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GATE 2022

CIVIL ENGINEERING

Exam held on
12/02/2022
(Forenoon Session)

Questions & Solutions

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SECTION - A GENERAL APTITUDE

Q.1 You should _____ when to say _____.

(a) no/no (b) no/know

(c) know/know (d) know/no

Ans. (d)

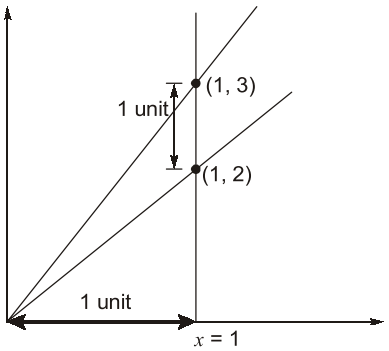
End of Solution

Q.2 Two straight lines pass through the origin $(x_0, y_0) = (0, 0)$. One of them passes through the point $(x_1, y_1) = (1, 3)$ 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) 1.5

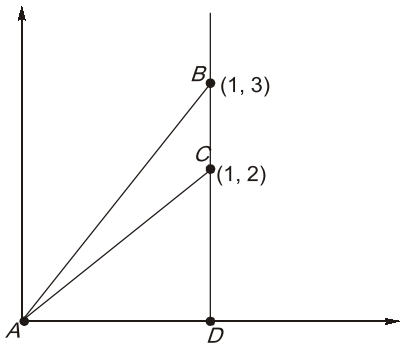
(c) 1.5 (d) 2.0

Ans. (a)



Method 1: $\text{Area} = \frac{1}{2} \times b \times h = \frac{1}{2} \times 1 \times 1 = 0.5 \text{ unit}^2$

Method 2:



$\text{Area ABC, } A = \text{Area (ABD)} - \text{Area (ACD)}$

$= \frac{1}{2} \times 3 \times 1 - \frac{1}{2} \times 2 \times 1 = \frac{1}{2} = 0.5 \text{ unit}^2$

End of Solution

Q.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

Ans. (d)

Given: $\frac{P}{Q} = \frac{1}{2}, \frac{Q}{R} = \frac{4}{3}, \frac{R}{S} = \frac{4}{5}$

$$\frac{R}{S} = \frac{4\times3}{5\times3}$$

$$\frac{Q}{R} = \frac{4\times4}{3\times4}$$

$$\frac{P}{Q} = \frac{1\times8}{2\times8}$$

P : Q : R : S

8 : 16 : 12 : 15

$$U = 15 \times 1.5 = 22.5$$

$$\frac{P}{U} = \frac{8}{22.5} = \frac{8\times2}{22.5\times2} = \frac{16}{45}$$

End of Solution

Q.4 Given the statements:

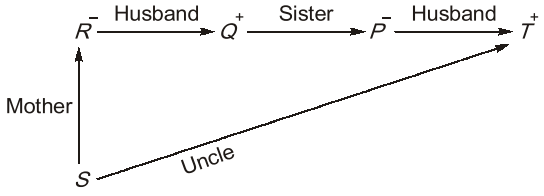
- P is the sister of Q.
- Q is the husband of R.
- R is the mother of S.
- T is the husband of P.

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

(a) the grandfather (b) an uncle

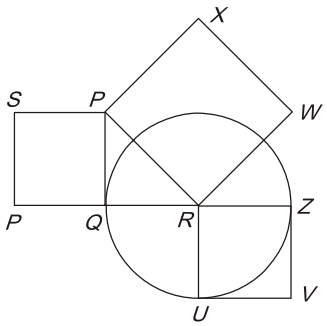
(c) the father (d) a brother

Ans. (b)



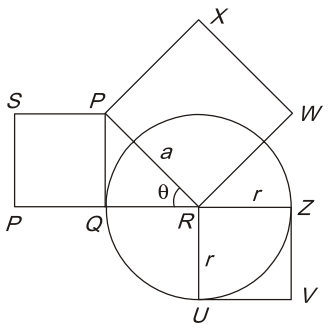
End of Solution

Q.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

Ans. (b)



$$R = a\cos\theta$$
$$A_{RUVZ} = r^2 = a^2\cos^2\theta$$
$$A_{PXWR} = a^2$$
$$A_{SPQT} = (a\sin\theta)^2 = a^2\sin^2\theta$$
$$A_{SPQT} = A_{PXWR} - A_{RUVZ}$$
$$= a^2 - a^2\cos^2\theta$$
$$= a^2(1 - \cos^2\theta)$$
$$a^2\sin^2\theta = a^2\sin^2\theta$$

End of Solution

Q.6 Healthy eating is a critical component of healthy aging. 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

Ans. (b)

End of Solution

Q.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 (in ₹)?

(a) 2500 (b) 3000

(c) 4687 (d) 8437

Ans. (b)

$$\frac{(P_R)_A}{(P_R)_B} = \frac{(I_A)\times T_A}{(I_B)\times T_B}$$

$$\frac{P_B}{P_{A+B}} = \frac{4}{9}$$

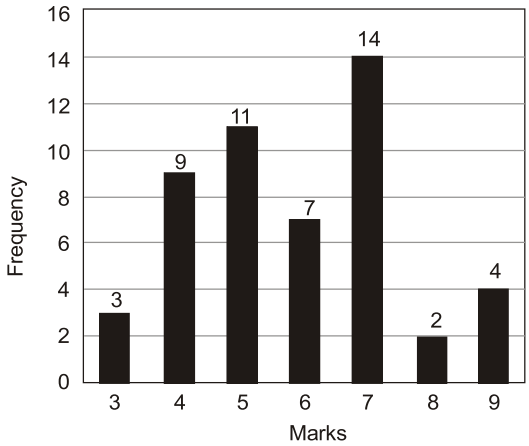
$$\frac{P_B}{P_A} = \frac{4}{5}$$

$$\frac{4}{5} = \frac{5000\times 6 \text{ months}}{I_B \times 8 \text{ months}}$$

$$I_B = \text{Rs. } 3000$$

End of Solution

Q.8

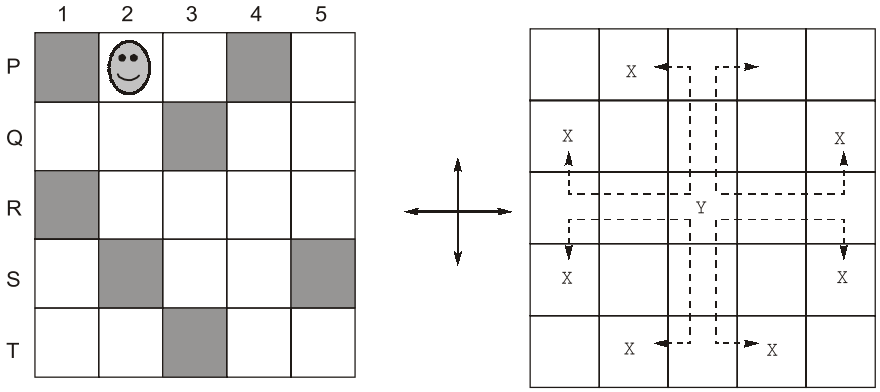


The above frequency chart shows the frequency distribution of marks obtained by a set of students in an exam.
From the data presented above, which one of the following is CORRECT?
(a) mean > mode > median
(b) mode > median > mean
(c) mode > mean > median
(d) median > mode > mean

Ans. (b)

End of Solution

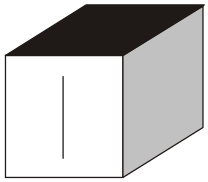
Q.9 In the square grid shown on the left, a person standing at P2 position is required to move to P5 position.
The only movement allowed for a step involves, "two moves along one direction followed by one move in a perpendicular direction". The permissible directions for movement are shown as dotted 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



(a) 4
(b) 5
(c) 6
(d) 7

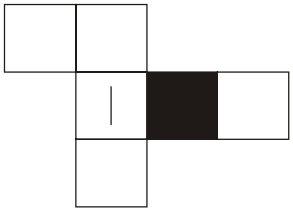
Ans. (b)

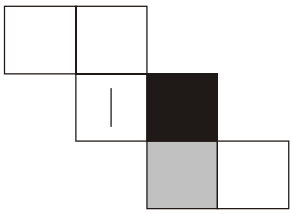
End of Solution

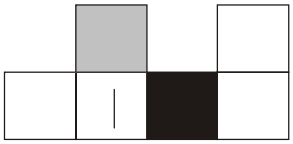
Q.10 

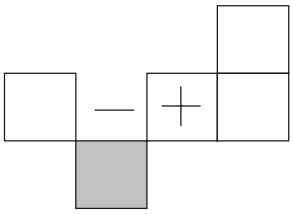
Consider a cube made by folding a single sheet of paper of appropriate shape. The interior faces of the cube are all blank. However, the exterior faces that are not visible in the above view may not be blank.

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

(a) 

(b) 

(c) 

(d) 

Ans. (b)

End of Solution

■■■■

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SECTION - B TECHNICAL

Q.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) $\dfrac{\partial^2 z}{\partial t^2} + \dfrac{\partial^2 z}{\partial y^2} = 0$

(b) $\dfrac{\partial^2 z}{\partial t^2} - \dfrac{\partial^2 z}{\partial y^2} = 0$

(c) $\dfrac{\partial z}{\partial t} - i\dfrac{\partial z}{\partial y} = 0$

(d) $\dfrac{\partial z}{\partial t} + i\dfrac{\partial z}{\partial y} = 0$

Ans. **(a)**

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

Differentiation w.r.t. y

$$z_y = \cos(y + it) - \sin(y - it)$$
$$z_{yy} = -\sin(y + it) - \cos(y - it)$$

With respect to t

$$z_t = \cos(y + it)(i) - \sin(y - it)(-i)$$
$$z_{tt} = \sin(y + it) + \cos(y - it)$$
$$z_{yy} + z_{tt} = 0$$

End of Solution

Q.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.

Ans. **(a)**

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

Because highest order of given equation is 3.
Order = 3

$$(y''' + x^2y) = \left[-x(y')^{3/2}\right]$$

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

As we can see power of y''' is 2.
Degree of given differential equation = 2.

End of Solution

Q.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 MPa (d) 22.5 MPa

Ans. (b)

$$\sigma_h = \frac{Pd}{2t} = 30 \text{ N/mm}^2$$

$$\sigma_l = \frac{Pd}{4t} = \frac{30}{2} = 15 \text{ N/mm}^2$$

$$\sigma_R = 0$$
$$\sigma_1 = \sigma_h$$
$$\sigma_2 = \sigma_l$$
$$\sigma_3 = \sigma_R$$

$$(\tau_{max})_{abs} = \frac{30-0}{2} = 15 \text{ N/mm}^2$$

End of Solution

Q.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.

Ans. (a)

The modular ratio, $m = \frac{E_s}{E_c} = \frac{280}{3\sigma_{cbc}}$

End of Solution

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

(a) $Ca(OH)_2$ + Reactive Superplasticiser + $H_2O \rightarrow$ C-S-H

(b) $Ca(OH)_2$ + Reactive Silicon dioxide + $H_2O \rightarrow$ C-S-H

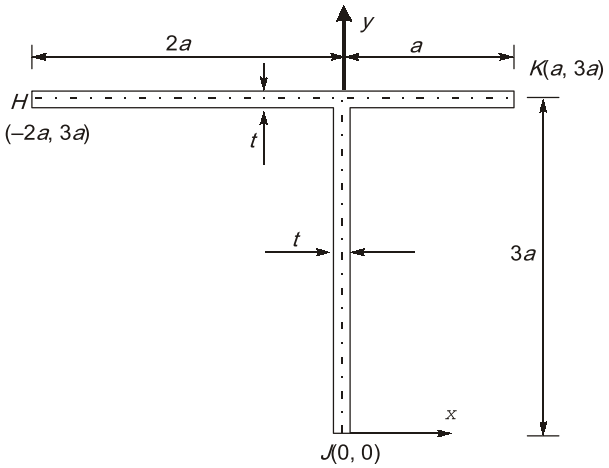
(c) $Ca(OH)_2$ + Reactive Sulphates + $H_2O \rightarrow$ C-S-H

(d) $Ca(OH)_2$ + Reactive Sulphur + $H_2O \rightarrow$ C-S-H

Ans. (b)

End of Solution

Q.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.

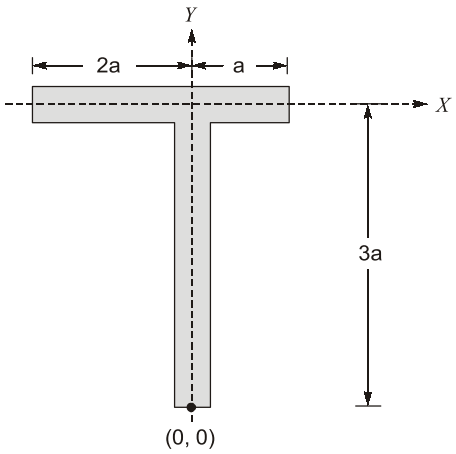


The coordinates of the shear center of this cross-section are:

(a) $x = 0,\ y = 3a$ (b) $x = 2a,\ y = 2a$

(c) $x = -a,\ y = 2a$ (d) $x = -2a,\ y = a$

Ans. (a)



Coordinates of shear centre = (0, 3*a*)

End of Solution

Q.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

Ans. (a)

$K \propto (\text{dia.})^2$

Sand > Silt > Clay

Sand > ML > CH

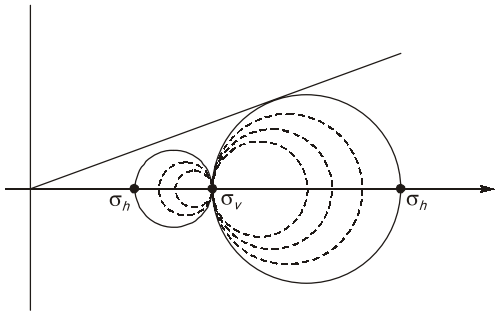
SW > SP > ML > CH

End of Solution

Q.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) $\sigma_v' + \sigma_h' = 0$

Ans. (a)



$\sigma'_h > \sigma'_v$

End of Solution

Q.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

Ans. (a)

Viscosity → Reynolds number

Pressure → Euler number

Gravity → Froude number
Compressibility → Mach number

End of Solution

Q.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 decreases and K increases.
(b) ψ increases and K decreases.
(c) Both ψ and K decrease.
(d) Both ψ and K increase.

Ans. (a)

$$h_c \propto \frac{1}{R}$$

$$K \propto S$$

Water content ↑ → R↑ R↑→ h_c ↓→ ψ ↓

Water content ↑ → S↑ → K↑

(a) → ψ decreases and K increases.

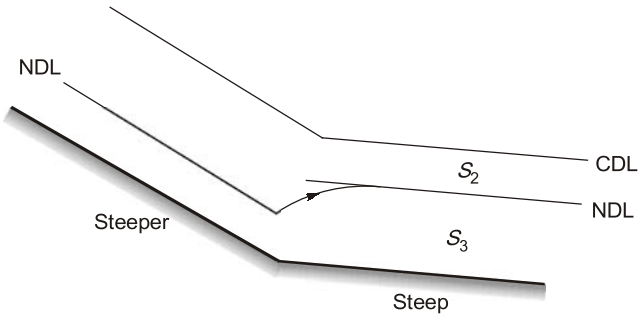
End of Solution

Q.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) S_1
(c) S_2
(d) either S_1 or S_2, depending on the magnitude of the slopes

Ans. (a)

Steeper slope → More bed slope than steep



End of Solution

Q.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

Ans. (a)

$$\text{Total Hardness} = 500 \text{ mg/}l \text{ as } CaCO_3$$

$$\text{No. of equivalents} = \frac{(\text{Weight})_{\text{gram}}}{\text{Equivalent weight of } CaCO_3}$$

$$= \frac{500 \times 10^{-3} g}{\frac{100}{2}} = \frac{500 \times 10^{-3} g}{50 \text{ g/eq}} = 0.01 \text{ eq}$$

$$= 0.01 \times 10^3 \text{ m-eq}$$
$$= 10 \text{ m-eq}$$

End of Solution

Q.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

Ans. (a)

Flying height, $H = 3500$ m
$h_{avg} = 460$ m
Focal length, $f = 152$ mm

Scale, $S = \frac{f}{H - h_{avg}}$

$$S = \frac{152}{3500 - 460} = \frac{1}{20000}$$

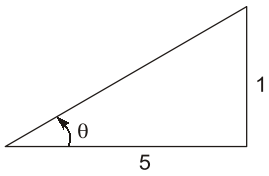
End of Solution

Q.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

Ans. (a)

Slope = 1 in 5
Measured length, $l' = 350$ m
Tape length = 50 m
Slope correction (C_{slope})



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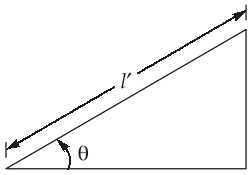
$$\theta = \tan^{-1}\left(\frac{1}{5}\right) = 11.31°$$



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

Tape correction,

True length, $L = 50$ m

$L' = 50 - 0.1 = 49.9$ m

$l' = 350$ m

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

$l = 349.3$ m

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

True length = Measured length + C_{net}

$= 350 + [-6.8 - 0.7] = 342.5$ m

End of Solution

Q.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

Ans. **(a, c)**

Given:

$\lambda_1 = 5$

$\lambda_2 = -2$

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

$Q_{\lambda_1} = (5)^3 - 4(5)^2 - 2(5)$

$= 125 - 100 - 10 = 15$

$Q_{\lambda_2} = ((-2)^3 - 4(-2)^2 - 2(-2)$

$= -8 - 16 + 4$

$= -20$

End of Solution

Q.26 For wastewater coming from a wood pulping industry, Chemical Oxygen Demand (COD) and 5-day Biochemical Oxygen Demand (BOD_5) 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

Ans. **(a, b)**

Wood pulp → Cellulose → BOM (biodegrable organic matter)

COD = BOM + NBOM

End of Solution

Q.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

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

End of Solution

Q.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.

Ans. **(a, b)**

On a horizontal curve

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

$$R = \frac{V^2}{g(e+f)}$$

To decrease R

→ velocity can be decreased

→ superelevation can be increased

End of Solution

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

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

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)

Ans. (3.162) (3.155 to 3.170)

When $n \to \infty$

$$x_{n+1} = x_n = \alpha$$

$$\alpha = \frac{1}{2}\left(\alpha + \frac{P}{\alpha}\right)$$

$$2\alpha = \frac{\alpha^2 + P}{\alpha}$$

$$\alpha^2 - P = 0$$

$$\alpha = \sqrt{P}$$

At $P = 10$

$$\sqrt{10} = 3.162$$

End of Solution

Q.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)

Ans. (0.125) (0.120 to 0.130)

$$\cos^4 x = (\cos^2 x)^2 = \left(\frac{1+\cos 2x}{2}\right)^2$$

$$= \frac{1}{4}\left[1 + \cos^2 2x + 2\cos 2x\right]$$

$$= \frac{1}{4}\left[1 + \frac{1+\cos 4x}{2} + 2\cos 2x\right]$$

$$f(x) = \frac{3}{8} + 0\cos x + \frac{1}{2} + \frac{1}{2}\cos 2x + 0\cos 3x + \frac{1}{8}\cos 4x + 0\cos 5x + \ldots..$$

$$f(4) + f(5) = \frac{1}{8} + 0 = \frac{1}{8}$$

End of Solution

Q.31 An uncompacted heap of soil has a volume of 10000 m^3 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)

Ans. (0.5)

$$(V_s)_{\text{heap}} = (V_s)_{\text{compacted soil}}$$

$$\left(\frac{V_T}{1+e}\right)_{heap} = \left(\frac{V_T}{1+e}\right)_{compacted\ soil}$$

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

$$e = 0.5$$

End of Solution

Q.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)

Ans. (4)

$$\sigma_z = \frac{3}{2\pi}\left(\frac{1}{1+\frac{r^2}{Z^2}}\right)^{5/2}\frac{Q}{Z^2}$$

$$r = 0$$

$$\sigma_z = \frac{3}{2\pi}\frac{Q}{Z^2}$$

$$(\sigma_z)_p = \frac{3}{2\pi}\frac{Q}{(1)^2}$$

$$(\sigma_z)_Q = \frac{3}{2\pi}\frac{Q}{(2)^2}$$

$$\frac{(\sigma_z)_p}{(\sigma_z)_q} = \frac{\frac{3}{2\pi}\frac{Q}{(1)^2}}{\frac{3}{2\pi}\frac{Q}{(2)^2}} = 4$$

End of Solution

Q.33 At a site, 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)

Ans. (10)

Friction ratio, $f_r = \frac{q_s}{q_t} = 1\%$

q_s = Sleeve friction
s_t = Tip friction

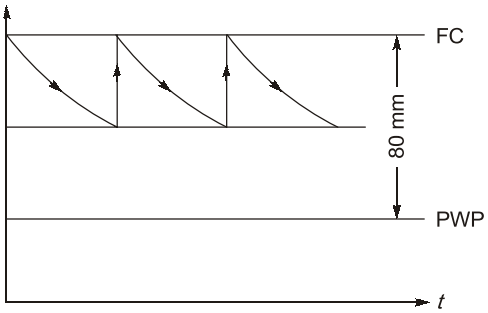
$$\frac{q_s}{q_t} = \frac{1}{100} \qquad (q_t = 1000 \text{ kPa})$$

$$q_s = \frac{1000}{100} = 10 \text{ kPa}$$

End of Solution

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

Ans. (14)



$$\text{Frequency} = \frac{\text{Depth of water needed}}{\text{Consumptive use}}$$

$$= \frac{40}{2.8} = 14.28 \text{ days}$$

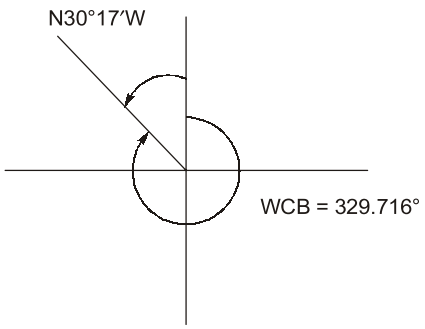
$f = 14$ days

$f = 14$ days (Considering depletion amount)

End of Solution

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

Ans. (328.72) (329.70 to 328.75)



$$WCB = 360 - \left(31 + \frac{17}{60}\right)^{\circ}$$
$$WCB = 329.716^{\circ}$$

End of Solution

Q.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) $(1, 0, \sqrt{2})$ (b) $(1, 0, -\sqrt{2})$

(c) $(-1, 0, \sqrt{2})$ (d) $(-1, 0, -\sqrt{2})$

Ans. **(a)**

Using potential matrix about *x*-axis,

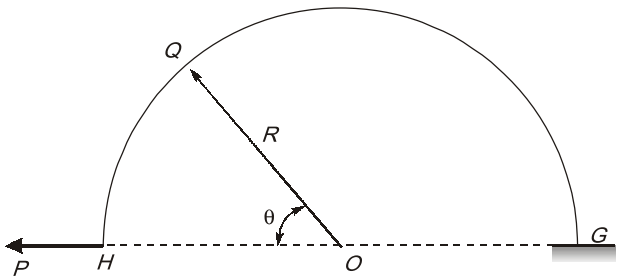
$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & \sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \\ 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}}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

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

Here answer is (a)

End of Solution

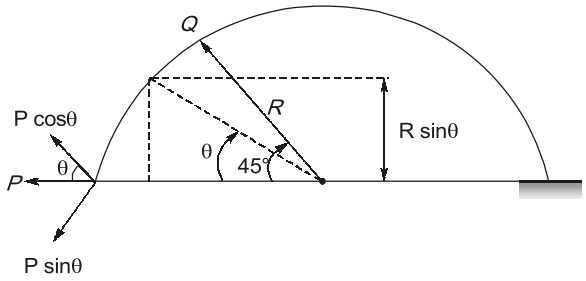
Q.37 A semi-circular bar of radius *R* m, in a vertical plane, is fixed at the end *G*, as shown in the figure. A horizontal load of magnitude *P* kN is applied at the end *H*. The magnitude of the axial force, shear force, and bending moment at point *Q* for θ = 45°, respectively, are



(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 kNm, $\frac{P}{\sqrt{2}}$ kN, and $\frac{PR}{\sqrt{2}}$ kNm (d) $\frac{P}{\sqrt{2}}$ kN, 0 kNm, and $\frac{PR}{\sqrt{2}}$ kNm

Ans. (a)



$$(F_Q) = P\sin\theta = \frac{P}{\sqrt{2}} \qquad (\text{at } \theta = 45°)$$

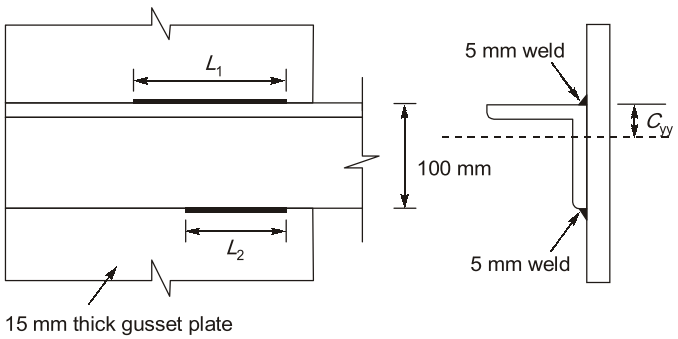
$$(S_Q) = P\cos\theta = \frac{P}{\sqrt{2}} \qquad (\text{at } \theta = 45°)$$

$$M_Q = PR \sin\theta$$

$$= \frac{PR}{\sqrt{2}} \qquad (\text{at } \theta = 45°)$$

End of Solution

Q.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 (roundedoff 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

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Ans. (a)

As per IS : 800-2007 Clause no. 11.2.1

Full strength of tension memeber,

$$P = \sigma_{at} \times A_g$$
$$P = 150 \times 1903$$
$$P = 285450\ \text{N}$$

Weld strength of L_1, $P_1 = L_1 \times (0.7 \times s) \times 108$

$$= L_1 \times 0.7 \times 5 \times 108$$
$$P_1 = 378L_1 \quad \ldots(i)$$

Weld strength of L_2, $P_2 = L_2 \times (0.7 \times s) \times 108$

$$= L_2 \times 0.7 \times 5 \times 108$$
$$P_2 = 378L_2 \quad \ldots(ii)$$

Applying moment CG equal to zero,

$$P_1 \times 28.4 = P_2 \times (100 - 28.4)$$
$$\frac{P_1}{P_2} = \frac{71.6}{28.4}$$
$$\frac{L_1 \times 378}{L_2 \times 378} = \frac{71.6}{28.4} = 2.521$$
$$L_1 = 2.521\ L_2 \quad \ldots(iii)$$

Total weld strength = Tensile strength

$$(L_1 + L_2) \times 3.5 \times 108 = 285450$$
$$L_1 + L_2 = 755.158$$

Using equation (iii),

$$2.521\ L_2 + L_2 = 755.158$$
$$L_2 = 214.472\ \text{mm}$$
$$L_1 = 540.685\ \text{mm}$$

End of Solution

Q.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?

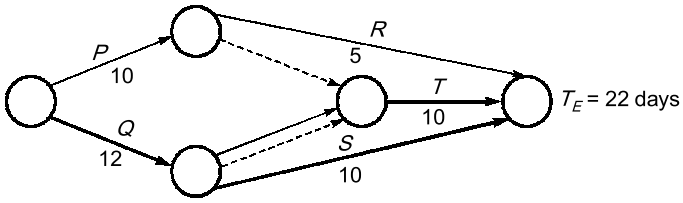
(a) Total duration of the project = 22 days, Critical path is Q → S

(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

Ans. (a)



Critical path = *Q–S* and Q-T also (max. time taken along the path)
= 22 days

End of Solution

Q.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 = 1

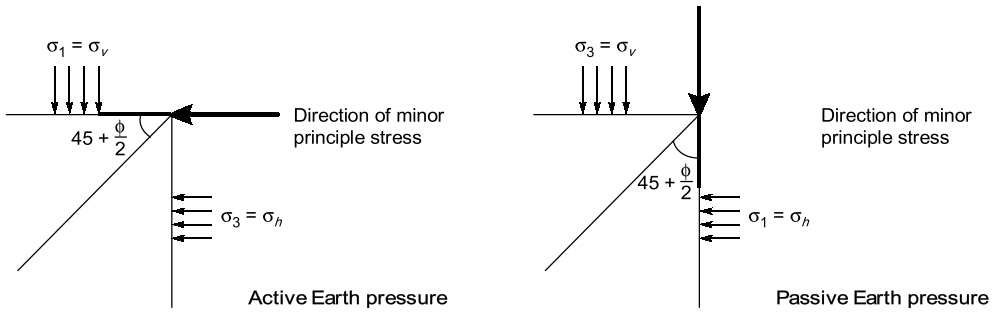
(a) 1-S, 2-P, 3-Q, 4-R
(b) 1-Q, 2-S, 3-P, 4-R
(c) 1-Q, 2-P, 3-R, 4-S
(d) 1-S, 2-Q, 3-P, 4-R

Ans. (a)
Normally consolidated soil → OCR = 1
Quick clay → Sensitivity > 16
Sand in critical state → Dilation angle is zero
Clay of high plasticity → W_L > 50

End of Solution

Q.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

Ans. (c)



End of Solution

Q.42 Henry's law constant for transferring O_2 from air into water, at room temperature, is $1.3\ \frac{\text{mmol}}{\text{liter - atm}}$. 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

Ans. (a)

$$O_2 \text{ dissolved} = 1.3 \text{ mmol/litre/atm} \times 0.21 \text{ atm}$$
$$= 0.273 \text{ mmol/litre}$$
$$\eta = \frac{\text{Given mass}}{\text{Molar mass}}$$
$$\text{Mass of } O_2 = 0.273 \times 10^{-3} \text{ mol/litre} \times 32\text{g}$$
$$= 8.736 \times 10^{-3} \text{ g/litre}$$
$$= 8.736 \text{ mg/litre}$$

End of Solution

Q.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 $CaCO_3$) will be

(a) 400 and 100, respectively. (b) 400 and 300, respectively.

(c) 500 and 100, respectively. (d) 800 and 200, respectively.

Ans. (a)

Total hardness, $$TH = \left[Ca^{+2}\right] \times \frac{50}{20} + \left[Mg^{+2}\right] \times \frac{50}{12}$$

$$= 100 \times \frac{50}{20} + 36 \times \frac{50}{12}$$

$$= 400 \text{ mg/}l \text{ as } CaCO_3$$

Total alkalinity, $TA = \left[HCO_3^-\right] \times \frac{50}{61} = 122 \times \frac{50}{61}$

$= 100$ mg/l as $CaCO_3$

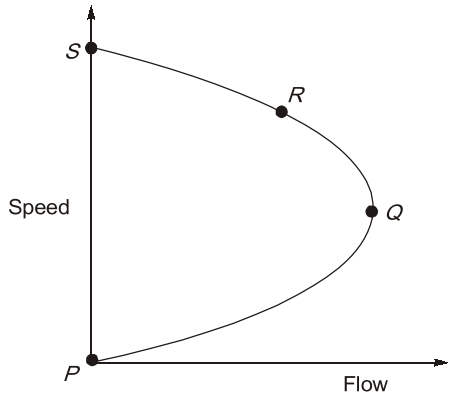
Temporary hardness (carbonate hardness)

$= \min \begin{cases} TA = 100 \text{ mg/}l \text{ as } CaCO_3 \\ TH = 400 \text{ mg/}l \text{ as } CaCO_3 \end{cases}$

$= 100$ mg/l as $CaCO_3$

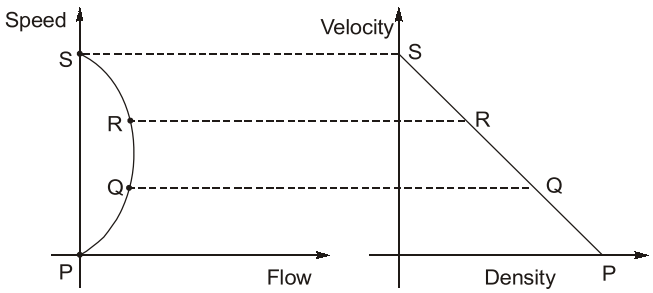
End of Solution

Q.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) $k_Q > k_R > k_P > k_S$

Ans. (a)



$k_P > k_Q > k_R > k_S$

End of Solution

Q.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.

Ans. **(a, d)**

For finding intersection point

$$3 - x = x - 1$$

At $x = 2$

So, $3 - x$ and $x - 1$ intersects at $x = 2$.

$$f(x) = \begin{cases} 3-x & x<2 \\ x-1 & x>2 \\ 1 & x=2 \end{cases}$$

Check for continuity

$$f(2^-) = f(2^+) = f(2)$$

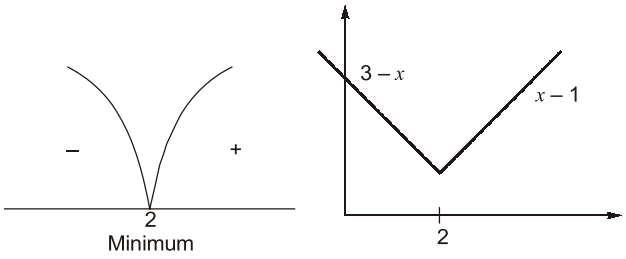
It is continuous in its domain.

Check for differentiability

$$f'(x) = \begin{cases} -1 & x<2 \\ 1 & x>2 \end{cases}$$

It is not differentiable.

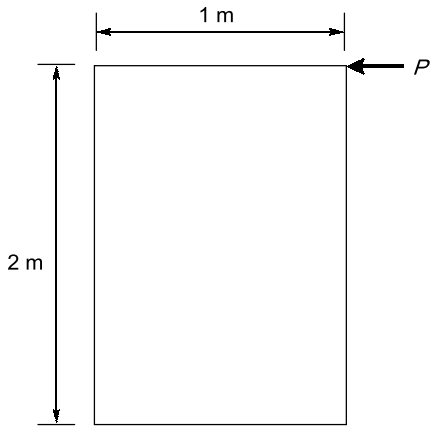
For maximum and minima



It has local minima at $x = 2$

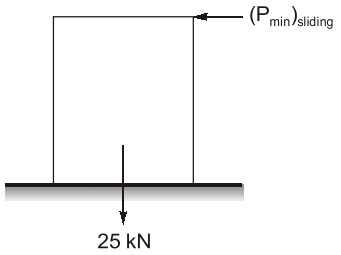
End of Solution

Q.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 $P \le 6$ kN.
(d) The motion of the body will occur by sliding only.

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



Minimum force for sliding

$$(P_{min})_{sliding} = (f_s)_{max} \quad ...(i)$$

Applying equilibrium equation in vertical direction

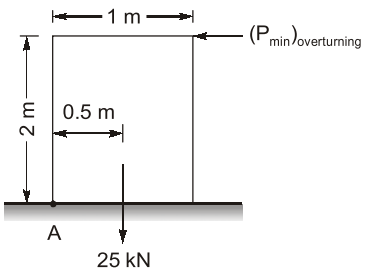
Normal reaction = Weight

$$N = mg = 25 \text{ kN} \quad ..(ii)$$

Using eq. (i) and (ii)

$$(P_{min})_{sliding} = \mu N \quad \text{(Verge of sliding)}$$
$$= 0.3 \times 25 = 7.5 \text{ kN}$$

Minimum force for overturning



At the verge of overturning

$$(P_{min})_{overturning} \times 2 = W \times 0.5$$

$$(P_{min})_{overturning} = \frac{25 \times 0.5}{2} = 6.25 \text{ kN}$$

Here, $(P_{min})_{overturning} < (P_{min})_{sliding}$

First overturning will take place.

Sliding will not take place.

End of Solution

Q.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.

Ans. (a, b)

End of Solution

Q.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)

Ans. (6.4) (6.6 to 6.8)

	x_0	x_1	x_2
x	1	1.2	1.4
$f(x)$	3	–	?
	y_0	y_1	y_2

For finding y_2, two iteration has to be followed.

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

$$y_1 = y_o + hf(x_o, y_o)$$
$$= 3 + 0.2\, f(1, 3)$$
$$= 3 + 0.2\,[4(1 + 2) - 3]$$
$$= 3 + 0.2\,(12 - 3)$$
$$= 4.8$$

$$y_2 = y_1 + hf(x_1, y_1)$$
$$= 4.8 + 0.2\, f(12, 4.8)$$
$$= 4.8 + 0.2\,[4(1.2 + 2) - 4.8]$$
$$= 4.8 + 0.2\,(12.8 - 4.8)$$
$$= 4.8 + 1.6 = 6.4$$

End of Solution

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Q.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)

Ans. (1.9) (1.8 to 2.0)

x	y	x^2	xy
5	16	25	80
2	10	4	20
4	13	16	52
3	12	9	36
$\Sigma x = 14$	$\Sigma y = 51$	$\Sigma x^2 = 54$	$\Sigma xy = 188$

We know that, normal equation for fitting of straight lines are

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

and $$\Sigma xy = a\,\Sigma x + b\,\Sigma x^2$$

Here, $n = 4$

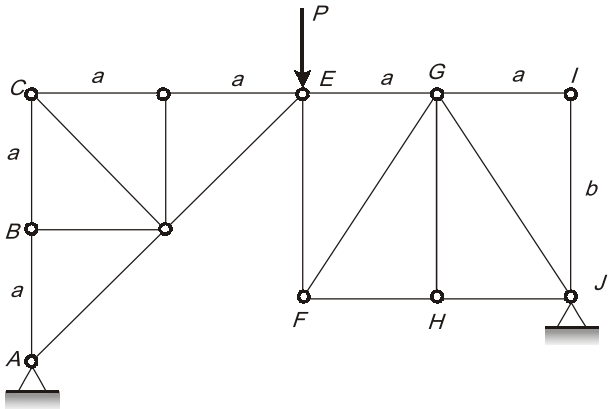
So, $51 = 4a + b(14)$

$188 = a(14) + b(54)$

$\Rightarrow$ After solving, $a = 6.1$ and $b = 1.9$

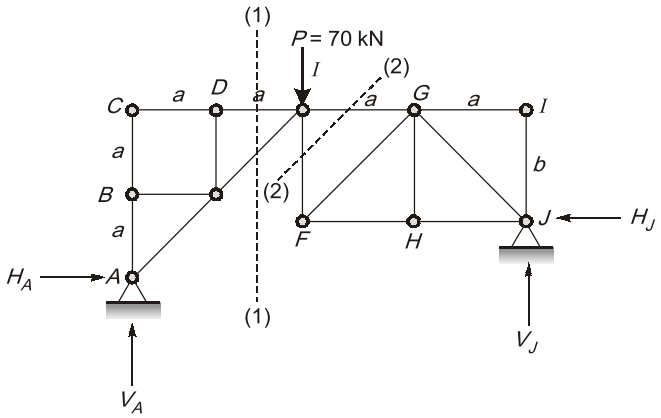
End of Solution

Q.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)

Ans. (30)



$$\Sigma M_J = 0$$

$$\Rightarrow V_A \times 8 - H_A \times 1 - 70 \times 4 = 0$$

$$8V_A - H_A = 280 \quad \text{...(i)}$$

To find H_A (Cut the truss by 1 - 1)

Consider left hand side

$$\Sigma M_E = 0$$

$$\Rightarrow \quad V_A \times 4 - H_A \times 4 = 0$$

$$V_A = H_A \quad \text{... (ii)}$$

Using (i) in (ii) $\quad 8V_A - V_A = 280$

$$7V_A = 280$$

$$V_A = 40 \text{ kN}$$

$$H_A = 40 \text{ kN}$$

$$\Rightarrow \quad H_J = 40 \text{ kN}$$

$$V_J = 70 - 40 = 30 \text{ kN}$$

To find force in member EF (Cut the truss by 2-2)

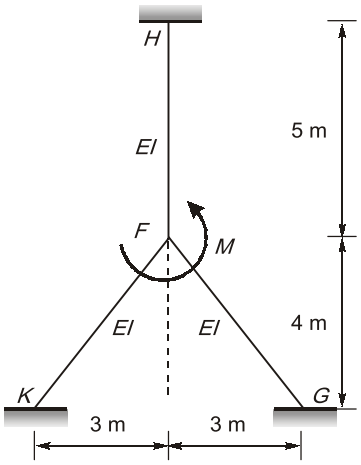
Consider right hand side,

Force in the member $EF, F_{EF} = V_J$

$$F_{EF} = 30 \text{ kN}$$

End of Solution

Q.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 $EI = 10^5$ 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)

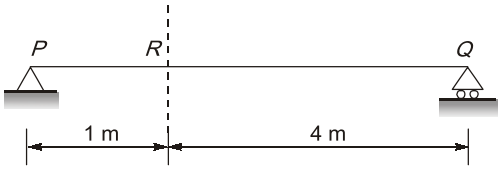
Ans. (60)

$$\frac{M}{6} = 10 \text{ kNm}$$

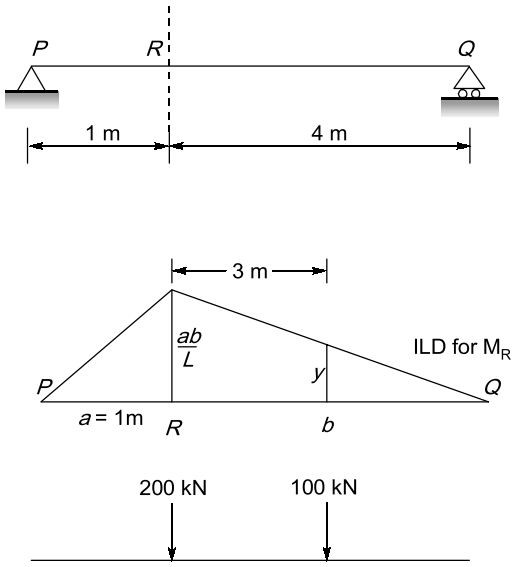
$$M = 60 \text{ kNm}$$

End of Solution

Q.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)



Ans. (180)



$$\frac{ab}{L} = \frac{1\times 4}{5} = 0.8\text{ m}$$

To get maximum BM at R

$$BM_{max} = 200\times\frac{ab}{L} + 100\times y$$

$$\frac{ab/L}{b} = \frac{y}{4-3} \Rightarrow \frac{0.8}{4} = \frac{y}{1} = 0.2\text{ m}$$

$$BM_{max} = 200 \times 0.8 + 100 \times 0.2 = 180\text{ kNm}$$

End of Solution

Q.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)

Ans. (101)

$B = 300$ mm
$d = 580$ mm
$V_u = 440$ kN

Concrete used is M30
Raft steel is Fe415

1. $$V_{cu} = \tau_c Bd = 0.66\times 300\times\frac{580}{1000} = 114.84\text{ kN}$$

2. $$V_{su} = V_u - V_{cu} = 440 - 114.84\text{ kN} = 325.16\text{ kN}$$

3. Spacing of 2-legged shear reinforcement

$$s_v = \frac{A_{sv} \times 0.87 f_y \times d}{V_{su}}$$

$$= \frac{2 \times \frac{\pi}{4} \times (10)^2 \times 0.87 \times 415 \times 580}{325.16 \times 1000}$$

$$= 101.16 \text{ mm (say 101 mm)}$$

End of Solution

Q.54 A square concrete pile of 10 m length is driven into a deep layer of uniform homogeneous clay. 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 N_c = 9; adhesion factor α = 0.7)

Ans. (400)

$$Q_{up} = q_b A_b + q_s A_s$$

$$C_u = \frac{q_u}{2} = \frac{100}{2} = 50 \text{ kN/m}^2$$

$$= 9 \times CB^2 + \alpha \bar{C}(4BL)$$

$$632 \text{ kN} = 9 \times 50 \times B^2 + 0.7 \times 50 \times (4B \times 10)$$

$$B = 0.4 \text{ m}$$

$$B = 400 \text{ mm}$$

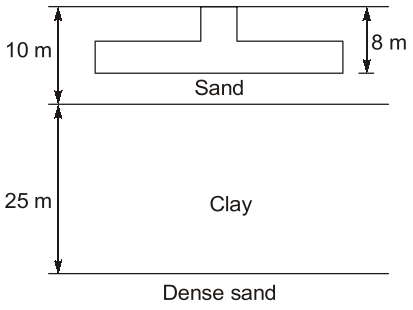
End of Solution

Q.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 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)

Ans. (1736) (1735 to 1737)

Lab	Field
2 way	
$d = \frac{H_0}{2} = \frac{25}{2}$ mm	
50% → 10 min	25% → t



$$(T_v)_{50} = C_v \frac{t}{d^2} \qquad \text{(from lab)}$$

$$\frac{\pi}{4}(0.5)^2 = C_v \times \frac{10 \text{ min}}{\left(\frac{25}{2} \times 10^{-3}\right)^2} \qquad \text{...(i)}$$

$$(T_v)_{25} = C_v \frac{t}{d^2} \qquad \text{(from field)}$$

$$\frac{\pi}{4}(0.25)^2 = C_v \frac{t}{(12.5)^2} \qquad \text{...(ii)}$$

Since the soil is same $\rightarrow C_v$ same

$$\frac{\pi}{4}(0.25)^2 = \frac{\frac{\pi}{4}(0.5)^2 \times \left(12.5 \times 10^{-3}\right)^2}{10} \times \frac{t}{(12.5)^2}$$

$$t = 1736 \text{ days}$$

End of Solution

Q.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
Streamflow (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)

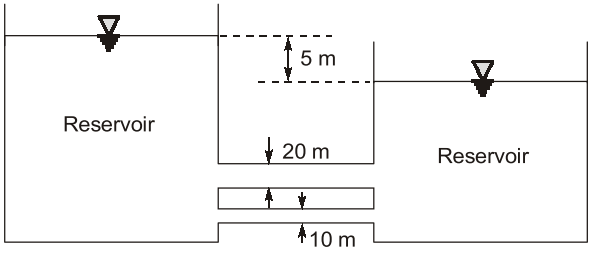
Ans. (12) (12 to 12)

Time	Ordinate of 2hr DRH	Ordinate of 2hr UH = Ord. of 2 hr DRH / Rainfall excess of 3cm	S-curve lag by 2hr	S-curve Ordinates (S_2)	S_1 curve	Ordinate of 1hr UH = $\frac{S_2 - S_1}{1/2}$
0	0	0	—	0	—	0
1	6	2	—	2	0	4
2	24	8	0	8	2	12
3	30	10	2	12	8	8
4	21	7	8	15	12	6
5	15	5	12	17	15	4
6	6	2	15	17	17	0
7	0	0	17	17	17	0
			17	17	17	0

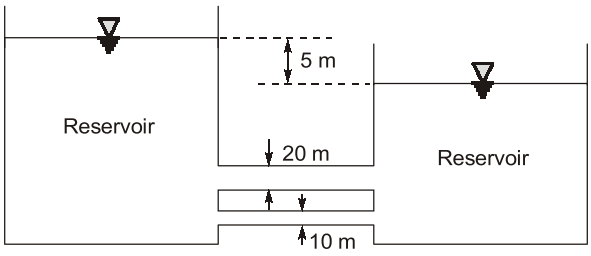
End of Solution

Q.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. (5.66) (5.60 to 5.72)



$$h_{f1} = h_{f2}$$

$$\frac{8Q_1^2}{\pi^2 g} \times \frac{fl}{D_1^5} = \frac{8Q_2^2}{\pi^2 g} \times \frac{fl}{D_2^5}$$

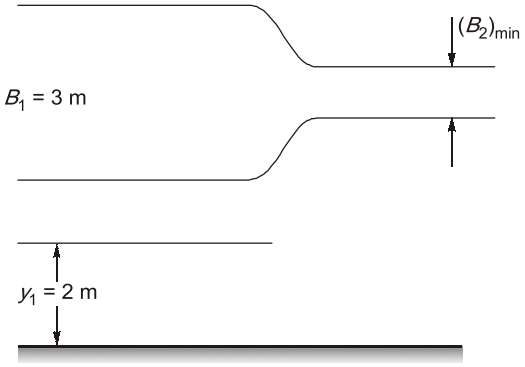
$$\left(\frac{Q_1}{Q_2}\right)^2 = \left(\frac{D_1}{D_2}\right)^5$$

$$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right)^{5/2} = \left(\frac{0.2}{0.1}\right)^{5/2} = 5.66$$

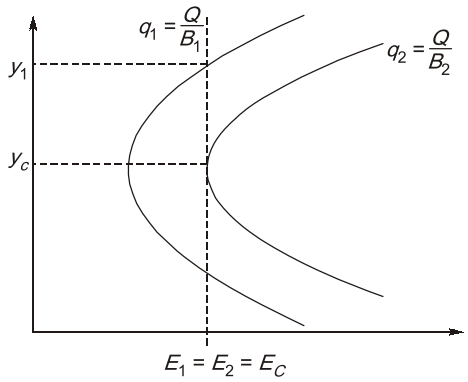
End of Solution

Q.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)

Ans. (2.15) (2.10 to 2.20)



$$Q = A_1V_1$$
$$12 = 3 \times 2 \times V_1$$
$$V_1 = 2 \text{ m/s}$$
$$F_{r_1} = \frac{V_1}{\sqrt{gy_1}} = \frac{2}{\sqrt{g \times 2}} = 0.45 < 1 \quad \text{(Subcritical flow)}$$



Method 1:

$$(B_2)_{min} = \sqrt{\frac{27Q^2}{8gE_1^3}} \quad \text{... (i)}$$

$$E_1 = y_1 + \frac{V_1^2}{2g} = 2 + \frac{(2)^2}{2g} = 2.2038 \text{ m}$$

Using (i)

$$(B_2)_{min} = \sqrt{\frac{27 \times 12^2}{8 \times 9.81 \times (2.2038)^3}} = 2.15 \text{ m}$$

Method 2:

$$E_1 = E_C = \frac{3}{2}y_c$$
$$y_c = 1.46 \text{ m}$$
$$\left(\frac{q_2^2}{g}\right)^{1/3} = 1.46 \text{ m}$$

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$$q_2 = 5.57 \text{ m}^3/\text{s/m}$$

$$\frac{Q}{(B_2)_{min}} = 5.57$$

$$(B_2)_{min} = 2.15 \text{ m}$$

End of Solution

Q.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 NO_3^-/liter. The total nitrogen concentration in this wastewater is _____ milligram nitrogen per liter.
(round off to one decimal place)

Ans. (58.8) (58.4 to 59.2)

$$N_2 \text{ mg/litre} = \left(\frac{34}{17} + \frac{6.2}{62}\right) \times 28$$

$$= 58.8 \text{ mg/}l \text{ as } N_2$$

End of Solution

Q.60 A 2 % sewage sample (in distilled water) was incubated for 3 days at 27 °C temperature. After incubation, a 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)

Ans. (1003)

$$BOD_3(27°C) = (DO_i - DO_f) \times \left(\frac{V_1 + V_2}{V_1}\right) = 10 \text{ mg/}l \times 50$$

$$= 500 \text{ mg/}l$$

$$BOD_3(27°C) = L_o(1 - e^{-kt})$$

$$500 = L_o\,(1 - e^{-0.23 \times 3})$$

$$L_o = 1003 \text{ mg/}l$$

End of Solution

Q.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 m^3/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)

Ans. (0.4)

SOR, $$V_o = \frac{500}{5 \times 40} = 2.5 \text{ m/h}$$

$$\eta = \frac{V_s}{V_o} \times 100 = \frac{1}{2.5} = 0.4 \text{ or } 40\%$$

End of Solution

Q.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)

Ans. **(48)**

Cycle time, $T = 100$ sec

Amber time = 4 sec

Red time = 50 sec

Lost time per phase = 2 sec

$t_{SL} + t_{CL} = 2$ sec

$T = G + A + R$

$100 = G + 4 + 50$

$\Rightarrow \quad G = 46$ sec

Effective green, $G_i = G + A - \text{Lost time}$

$G_i = 46 + 4 - 2 = 48$ sec

End of Solution

Q.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)

Ans. **(0.80) (0.75 to 0.85)**

$\lambda_C = 4$ Vehicle/hr $= 2$ Vehicle/30 min

$\lambda_B = 2$ Vehicle/hr $= 1$ Vehicle/30 min

$\lambda_{\text{Vehicle}} = 3$ Vehicle/30 min

$P(x < 2) = 1 - P(x \le 1)$

$= 1 - [P(x = 0) + P(x = 1)]$

$$= 1 - \left[\frac{e^{-\lambda}\lambda^0}{0!} + \frac{e^{-\lambda}\lambda^1}{1!}\right] = 1 - e^{-3}(1+3) = 1 - \frac{4}{e^3} = 0.8$$

End of Solution

Q.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)

Ans. (0.8) (0.79 to 0.81)

$$PHF_{10} = \frac{V}{\left(\frac{60}{n}\right)V_n(\max)}$$

$$V = 10 \times 10 + 11 \times 10 + 12 \times 10 + 15 \times 10 + 13 \times 10 + 11 \times 10$$

$$V = 720 \text{ veh}$$

$$(V_n)_{max} = 15 \times 10 \qquad (t = 30 \text{ to } 40 \text{ min})$$

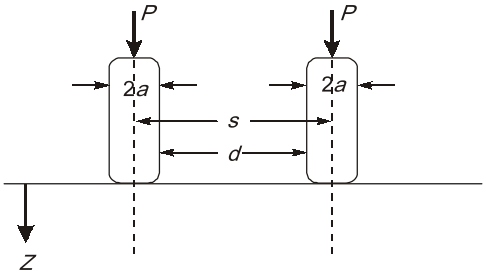
$$= 150 \text{ veh}$$

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

End of Solution

Q.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)



Ans. (0.5)

ESWL @ depth $\frac{d}{2}$ = P

ESWL @ depth 2S = 2P

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

End of Solution

■■■■