+4\times9}{3+9+11+7+14+2+4}$$

$$= \frac{9+36+55+42+98+16+36}{50}$$

$$= \frac{292}{50} = 5.84$$

Calculation of median:

No. of variates, $N = \sum f_i = 50$ (even)

$$\text{Median} = \text{mean of } \frac{N^{th}}{2} \& \left(\frac{N}{2}+1\right)^{th} \text{ variate}$$

$$= \text{mean of } 25^{th} \& 26^{th} \text{ variate}$$

$$= \frac{6+6}{2} = 6$$

Mode = Marks corresponding to maximum frequency = 7

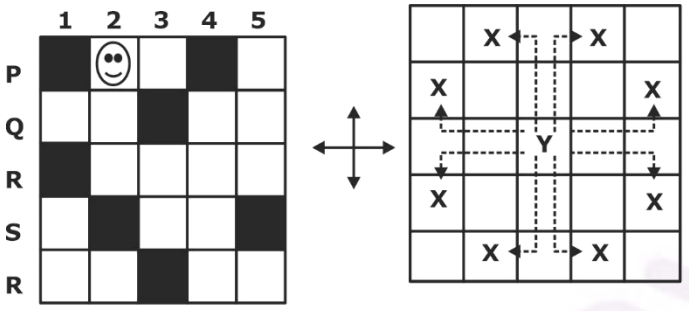
Hence, mode > median > mean

9. In the square grid shown on the left, a person standing at P2 position is required to move to P5 position.

The only movement allowed for a step involves "two moves along one direction followed by one move in a perpendicular direction". The permissible directions for movement are shown as dotted arrows in the right.

For example, a person at a given position Y can move only to the positions marked X on the right.

Without occupying any of the shaded squares at the end of each step, the minimum number of steps required to go from P2 to P5 is



Example : Allowed steps for a person at Y

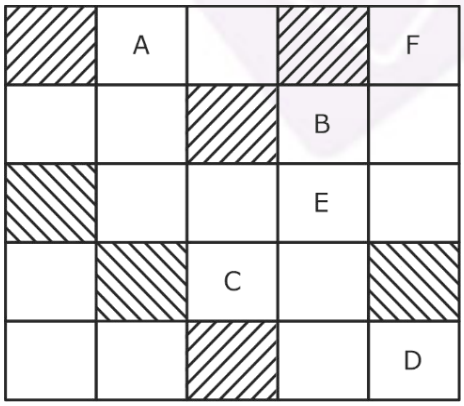
A. 4 B. 5

C. 6 D. 7

[MCQ: 2 Marks]

Ans. (B)

Sol.

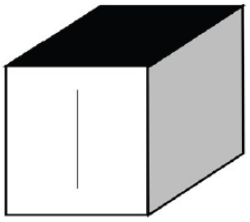


Moves will be A – B – C – D – E = F

i.e., A to B, B to C, C to D, D to E and E to F

Minimum no. of steps = 5

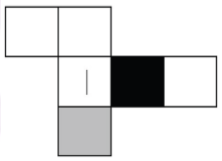
10.

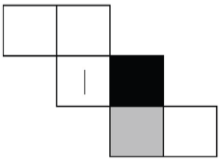


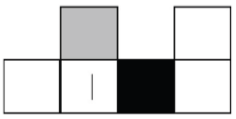
Consider a cube made by folding a single sheet of paper of appropriate shape.

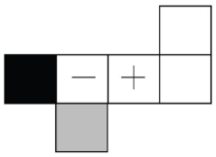
The interior faces of the cube are all blank. However, the exterior faces that are not visible in the above view may not be blank.

Which one of the following represents a possible unfolding of the cube?

A. 

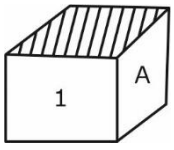
B. 

C. 

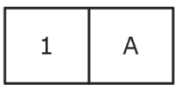
D. 

[MCQ: 2 Marks]

Ans. (D)



On unfolding, the given alignment will always be followed:

 and 

Which is only shown in option D.

11. Consider the following expression:

$Z = \sin(y + it) + \cos(y - it)$

where z, y, and t are variables, and $i = \sqrt{-1}$ is a complex number. The partial differential equation derived from the above expression is

A. $\frac{\partial^2 Z}{\partial y^2} + \frac{\partial^2 Z}{\partial t^2} = 0$ B. $\frac{\partial^2 Z}{\partial t^2} - \frac{\partial^2 Z}{\partial y^2} = 0$

C. $\frac{\partial z}{\partial t} - i\frac{\partial z}{\partial y} = 0$ D. $\frac{\partial z}{\partial t} + i\frac{\partial z}{\partial y} = 0$

[MCQ: 1 Mark]

Ans. (A)

Sol.

$Z = \sin(y + it) + \cos(y - it)$

$\frac{\partial Z}{\partial y} = \cos(y + it) - \sin(y - it)$

$\frac{\partial^2 Z}{\partial y^2} = -\sin(y + it) - \cos(y - it) = -z$ …(1)

$\frac{\partial Z}{\partial t} = i\cos(y + it) + i\sin(y - it)$

$\frac{\partial^2 Z}{\partial t^2} = -i^2\sin(y + it) - i^2\cos(y - it)$

$= \sin(y + it) + \cos(y - it) = Z$ …(2)

Adding (1) and (2) we get

$\frac{\partial^2 Z}{\partial y^2} + \frac{\partial^2 Z}{\partial t^2} = 0$

12. For the equation

$$\frac{d^3y}{dx^3} + x\left(\frac{dy}{dx}\right)^{3/2} + x^2y = 0$$

the correct description is

A. an ordinary differential equation of order 3 and degree 2.

B. an ordinary differential equation of order 3 and degree 3.

C. an ordinary differential equation of order 2 and degree 3.

D. an ordinary differential equation of order 3 and degree 3/2.

[MCQ: 1 Mark]

Ans. (A)

Sol.

$$\frac{d^3y}{dx^3} + x\left(\frac{dy}{dx}\right)^{3/2} + x^2y = 0$$

$$\Rightarrow x\left(\frac{dy}{dx}\right)^{3/2} = -\left(x^2y + \frac{d^3y}{dx^3}\right)$$

Squaring both sides, we get

$$x^2\left(\frac{dy}{dx}\right)^3 = -\left(x^2y + \frac{d^3y}{dx^3}\right)^2$$

The above expression is free from fractional powers.

The order of the differential equation is the highest order of derivative in the differential equation after removing the fractional powers, and its corresponding power is called the degree of the differential equation.

Order = 3

Degree = 2

13. The hoop stress at a point on the surface of a thin cylindrical pressure vessel is computed to be 30.0 MPa. The value of maximum shear stress at this point is

A. 7.5 MPa B. 15.0 MPa

C. 30.0 MPa D. 22.5 MPa

[MCQ: 1 Mark]

Ans. B

Sol. Maximum shear stress

$$= \left|\frac{\sigma_1 - \sigma_2}{2}\right| \text{ or } \left|\frac{\sigma_2 - \sigma_3}{2}\right| \left|\frac{\sigma_3 - \sigma_1}{2}\right|$$

$\sigma_1 = 30\ N/mm^2$

$\sigma_2 = 0$

$\sigma_3 = 0$

$$\Rightarrow \text{Maximum shear stress} = \left|\frac{30-0}{2}\right|$$

$$\boxed{\text{Maximum shear stress} = 15\,N/mm^2}$$

14. In the context of elastic theory of reinforced concrete, the modular ratio is defined as the ratio of

A. Young's modulus of elasticity of reinforcement material to Young's modulus of elasticity of concrete.

B. Young's modulus of elasticity of concrete to Young's modulus of elasticity of reinforcement material.

C. Shear modulus of reinforcement material to the shear modulus of concrete.

D. Young's modulus of elasticity of reinforcement material to the shear modulus of concrete.

[MCQ: 1 Mark]

Ans. (A)

Sol

$$m = \frac{E_S}{E_C} = \frac{280}{3\sigma_{cbc}}$$

m= modular ratio

E_S= young's modulus of elasticity of steel (reinforcement)

E_C= young's modulus of elasticity of concrete.

15. Which of the following equations is correct for the Pozzolanic reaction?

A. $Ca(OH)_2$ + Reactive Super plasticizer + $H_2O \rightarrow$ C – S – H

B. $Ca(OH)_2$ + Reactive Silicon dioxide + $H_2O \rightarrow$ C – S – H

C. $Ca(OH)_2$ + Reactive Sulphates + $H_2O \rightarrow$ C – S – H

D. $Ca(OH)_2$ + Reactive Sulphur + $H_2O \rightarrow$ C – S – H

[MCQ: 1 Mark]

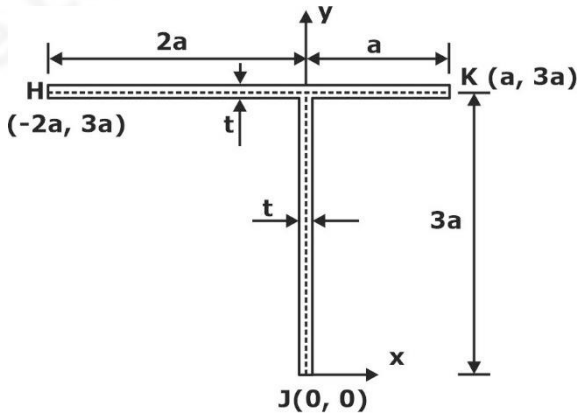
Ans. (B)

Sol.

- The pozzolanic reaction occurs between Ca $(OH)_2$ with silicic acid /Reactive silicide
- This reaction will produce C–S–h (Gel)

$$Ca(OH)_2 + \text{Reactive Silica dioxide} + H_2O \rightarrow \underset{(Gel)}{C-S-H}$$

16. Consider the cross-section of a beam made up of thin uniform elements having thickness t (t ≪ a) shown in the figure. The (x, y) coordinates of the points along the center-line of the cross-section are given in the figure.



The coordinates of the shear center of this cross-section are:

A. x = 0, y = 3a B. x = 2a, y = 2a

C. x = – a, y = 2a D. x = – 2a, y = a

[MCQ: 1 Mark]

Ans. A

Sol. As the section is formed by thin dements shear centre lies at the point of intersection of the axis of thin symmetry elements.

Hence coordinates are

(0, 3a)

17. Four different soils are classified as CH, ML, SP, and SW, as per the Unified Soil Classification System. Which one of the following options correctly represents their arrangement in the decreasing order of hydraulic conductivity?

A. SW, SP, ML, CH B. CH, ML, SP, SW

C. SP, SW, CH, ML D. ML, SP, CH, SW

[MCQ: 1 Mark]

Ans. A

Sol. $K_{gravel} > k_{sand} > k_{silt} > k_{clay}$

Where K indicates permeability

18. Let σ_v' and σ_h' denote the effective vertical stress and effective horizontal stress, respectively. Which one of the following conditions must be satisfied for a soil element to reach the failure state under Rankine's passive earth pressure condition?

A. $\sigma_v' < \sigma_h'$ B. $\sigma_v' > \sigma_h'$

C. $\sigma_v' = \sigma_h'$ D. $\sigma_v' + \sigma_h' = 0$

[MCQ: 1 Mark]

Ans. A

Sol. For passive earth pressure

$\boxed{\sigma_h' > \sigma'_v}$

σ_h' is major principal stress in the passive case and is minor principal stress.

19. With respect to fluid flow, match the following in Column X with Column Y:

Column X		Column Y	
P.	Viscosity	I.	Mach number
Q.	Gravity	II.	Reynolds number
R.	Compressibility	III.	Euler number
S.	Pressure	IV.	Froude number

Which one of the following combinations is correct?

A. (P) – (II), (Q) – (IV), (R) – (I), (S) – (III)

B. (P) – (III), (Q) – (IV), (R) – (I), (S) – (II)

C. (P) – (IV), (Q) – (II), (R) – (I), (S) – (III)

D. (P) – (II), (Q) – (IV), (R) – (III), (S) – (I)

[MCQ: 1 Mark]

Ans. A

Sol. Reynold's number is related to inertia force and viscous force.

- Froude number is related to inertia force and gravity force.
- Mach number is related to inertia force and elastic force.
- Euler number is related to inertia force and pressure force.

20. Let ψ represent soil suction head and K represent hydraulic conductivity of the soil. If the soil moisture content θ increases, which one of the following statements is **TRUE**?

A. ψ decrease and K increases.

B. ψ increases and K decreases.

C. Both ψ and K decrease.

D. Both ψ and K increase.

[MCQ: 1 Mark]

Ans. A

Sol. Soil suction: The negative pressure of water held above the water table results in an attractive force between particles. Suction decreases with an increase in moisture content due to an increase in the meniscus radius.

Hydraulic conductivity increases with an increase in moisture content.

21. A rectangular channel with Gradually Varied Flow (GVF) has a changing bed slope. If the change is from a steeper slope to a steep slope, the resulting GVF profile is

A. S_3

B. S1

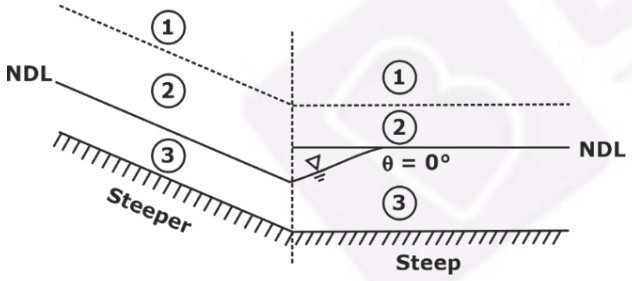
C. S_2

D. either S_1 or S_2, depending on the magnitude of the slopes

[MCQ: 1 Mark]

Ans. A

Sol.



The Control section lies upstream; thereby S3 profile is formed.

22. The total hardness in raw water is 500 milligram per liter as $CaCO_3$. The total hardness of this raw water, expressed in milligram equivalent per liter, is

(Consider the atomic weights of Ca, C, and O as 40 g/mol, 12 g/mol, and 16 g/mol, respectively.)

A. 10 B. 100

C. 1 D. 5

[MCQ: 1 Mark]

Ans. A

Sol. Total hardness = 500mg/ℓ as $CaCO_3$

$$\text{Equivalent weight for } CaCO_3 = \frac{\text{Weight}}{\text{valence}} = \frac{100}{2}$$

= 50g

Number of equivalents =

$$\frac{\text{Weight}}{\text{Equivalent weight}} = \frac{500\times10^{-3}\text{g}}{50\text{g/eq}} = 0.01\text{eq}/\ell$$

$$= 0.01\times1000 = \boxed{10\,\text{meq}/\ell}$$

23. An aerial photograph is taken from a flight at a height of 3.5 km above mean sea level, using a camera of focal length 152 mm. If the average ground elevation is 460 m above mean sea level, then the scale of the photograph is

A. 1: 20000

B. 1: 20

C. 1: 100000

D. 1: 2800

[MCQ: 1 Mark]

Ans. (A)

Sol. H= 3.5 km = 3500 m

h_{avg} = 460 m

f = 152 mm = 152 × 10^{-3} m

$$\text{Scale} = \frac{f}{H-\text{havg}} = \frac{152\times10^{-3}}{3500-460} = \frac{1}{20000}$$

24. A line between stations P and Q laid on a slope of 1 in 5 was measured as 350 m using a
50 m tape. The tape is known to be short by 0.1 m.
The corrected horizontal length (in m) of the line PQ will be

A. 342.52 B. 349.30
C. 356.20 D. 350.70

[MCQ: 1 Mark]

Ans. (A)

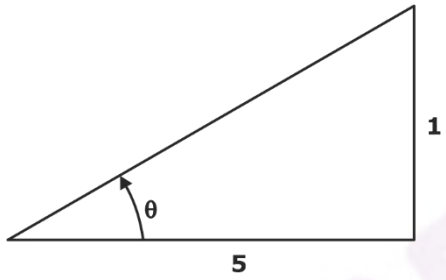
Sol.

Slope =1 in 5

$l' = 350$ meter

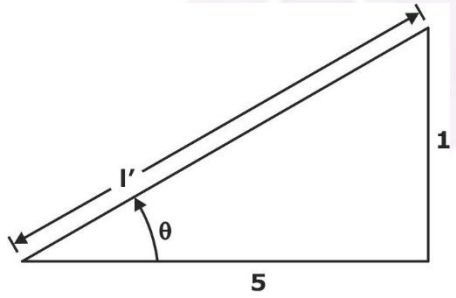
L=Tape length = 50 meter

Correction due to slope



$\tan\theta = \frac{1}{5}$

θ = 11.31 degree



$C_{slope} = l' \cos\theta - l' = 350(\cos\theta - 1)$

$C_{slope} = 350(\cos 11.31 - 1) = -6.8$ m

Tape is short by 0.1 m

$L' = 50 - 0.1 = 49.9$ m

$l^{l} = 350$ m

l = true length

$$l = \frac{L'}{L} \times l' = \frac{49.9}{50} \times 350 = 349.3\,m$$

$C_{length} = 349.3 - 350 = -0.7$ m

Ture length = 350 + (−6.8) + (−0.7)

= 342.5 m

25. The matrix M is defined as

$$M = \begin{bmatrix} 1 & 3 \\ 4 & 2 \end{bmatrix}$$

and has eigenvalues 5 and − 2. The matrix Q is formed as

$$Q = M^3 - 4M^2 - 2M$$

Which of the following is/are the eigenvalue(s) of matrix Q?

A. 15 B. 25
C. −20 D. −30

[MSQ: 1 Mark]

Ans. (A, C)

Sol.

$$M = \begin{bmatrix} 1 & 3 \\ 4 & 2 \end{bmatrix}$$

Eigenvalues of M are 5 and −2

$Q = M^3 - 4M^2 - 2M$

Hence, eigenvalues of matrix Q = $(5)^3 - 4 \times (5)^2 - 2 \times 5$ and $(-2)^3 - 4(-2)^2 - 2 \times (-2)$

= 125 − 100 − 10 and -8 − 16 + 4

= 15 and − 20

26. For wastewater coming from a wood pulping industry, Chemical Oxygen Demand (COD) and 5-day Biochemical Oxygen Demand (BOD5) were determined. For this wastewater, which of the following statement(s) is/are correct?

A. COD > BOD_5
B. COD ≠ BOD_5
C. COD < BOD_5
D. COD = BOD_5

[MSQ: 1 Mark]

Ans. A, B

Sol. Chemical oxygen demand (COD) includes oxygen required for both biodegradable and non-degradable organic matter; however,

BOD is oxygen demand for biodegradable organic only.

$$\Rightarrow \boxed{\begin{array}{l}\text{COD} > \text{BOD} \\ \text{or} \\ \text{COD} \neq \text{BOD}\end{array}}$$

27. Which of the following process(es) can be used for conversion of salt water into fresh water?

A. Microfiltration B. Electrodialysis

C. Ultrafiltration D. Reverse osmosis

[MSQ: 1 Mark]

Ans. B, D

Sol. Electrodialysis and reverse osmosis processes are used for desalination.

28. A horizontal curve is to be designed in a region with limited space. Which of the following measure(s) can be used to decrease the radius of curvature?

A. Decrease the design speed.

B. Increase the superelevation.

C. Increase the design speed.

D. Restrict vehicles with higher weight from using the facility.

[MSQ: 1 Mark]

Ans. (A, B)

Sol.

$$e + f = \frac{V^2}{127R}$$

To decrease R → Decrease V, and increase €

$$\frac{P}{W} = \frac{V^2}{gR}$$

$$W \propto \frac{1}{V^2} \quad \ldots(1)$$

$$e + f = \frac{V^2}{127R}$$

$$V \propto R \quad \ldots(2)$$

By (1) and (2)

$$W \propto \frac{1}{R^2}$$

So as weight decreases (higher weight not allowed) radius of curvature will increase.

29. Consider the following recursive iteration scheme for different values of variable P with the initial guess $x_1 = 1$:

$$x_{n+1} = \frac{1}{2}\left(x_n + \frac{P}{x_n}\right), \quad n = 1, 2, 3, 4, 5$$

For P = 2, x_5 is obtained to be 1.414, rounded-off to three decimal places. For P = 3, x_5 is obtained to be 1.732, rounded-off to three decimal places.

If P = 10, the numerical value of x_5 is _____ . (round off to three decimal places)

[NAT: 1 Mark]

Ans. (3.100-3.200)

Sol. $x_{n+1} = \frac{1}{2}\left(x_n + \frac{p}{x_n}\right)$

To obtain the equation for which this recursion relation is developed, we need to put $x_{n+1} = x_n = x$

$$x = \frac{1}{2}\left(x + \frac{p}{x}\right)$$

$$2x = x + \frac{p}{x}$$

$$x^2 = p$$

For p = 10

$$x = \sqrt{10} = 3.162$$

30. The Fourier cosine series of a function is given by:

$$f(x) = \sum_{n=0}^{\infty} f_n \cos nx$$

For f (x) = $\cos^4 x$, the numerical value of (f_4 + f_5) is _____ . (round off to three decimal places)

[NAT: 1 Mark]

Ans. (0.120-0.130)

Sol. $f(x) = \sum_{n=0}^{\alpha} f_n \cos nx$

$\cos^4 x = f_o + f_1 \cos x + f_2 \cos 2x + f_3 \cos 3x + \ldots..$

$$\left(\frac{1+\cos 2x}{2}\right)^2 = f_0 + f_1 \cos x + f_2 \cos 2x + f_3 \cos 3x + \ldots$$

$$\Rightarrow \frac{1+\cos^2 2x + 2\cos 2x}{4}$$

$$= f_0 + f_1 \cos x + f_2 \cos 2x + f_3 \cos 3x + \ldots$$

$$\Rightarrow \frac{1}{4} + \frac{1}{4}\left(\frac{1+\cos 4x}{2}\right) + \frac{1}{2}\cos 2x = f_0 + f_1 \cos x + f_2 \cos 2x + f_3 \cos 3x + \ldots..$$

$$\Rightarrow \frac{3}{8} + \frac{1}{2}\cos 2x + \frac{1}{8}\cos 4x = f_0 + f_1 \cos x + f_2 \cos 2x + f_3 \cos 3x + f_4 \cos 4x + \ldots$$

Comparing the coefficients

$$f_4 = \frac{1}{8},\ f_5 = 0$$

$$f_4 + f_5 = \frac{1}{8} = 0.125$$

31. An uncompacted heap of soil has a volume of 10000 m3 and void ratio of 1. If the soil is compacted to a volume of 7500 m^3, then the corresponding void ratio of the compacted soil is _____. (round off to one decimal place)

[NAT: 1 Mark]

Ans. (0.5-0.5)

Sol. Volume of uncompacted heap of soil

V_{T1} = 1000 m^3

Void ratio of uncompacted heap of soil,

e_1 = 1

Volume of compacted soil = V_{T2} = 7500 m^3

Volume of solids in uncompacted soil = volume of solids in compacted soil

$\Rightarrow V_{S1} = V_{S2}$

$$\Rightarrow \frac{V_{T1}}{1+e_1} = \frac{V_{T2}}{1+e_2}$$

$$\frac{10000}{1+1} = \frac{7500}{1+e_2}$$

$$\boxed{e_2 = 0.5}$$

32. A concentrated vertical load of 3000 kN is applied on a horizontal ground surface. Points P and Q are at depths 1 m and 2 m below the ground, respectively, along the line of application of the load. Considering the ground to be a linearly elastic, isotropic, semi-infinite medium, the ratio of the increase in vertical stress at P to the increase in vertical stress at Q is _____. (in integer)

[NAT: 1 Mark]

Ans. (4-4)

Sol. Stress at depth 'z', $\sigma_z = k_B \frac{Q}{2^2}$

$\Rightarrow$ At point P, Z=1m

$$\sigma_{zP} = k_B \frac{Q}{(1)^2}$$

At point Q, Z = 2 m,

$$\sigma_{zQ} = k_B \frac{Q}{(2)^2}$$

$$\Rightarrow \frac{\sigma_{2P}}{\sigma_{2Q}} = \frac{k_0 \frac{Q}{(1)^2}}{k_B \frac{Q}{(2)^2}} = 4$$

33. At a site, a Static Cone Penetration Test was carried out. The measured point (tip) resistance q_c was 1000 kPa at a certain depth. The friction ratio (f_r) was estimated as 1 % at the same depth.

The value of sleeve (side) friction (in kPa) at that depth was _____ . (in integer)

[NAT: 1 Mark]

Ans. (10-10)

$$\text{Friction ratio (fr)} = \frac{\text{sleave friction}}{\text{Cone resistance}} \times 100$$

$$\Rightarrow 1 = \frac{\text{sleave friction}}{1000} \times 100$$

$$\boxed{\text{sleave friction} = 10\,\text{kN}}$$

34. During a particular stage of the growth of a crop, the consumptive use of water is 2.8 mm/day. The amount of water available in the soil is 50 % of the maximum depth of available water in the root zone. Consider the maximum root zone depth of the crop as 80 mm and the irrigation efficiency as 70 %.

[NAT: 1 Mark]

Ans. (13-15)

Sol. C_u = 2.8 mm/day

Max. depth of root zone = 80 mm

Available water in the soil = 50% of Max. root zone depth

$$= \frac{50}{100} \times 80 = 40\,\text{mm}$$

So, the Frequency of irrigation

$$= \frac{40\,\text{mm}}{2.8\,\text{mm/day}} = 14.28 \text{ days} = 14 \text{ days}$$

Here Irrigation efficiency is of no use because frequency only depends upon the actual requirement of the crop.

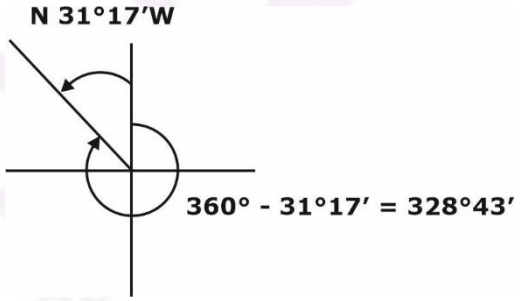
The interval between irrigation (in days) will be _____. (round off to the nearest integer)

35. The bearing of a survey line is N31° 17'W. Its azimuth observed from the north is _____ deg. (round off to two decimal places)

[NAT: 1 Mark]

Ans. 328.72°

Sol.



328°43' will be equal to 328.7169 ≃ 328.72°

Note: azimuth means angle measured from North in Clockwise direction so that WCB value will be our answer in this case.

36. The Cartesian coordinates of a point P in a right-handed coordinate system are (1, 1, 1). The transformed coordinates of P due to a 45° clockwise rotation of the coordinate system about the positive x-axis are

A. $\left(1, 0, \sqrt{2}\right)$ B. $\left(1, 0, -\sqrt{2}\right)$

C. $\left(-1, 0, \sqrt{2}\right)$ D. $\left(-1, 0, -\sqrt{2}\right)$

[MCQ: 2 Marks]

Ans. (A)

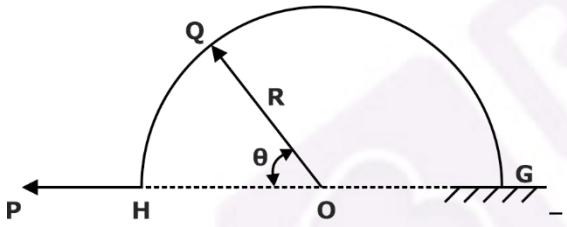
Sol.

The rotation matrix around the x-axis is given as:

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \\ 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 \\ 0 \\ \sqrt{2} \end{bmatrix}$$

37. A semi-circular bar of radius R m, in a vertical plane, is fixed at the end G, as shown in the figure. A horizontal load of magnitude P kN is applied at the end H. The magnitude of the axial force, shear force, and bending moment at point Q for θ = 45°, respectively, are



A. $\frac{P}{\sqrt{2}}$ kN, $\frac{P}{\sqrt{2}}$ kN, and $\frac{PR}{\sqrt{2}}$ kNm –

B. $\frac{P}{\sqrt{2}}$ kN, $\frac{P}{\sqrt{2}}$ kN, and 0 kNm

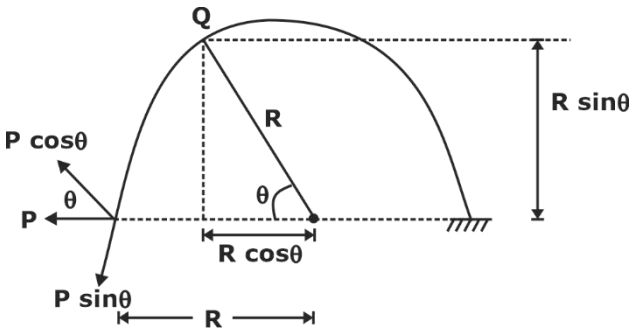
C. 0 kN, $\frac{P}{\sqrt{2}}$ kN, and $\frac{PR}{\sqrt{2}}$ kNm

D. $\frac{P}{\sqrt{2}}$ kN, 0 kN, and $\frac{PR}{\sqrt{2}}$ kNm

[MCQ: 2 Marks]

Ans. A

Sol.



Axial force at Q = P sinθ

$= P \times (\sin 45°)$

$= \frac{P}{\sqrt{2}}$ kN

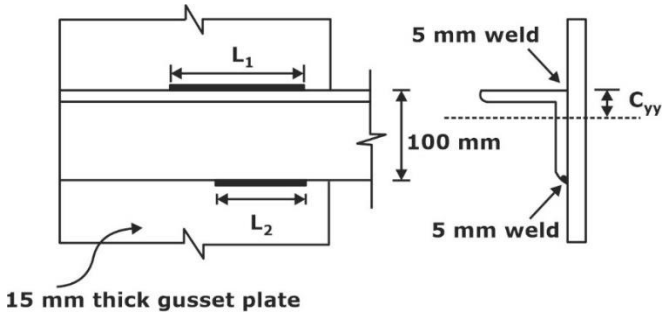
Shear force at Q = P × cos (45°)

$= \frac{P}{\sqrt{2}}$ kN

Bending moment at Q = P × R sinθ

$= \frac{PR}{\sqrt{2}}$ kNm

38. A weld is used for joining an angle section ISA 100 mm × 100 mm × 10 mm to a gusset plate of thickness 15 mm to transmit a tensile load. The permissible stress in the angle is 150 MPa, and the permissible shear stress on the section through the throat of the fillet weld is 108 MPa. The location of the centroid of the angle is represented by C_{yy} in the figure, where C_{yy} = 28.4 mm. The area of cross-section of the angle is 1903 mm^2. Assuming the effective throat thickness of the weld to be 0.7 times the given weld size, the lengths L_1 and L_2 (round off to the nearest integer) of the weld required to transmit a load equal to the full strength of the tension member are, respectively



A. 541 mm and 214 mm

B. 214 mm and 541 mm

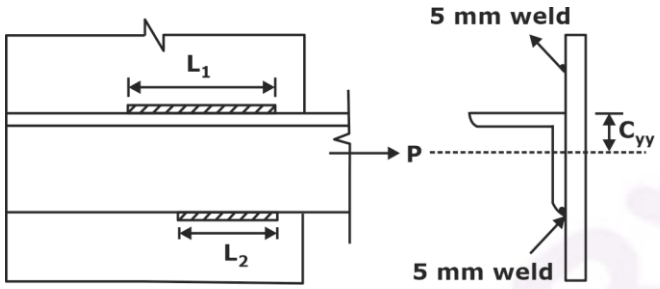
C. 380 mm and 151 mm

D. 151 mm and 380 mm

[MCQ: 2 Marks]

Ans. A

Sol.



Permissible stress of angle section = 150 MPa

Permissible shear stress of filled weld = 108 MPa

Area of angle section(A)= 1903mm^2

Strength of tension member

P = 150 × 1903

P = 285.450 kN

Now, ℓ_1 (0.7 × 5) × 108 + ℓ_2 (0.7 × 5) × 108 = 285.450 × 10^3

$\boxed{\ell_1 + \ell_2 = 755.16}$

ΣM@ ℓ_2 = 0

⇒ ℓ_1 (0.7 × 5) × 108 × 100= P × (100 – 28.4)

ℓ_1 (0.7 × 5 × 108 × 100) = 285.45 × 10^3 × 7.16

$\boxed{\ell_1 = 540.69 \simeq 541 \text{ mm}}$

From (1), ℓ_2 = 755.16 – ℓ_1

$\boxed{\ell_2 = 214.46 = 214 \text{ mm}}$

39. The project activities are given in the following table along with the duration and dependency.

Activities	Duration (days)	Depends on
P	10	–
Q	12	–
R	5	P
S	10	Q
T	10	P, Q

Which one of the following combinations is correct?

A. Total duration of the project = 22 days, Critical path is Q → S

B. Total duration of the project = 20 days, Critical path is Q → T

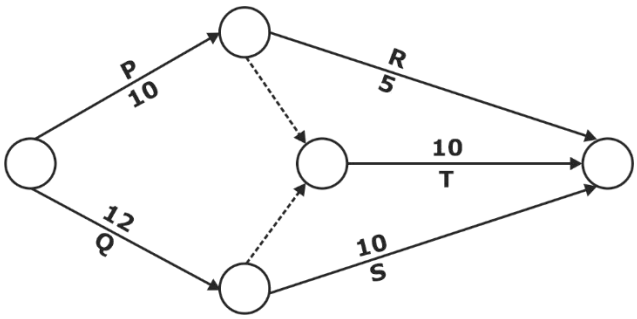
C. Total duration of the project = 22 days, Critical path is P → T

D. Total duration of the project = 20 days, Critical path is P → R

[MCQ: 2 Marks]

Ans. A

Sol. Based on Data



Critical Path = Time wise longer path

For Q – S = time = 22 days

For Q – T time = 22 days

For P – T time = 20 days

For P–R = time = 5 days

So option A is correct

40. The correct match between the physical states of the soils given in Group I and the governing conditions given in Group II is

Group I		Group II	
1.	Normally consolidated soil	P.	Sensitivity > 16
2.	Quick clay	Q.	Dilation angle = 0
3.	Sand in critical state	R.	Liquid limit > 50
4.	Clay of high plasticity	S.	Over consolidation ratio = I

A. 1-S, 2-P, 3-Q, 4-R B. 1-Q, 2-S, 3-P, 4-R

C. 1-Q, 2-P, 3-R, 4-S D. 1-S, 2-Q, 3-P, 4-R

[MCQ: 2 Marks]

Ans. A

Sol. → For normally consolidated soil,

OCR = 1

Sensitivity	Classification
1 – 4	Normal
4 – 8	Sensitive
8 – 15	Extra-sensitive
>15	Quick

→ Sand in a critical state has dilation angle = 0

→ Clay of high plasticity, $W_L > 50$

41. As per Rankine's theory of earth pressure, the inclination of failure planes is $\left(45+\frac{\phi}{2}\right)^{\circ}$ with respect to the direction of the minor principal stress.

The above statement is correct for which one of the following options?

A. Only the active state and not the passive state

B. Only the passive state and not the active state

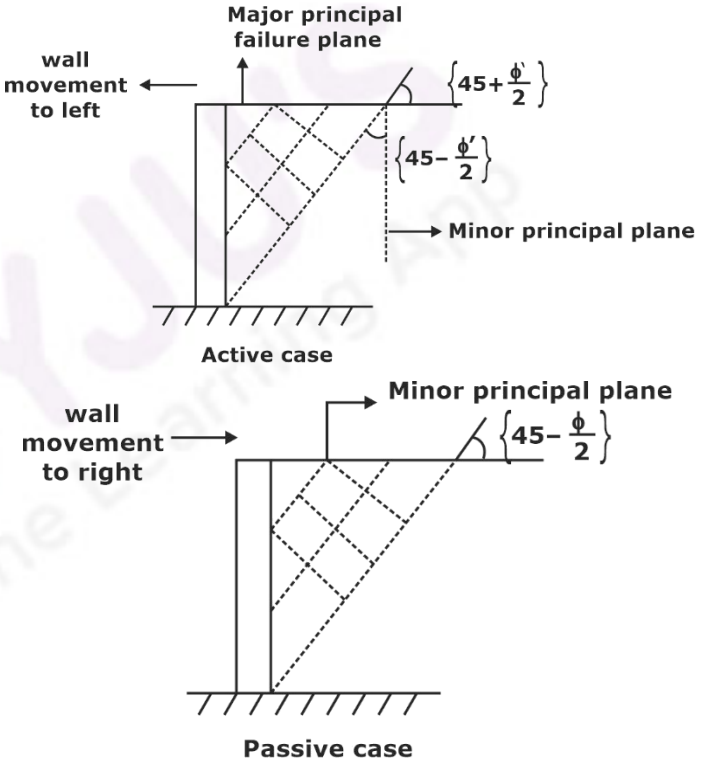
C. Both active as well as passive states

D. Neither active nor passive state

[MCQ: 2 Marks]

Ans. C

Sol.



42. Henry's law constant for transferring O_2 from air into water, at room temperature, is 1.3 $\frac{\text{mmol}}{\text{liter}-\text{atm}}$. Given that the partial pressure of O_2 in the atmosphere is 0.21 atm, the concentration of dissolved oxygen (mg/liter) in water in equilibrium with the atmosphere at room temperature is

(Consider the molecular weight of O_2 as 32 g/mol)

A. 8.7 B. 0.8

C. 198.1 D. 0.2

[MCQ: 2 Marks]

Ans. A

Sol. Given

Henry's constant = k = $1.3\frac{m-mol}{lt-atm}$

Partial pressure = P = 0.21 atm

By henry's law:

$C_g = kP$

Where C_g = concentration of dissolved gas

$\Rightarrow C_g = 1.3 \frac{m-mol}{lt-atm} \times 0.21$

C_g = 0.273 mmol/lt

C_g = 0.273 × 32 mmol/lt

C_g = 8.736 mg/lt

$\boxed{C_g = 8.7\,mg/lt}$

43. In a water sample, the concentrations of Ca^{2+}, Mg^{2+} and HCO_3^- are 100 mg/L, 36 mg/L and 122 mg/L, respectively. The atomic masses of various elements are:

Ca = 40, Mg = 24, H = 1, C = 12, O = 16.

The total hardness and the temporary hardness in the water sample (in mg/L as CaCO3) will be

A. 400 and 100, respectively.

B. 400 and 300, respectively.

C. 500 and 100, respectively.

D. 800 and 200, respectively.

[MCQ: 2 Marks]

Ans. A

Sol. Total hardness (T_H)

= $[Ca^{2+}] + [Mg^{2+}]$

$= \left[\frac{100}{20} + \frac{36}{12}\right] \times 50$ as $CaCo_3$

= 400 mg/ℓ as $CaCo_3$

Alkalinity = $\left[HCo_3^-\right]$

$= \left[\frac{122}{61}\right] \times 50$ as $CaCo_3$

= 100 mg/ℓ as $CaCo_3$

Carbonates hardness is minimum of

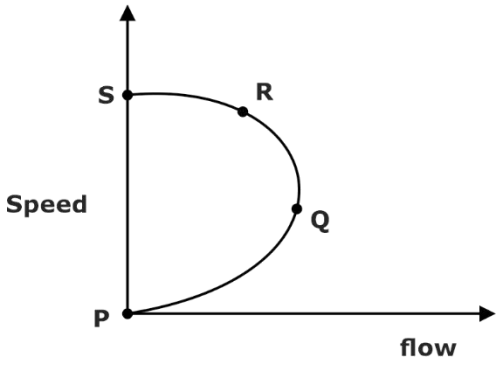
[T_H, alkalinity]

= min [400, 100]

= 100 mg/ℓ

$\Rightarrow \boxed{\text{Carbonate hardness} = 100\,mg/l\ ,\ T_H = 400\ mg/l}$

44. Consider the four points P, Q, R, and S shown in the Greenshields fundamental speed-flow diagram. Denote their corresponding traffic densities by k_P, k_Q, k_R, and k_S, respectively. The correct order of these densities is



A. $k_P > k_Q > k_R . K_S$

B. $k_S > k_R > k_Q > k_P$

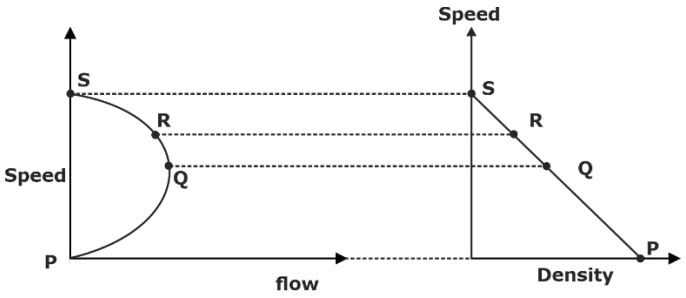
C. $k_Q > k_R > k_S > k_P$

D. $k_Q > k_R > k_P > k_S$

[MCQ: 2 Marks]

Ans. (A)

Sol.



As per relation should be

$K_P > k_Q > k_R > k_S$

45. Let max {a, b} denote the maximum of two real numbers a and b. Which of the following statement(s) is/are **TRUE** about the function f (x) = max {3 – x, x – 1} ?

A. It is continuous on its domain.

B. It has a local minimum at $x = 2$.

C. It has a local maximum at $x = 2$.

D. It is differentiable on its domain.

[MSQ: 2 Marks]

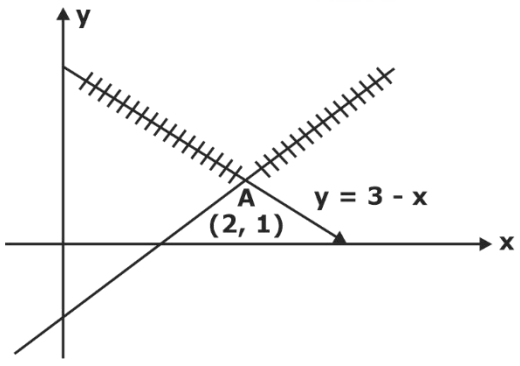
Ans. (A, B)

Sol.

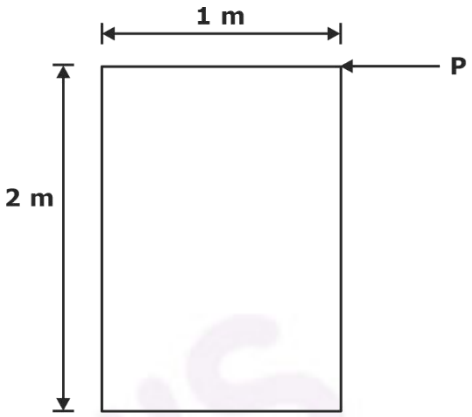
The required graph is the shaded portion

We can observe that,

- It is continuous in its domain
- It has local minima at x = 2
- At A, there is a sharp point; hence not differentiable



46. A horizontal force of P kN is applied to a homogeneous body of weight 25 kN, as shown in the figure. The coefficient of friction between the body and the floor is 0.3. Which of the following statement(s) is/are correct?



A. The motion of the body will occur by overturning.

B. Sliding of the body never occurs.

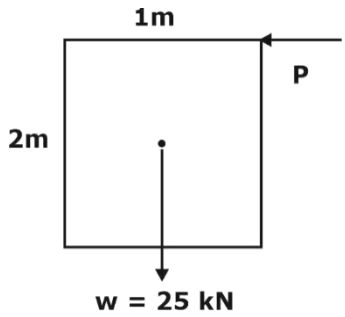
C. No motion occurs for P ≤ 6 kN.

D. The motion of the body will occur by sliding only.

[MSQ: 2 Marks]

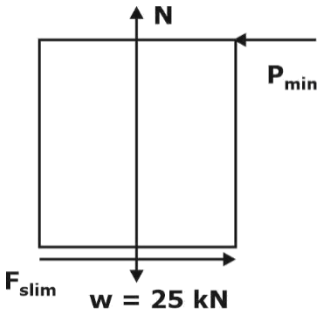
Ans. (A, B, C)

Sol.



Sliding condition

- Sliding will occur when $\Sigma F_x \neq 0$
- When $\Sigma F_x = 0$ to just start sliding at this condition we will get P_{min} for just sliding condition



$\Sigma F_x = 0 \quad P_{min} - F_{slim} = 0$

$P_{min} = F_{slim}$

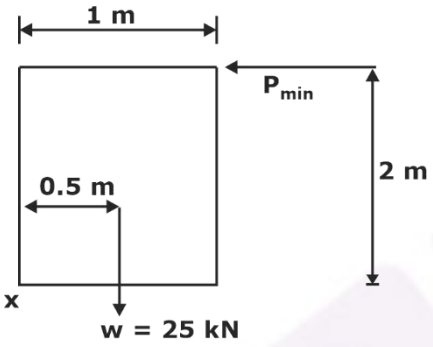
$F_{slim} = H_s\mu \quad \{N - w = 0\}$

$= 0.3 \times 25 \quad \{N = 25 \text{ kN}\}$

$= 7.5$ kN

Hence sliding will occur when P is greater than 7.5 kN.

Overturning condition



P_{min} required to just overturn the block

$\Sigma M_x = 0$

$-P_{min} \times 2 + w \times 0.5 = 0$

$P_{min} = \frac{25 \times 0.5}{2} = 6.25$ kN

If the force exceeds 6.25 kN, then the block will overturn.

(P_{min}) overturning < (P_{min}) sliding Condition

→ If force is less than 6.25 kN. Then no motion occurs.

→ If force $6.25 \leq P < 7.5$ then overturning will occur.

Hence, A, B and C are correct options.

47. In the context of cross-drainage structures, the correct statement(s) regarding the relative positions of a natural drain (stream/river) and an irrigation canal is/are

A. In an aqueduct, natural drain water goes under the irrigation canal, whereas in a super-passage, natural drain water goes over the irrigation canal.

B. In a level crossing, natural drain water goes through the irrigation canal.

C. In an aqueduct, natural drain water goes over the irrigation canal, whereas in a super-passage, natural drain water goes under the irrigation canal.

D. In a canal syphon, natural drain water goes through the irrigation canal.

[MSQ: 2 Marks]

Ans. (A, B)

Sol. A natural drain (river) gives under the irrigation canal in an aqueduct.

In a super–Passage, a Natural drain goes over the irrigation canal.

In a level crossing, a Natural drain goes through the irrigation canal.

48. Consider the differential equation

$$\frac{dy}{dx} = 4(x+2) - y$$

For the initial condition y = 3 at x = 1, the value of y at x = 1.4 obtained using

Euler's method with a step-size of 0.2 is _____. (round off to one decimal place)

[NAT: 2 Marks]

Ans. (6.3-6.5)

Sol.

$$\frac{dy}{dx} = 4(x+2) - y = f(x,y)$$

$y(1) = 3,\ y(1.4) = ?$

$h = 0.2$

x	1	1.2	1.4
y	3		

2 iterations are required

$y_1 = y_0 + hf(x_0, y_0)$

$= 3 + 0.2 \times [4(1+2)-3] = 3 + 0.2 \times 9 = 4.8$

$y_2 = y_1 + hf(x_1, y_1)$

$= y_1 + hf(1.2, 4.8)$

$= 4.8 + 0.2 \times [4(1.2+2) - 4.8]$

$= 4.8 + 1.6$

$= 6.4$

θ value of y at x = 1.4 is 6.4

49. A set of observations of independent variable (x) and the corresponding dependent variable (y) is given below.

X	5	2	4	3
Y	16	10	13	12

Based on the data, the coefficient a of the linear regression model

$$Y = a + bx$$

is estimated as 6.1.

The coefficient b is _____ . (round off to one decimal place)

[NAT: 2 Marks]

Ans. (1.9-1.9)

Sol.

x	5	2	4	3
y	1.6	10	13	12

$\Sigma x = 5 + 2 + 4 + 3 = 14$

$\Sigma y = 16 + 10 + 13 + 12 = 51$

$y = a + bx$

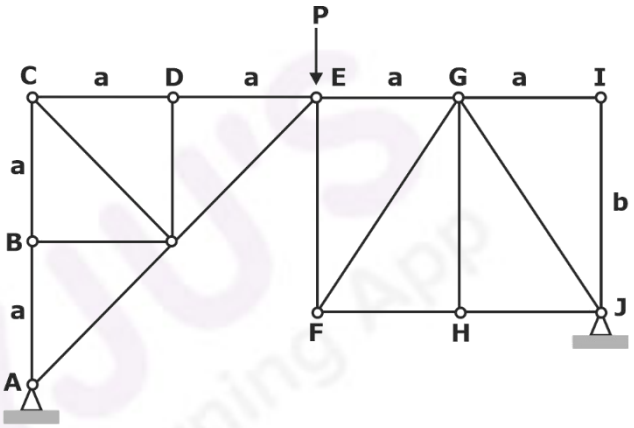
$\Rightarrow \Sigma y = na + b\Sigma x$

$\Rightarrow 51 = 4 \times 6.1 + b \times 14$

$\Rightarrow 51 = 24.4 + 14b$

$b = 1.9$

50. The plane truss shown in the figure is subjected to an external force P. It is given that P = 70 kN, a = 2 m, and b = 3 m.

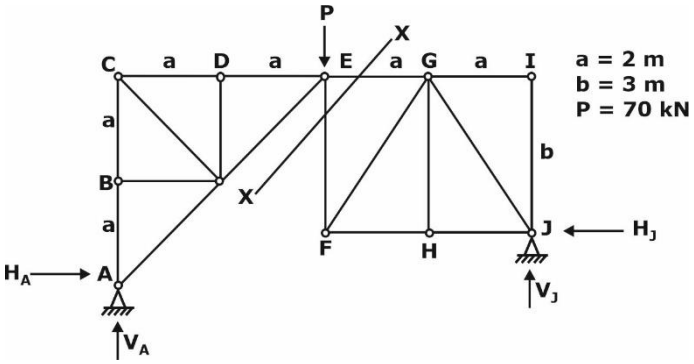


The magnitude (absolute value) of force (in kN) in member EF is _____. (round off to the nearest integer)

[NAT: 2 Marks]

Ans. (28-32)

Sol.



$\Sigma M_E = 0$

$\Rightarrow -H_A(4) + V_A(4) = 0$

$\Rightarrow V_A = H_A$ ...(i)

$\Sigma M_J = 0$

$\Rightarrow V_A(8) - 70(4) - H_A(4-3) = 0$

$8V_A - 280 - H_A = 0$

$8V_A - H_A = 280$ ...(ii)

From (i) and (ii)

$8V_A - V_A = 280$

$\Rightarrow V_A = 40$ kN.

So $H_A = V_A = 40$ kN

Now cut a section X–X and Consider LHS of the section:

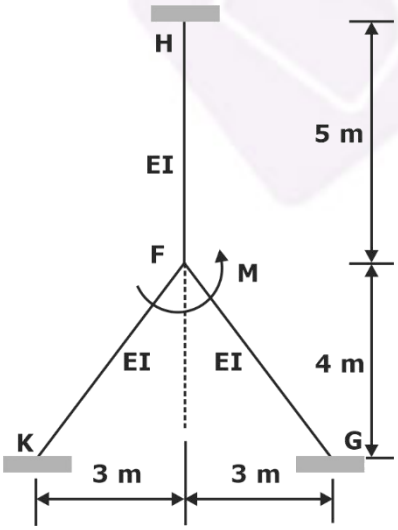
$P + F_{EF} = V_A$

$70 + F_{EF} = 40$

$F_{EF} = -30$ kN

i.e. 30 kN compressive

51. Consider the linearly elastic plane frame shown in the figure. Members HF, FK and FG are welded together at joint F. Joints K, G and H are fixed supports. A counter-clockwise moment M is applied at joint F. Consider flexural rigidity EI = 105 kN-m^2 for each member and neglect axial deformations.

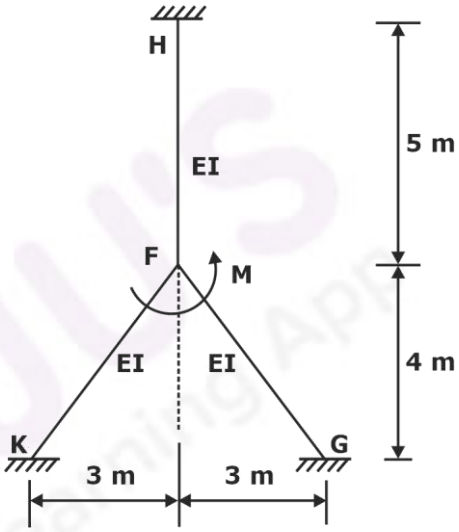


If the magnitude (absolute value) of the support moment at H is 10 kN-m, the magnitude (absolute value) of the applied moment M (in kN-m) to maintain static equilibrium is _____. (round off to the nearest integer)

[NAT: 2 Marks]

Ans. (57-63)

Sol.



Length HF = KF = GF = 5 m.

So, Distribution factors for HF, KF and GF are equal. i.e., $\frac{4EI}{l} = \frac{4EI}{5}$

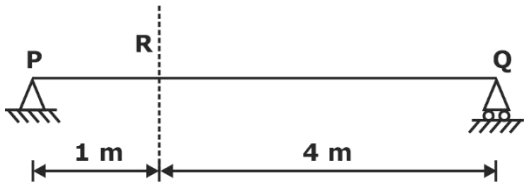
This means all 3 members will take an equal moment. So, moment M will be divided into 3 equal shares, i.e., $\frac{M}{3}$

At $H = \frac{1}{2}\left(\frac{M}{3}\right) = \frac{M}{6}$.

Now. $\frac{M}{6} = 10$ [given]

$\Rightarrow M = 6 \times 10 = 60$ kN.m.

52. Consider a simply supported beam PQ as shown in the figure. A truck having 100 kN on the front axle and 200 kN on the rear axle moves from left to right. The spacing between the axles is 3 m. The maximum bending moment at point R is _____ kNm. (in integer)

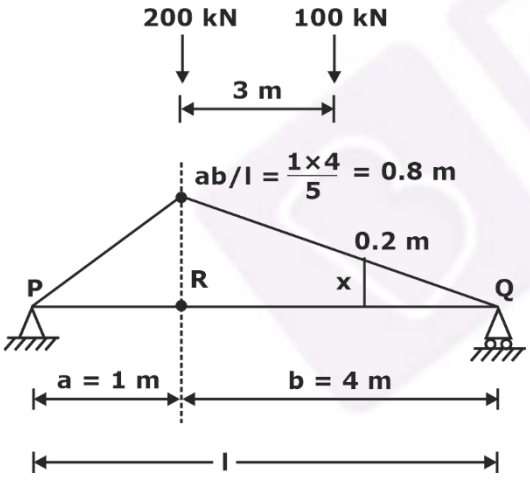


[NAT: 2 Marks]

Ans. (180-180)

Sol. Firstly, draw the ILD for bending moment at R. Then, we can adjust the load on the ILD to get the maximum bending moment value.

ILD for B.M. at R: Consider an imaginary hinge at R, then lift the beam such that the beam rotates by an angle of unity. For this, displacement given $= \frac{ab}{l}$



For getting max. B.M. put the 200 kN load on R.

$4m \rightarrow 0.8$

$(4-3)\ m \rightarrow \frac{0.8}{4} = 0.2\,m \Rightarrow x = 0.2\,m$

So, max B.M. = 200 (0.8) + 100 (0.2) = 180 kNm

53. A reinforced concrete beam with rectangular cross-section (width = 300 mm, effective depth = 580 mm) is made of M30 grade concrete. It has 1% longitudinal tension reinforcement of Fe 415 grade steel. The design shear strength for this beam is 0.66 N/mm^2. The beam has to resist a factored shear force of 440 kN. The spacing of two-legged, 10 mm diameter vertical stirrups of Fe 415 grade steel is _____mm. (round off to the nearest integer)

[NAT: 2 Marks]

Ans. (100–102)

Sol. Given

B = 300 mm

d = 580 mm

V_u = 440 kN

M30 and Fe415

P_t % = 1%

$\tau_c = 0.66\,N/mm^2$

$$V_c = \tau_c \times B \times d = 0.66 \times 300 \times \frac{580}{1000}$$

$V_c = 114.84\,kN$

$V_S = V_u - V_c$

$V_S = 440 - 114.84 = 325.16$ kN

Spacing of 2-legged shear reinforcement

$$S_V = \frac{A_{sv} \times 0.87 \times fy \times d}{V_S}$$

$$S_V = \frac{2 \times \frac{\pi}{4} \times (10)^2 \times 0.87 \times 415 \times 580}{325.16 \times 10^3}$$

S_V = 101.162 mm

S_V = 101 mm (nearest integer)

54. A square concrete pile of 10 m length is driven into a deep layer of uniform homogeneous clay. The average unconfined compressive strength of the clay, determined through laboratory tests on undisturbed samples extracted from the clay layer, is 100 kPa. If the ultimate compressive load capacity of the driven pile is 632 kN, the required width of the pile is _____ mm. (in integer)

(Bearing capacity factor Nc = 9; adhesion factor $\alpha = 0.7$)

[NAT: 2 Marks]

Ans. (400-400)

Sol. Length of pile = 10 m

Unconfined compressive strength

= UCS = 100 kpa

Cohesion, $C = \frac{100}{2} = 50\,kN$

Ultimate load (P) = 632 kN

$\Rightarrow P = CN_c A_b + C_u A_f$

$P = CN_cB^2 + \alpha \times C_u \times (4 \times B \times L)$

$632 = 50 \times 9\, B^2 + 0.7 \times 50 \times 4 \times B \times 10$

$632 = 450B^2 + 1400B$

B = 0.4 m

$\boxed{B = 400\,mm}$

55. A raft foundation of 30 m × 25 m is proposed to be constructed at a depth of 8 m in a sand layer. A 25 m thick saturated clay layer exists 2 m below the base of the raft foundation. Below the clay layer, a dense sand layer exists at the site. A 25 mm thick undisturbed sample was collected from the mid-depth of the clay layer and tested in a laboratory oedometer under double drainage condition. It was found that the soil sample had undergone a 50 % consolidation settlement in 10 minutes. The time (in days) required for 25 % consolidation settlement of the raft foundation will be _____. (round off to the nearest integer)

[NAT: 2 Marks]

Ans. (1730-1740)

Sol. Laboratory condition:

H = 25 mm (double drainage)

U% = 50%

t = 10 minutes

$$\Rightarrow T_v = \frac{C_v \times t}{\left(\frac{0.025}{2}\right)^2}$$

$$\frac{\pi}{4}(0.5)^2 = \frac{C_v \times 10}{\left(\frac{0.025}{2}\right)^2}$$

$\Rightarrow C_v = 3.0679 \times 10^{-6} m^2/minutes$

$C_v = 3.0679 \times 10^{-6} \times 60 \times 24$

$\boxed{C_v = 4.4178 \times 10^{-3}\, m^2/day}$

Field condition:

$$T_v = \frac{C_v \times t}{H^2}$$

$$\frac{\pi}{4}(0.25)^2 = \frac{4.4178 \times 10^{-3} \times t}{\left(\frac{25}{2}\right)^2}$$

T = 1736.11 days

$\boxed{T = 1736 \text{ days}}$

56. A two-hour duration storm event with uniform excess rainfall of 3 cm occurred on a watershed. The ordinates of streamflow hydrograph resulting from this event are given in the table.

Time (hours)	0	1	2	3	4	5	6	7
Stream flow (m^3/s)	10	16	34	40	31	25	16	10

Considering a constant baseflow of 10 m^3/s, the peak flow ordinate (in m^3/s) of one-hour unit hydrograph for the watershed is _____ . (in integer)

[NAT: 2 Marks]

Ans. (12-12)

Sol.

Time (Hours) (I)	Stream flow (m^3/s) (II)	DRH(m^3/s) =col (II)-Base flow (III) (m^3/s)	2hr UH= $\frac{col \cdot III}{3}$ (m^3/s)
0	10	10–10 = 0	0
1	16	6	2
2	36	24	8
3	40	30	10
4	31	21	7
5	25	15	5
6	16	06	2
7	10	0	0

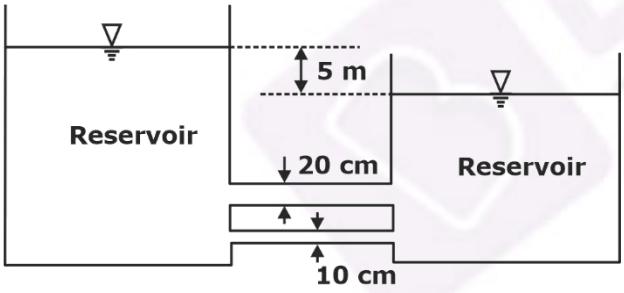
By using S-curve, 1-hour unit hydrograph will be

Time (hour) I	2hour UH ordinates II (m^3/s)	S-curve addition III (m^3/s)			S-curve IV (m^3/s)	S-curve lagged by 1 hour V (m^3/s)	Ordinates of 1 hour = (IV – V)$\frac{2}{1}$ (m^3/s)
0	0	-	-	-	0	-	0
1	2	-	-	-	2	0	$(2-0)\times\frac{2}{1}=4$
2	8	0	-	-	8	2	$\left(\frac{8-2}{1}\right)\times 2=12$
3	10	2			12	8	8
4	7	8	0		15	12	6
5	5	10	2		17	15	4

6	2	7	8	0	17	17	0
7	0	5	10	2	17	17	0
8	0	2	7	8	17	17	0
9	0	0	5	10	15	17	0
10	0	0	2	7	9	15	-
11	0	0	0	5	5	9	-
12	0	0	0	2	2	5	-
13	0	0	0	0	0	2	-
Maximum ordinate of 1 hour unit hydrograph = 12 m^3/s							

57. Two reservoirs are connected by two parallel pipes of equal length and of diameters 20 cm and 10 cm, as shown in the figure (not drawn to scale). When the difference in the water levels of the reservoirs is 5 m, the ratio of discharge in the larger diameter pipe to the discharge in the smaller diameter pipe is _____. (Round off to two decimal places)

(Consider only loss due to friction and neglect all other losses. Assume the friction factor to be the same for both the pipes)



Ans. (5.60-5.70)

Sol. For parallel pipes, the head loss is the same.

$$\Rightarrow \left[\frac{f\ell Q^2}{12.1D^5}\right]_1 = \left[\frac{f\ell Q^2}{12.1D^5}\right]_2$$

$$\Rightarrow f_1 = f_2,\ \ell_1 = \ell_2,$$

$$\Rightarrow \frac{Q_1^2}{D_1^5} = \frac{Q_2^2}{Q_2^5}$$

$$\Rightarrow \frac{Q_1}{Q_2} = \left[\frac{D_1}{D_2}\right]^{5/2}$$

$$\Rightarrow \frac{Q_1}{Q_2} = \left[\frac{D_1}{D_2}\right]^{5/2} = \left[\frac{20}{10}\right]^{5/2}$$

$$\Rightarrow \boxed{\frac{Q_1}{Q_2} = 5.656}$$

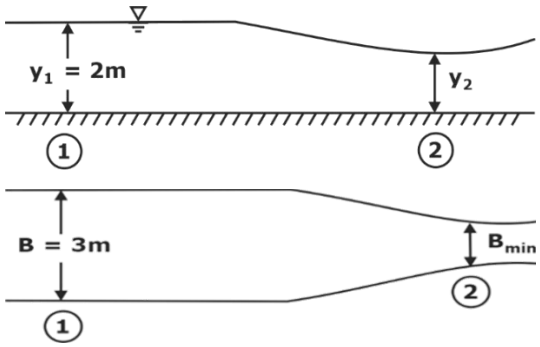
58. Depth of water flowing in a 3 m wide rectangular channel is 2 m. The channel carries a discharge of 12 m^3/s. Take g = 9.8 m/s^2.

The bed width (in m) at contraction, which just causes the critical flow, is _____ without changing the upstream water level. (round off to two decimal places)

[NAT: 2 Marks]

Ans. (2.05-2.35)

Sol.



Specific energy at (1), $E_1 = y_1 + \frac{V_1^2}{2g}$

$\Rightarrow y_1 = 2$ m

$V_1 = \frac{Q}{A_1} = \frac{12}{(3\times 2)} = 2\text{m/sec}$.

$\Rightarrow E_1 = 2 + \frac{2^2}{2\times 9.81}$

$\boxed{E_1 = 2.2038\,\text{m}}$

At section (2): For minimum width, flow is critical

$\Rightarrow E_1 = E_c = 2.2038$ m

$y_c = \frac{2}{3}E_c = 1.4692\,\text{m}$

$\Rightarrow E_c = y_c + \frac{Q^2}{2g(B_{min}\times y_c)^2}$

$\Rightarrow 2.2038 = 1.4692 + \frac{12^2}{2\times 9.81\times 1.4692^2\times B_{min}^2}$

$\boxed{B = 2.15\,\text{m}}$

59. A wastewater sample contains two nitrogen species, namely ammonia and nitrate. Consider the atomic weight of N, H, and O as 14 g/mol, 1 g/mol, and 16 g/mol, respectively. In this wastewater, the concentration of ammonia is 34 mg NH_3/liter and that of nitrate is 6.2 mg 3 NO_3^-/liter. The total nitrogen concentration in this wastewater is _____ milligram nitrogen per liter. (round off to one decimal place)

[NAT: 2 Marks]

Ans. (58.8)

Sol. Total nitrogen concentration is equal to the concentration of Nitrogen in Ammonia and Nitrate

Concentration of Nitrogen in

(ammonia + Nitrate)

$= \left[\frac{34}{17} + \frac{6.2}{62}\right]$ meq/lt

$= 2.1$ meq/lt $= 2.1\times\frac{14}{1}$ mg/lt as N_2

$= 29.4$ mg/ℓ as N_2

60. A 2 % sewage sample (in distilled water) was incubated for 3 days at 27 °C temperature. After incubation, dissolved oxygen depletion of 10 mg/L was recorded. The biochemical oxygen demand (BOD) rate constant at 27 °C was found to be 0.23 day^{-1} (at base e). The ultimate BOD (in mg/L) of the sewage will be_____. (round off to the nearest integer)

[NAT: 2 Marks]

Ans. (1000-1005)

Sol. BOD_3 = (Do consumed) × Dilution factor

$BOD_3 = 10 \times \frac{100}{2}$

$\boxed{BOD_3 = 500\,\text{mg}/\ell}$

Also $BOD_3 = BOD_u\,[1 - e^{-k\times t}]$

$500 = BOD_u\,[1 - e^{-0.23\times 3}]$

$\Rightarrow BOD_u = 1003.162$ mg/ℓ

$\boxed{BOD_u = 1003\,\text{mg/l}}$

61. A water treatment plant has a sedimentation basin of depth 3 m, width 5 m, and length 40 m. The water inflow rate is 500 m3/h. The removal fraction of particles having a settling velocity of 1.0 m/h is_____. (round off to one decimal place)

(Consider the particle density as 2650 kg/m^3 and liquid density as 991 kg/m^3)

[NAT: 2 Marks]

Ans. (0.38-0.42)

Sol. Width of basin = 5 m

Length of basin = 40 m

Depth of basin = 3 m

Water inflow rate = Q = 500 m^3/h

$$\text{Overflow rate, } V_s = \frac{Q}{A} = \frac{500}{5 \times 40} = 2.5\,\text{m/h}$$

Removal fraction =

$$\frac{\text{settling velocity of particle}}{\text{overflow rate}} = \frac{1}{2.5} = \boxed{0.4}$$

62. A two-phase signalized intersection is designed with a cycle time of 100 s. The amber and red times for each phase are 4 s and 50 s, respectively. If the total lost time per phase due to start-up and clearance is 2 s, the effective green time of each phase is _____s. (in integer)

[NAT: 2 Marks]

Ans. (48-48)

Sol. T = 100 S

A = 4 sec

R = 50 sec

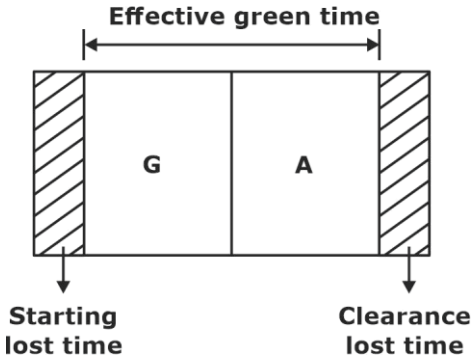
Last time per p have = 2s

T = G + A + R

100 = G + 4 + 50

⇒ G = 46 sec

G = effective green = G + A – lost time per phase = 46 + 4 – 2 = 48 s



63. At a traffic intersection, cars and buses arrive randomly according to independent Poisson processes at an average rate of 4 vehicles per hour and 2 vehicles per hour, respectively. The probability of observing at least 2 vehicles in 30 minutes is _____. (round off to two decimal places)

[NAT: 2 Marks]

Ans. 80%

Sol. Am = 0.6 – 0.9

$\lambda_{car} = 4\text{veh/h}$

For 30 min $\lambda_{car} = 2\,\text{vehicle}$

$\lambda_{bar} = 2\,\text{veh/h}$

For 30 min $\lambda_{bar} = 1\,\text{vehicle/h}$

Possibility of observing at least 2 vehicles in 30 minutes

$$P(x \geq 2) = 1 - P(x \leq 1)$$

$$P(x \geq 2) = 1 - \left(\frac{e^{-\lambda}\lambda^{\circ}}{0!} + \frac{e^{-\lambda}\lambda^{1}}{1!}\right)$$

$$P = 1 - \left(\frac{e^{-3}(3)^{\circ}}{0!} + \frac{e^{-3}(3)'}{1!}\right) = 0.8$$

IN PERCENTAGE =80%

64. The vehicle count obtained in every 10-minute interval of a traffic volume survey done in peak one hour is given below.

Time Interval (in minutes)	Vehicle Count
0–10	10
10–20	11
20–30	12
30–40	15
40–50	13
50–60	11

The peak hour factor (PHF) for 10 minute sub-interval is _____. (round off to one decimal place)

[NAT: 2 Marks]

Ans. (0.8-0.8)

Sol. V = 10 + 11 + 12 + 15 + 13 + 11 = 72 veh/min

In 10 min → V = 72 × 10 = 720 veh

$$(PHF)_n = \frac{V}{\left(\frac{60}{n}\right) \times V_n(max)}$$

$$(PHF)_{10} = \frac{V}{\left(\frac{60}{10}\right) \times V_{10}(max)}$$

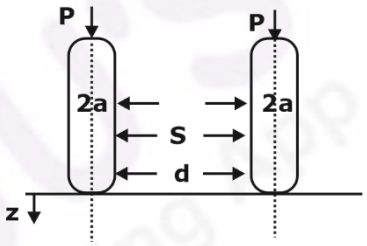
$(V_{10})_{max}$ = 15 veh/min

$(V_n)_{max}$ in 10 min = 15 × 10 = 150

$$= \frac{720}{\frac{60}{10} \times 150} = 0.8$$

65. For the dual-wheel carrying assembly shown in the figure, P is the load on each wheel, a is the radius of the contact area of the wheel, s is the spacing between the wheels, and d is the clear distance between the wheels. Assuming that the ground is an elastic, homogeneous, and isotropic half-space, the ratio of Equivalent Single Wheel Load (ESWL) at depth z = d/2 to the ESWL at depth z = 2s is _____. (round off to one decimal place)

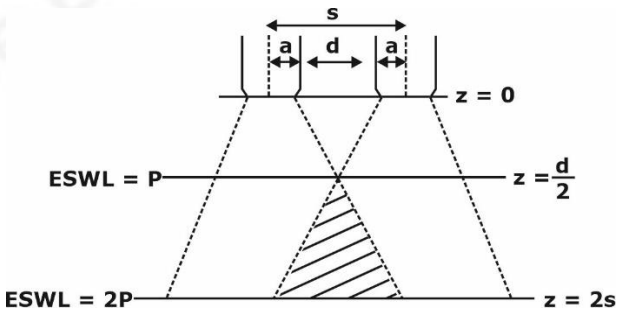
(Consider the influence angle to be 45° for the linear dispersion of stress with depth)



[NAT: 2 Marks]

Ans. (0.5-0.5)

Sol.



ESWL at depth $\frac{d}{2} = p$

ESWT at depth 2s = 2p

Ratio = $\frac{p}{2P} = \frac{1}{2} = 0.5$

****