IES MASTER

Institute for Engineers (IES/GATE/PSUs)

GATE 2018

CIVIL ENGINEERING

Detailed Solution

EXAM DATE: 11-02-2018

AFTERNOON SESSION (02:00 PM-05:00 PM)

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Section : General Aptitude

1. For non-negative intergers, a, b, c what would be the value of a+ b + c if

log a + log b + logc = 0?

(a) 3 (b) 1

(c) 0 (d) –1

Sol–1 : (a)

$\log a + \log b + \log c = 0 \Rightarrow \log(abc) = 0$

$\Rightarrow abc = e^0 = 1$

$\because a, b, c \in I$ and $abc = 1$

which is possible only when a = b = c = 1.

So, a + b + c = 1 + 1 + 1 = 3

2. $\underbrace{a+a+a+...+a}_{\text{n times}} = a^2b$ & $\underbrace{b+b+b+...b}_{\text{n times}} = ab^2$,

where a, b, n and m are natural numbers. What is the value of

$\left(\underbrace{m+m+m+...+m}_{\text{n times}}\right)\left(\underbrace{n+n+n+...+n}_{\text{n times}}\right)$?

(a) $2a^2b^2$ (b) a^4b^4

(c) ab (a+ b) (d) $a^2 + b^2$

Sol–2 : (b)

$na = a^2b \Rightarrow n = ab$

$mb = ab^2 \Rightarrow m = ab$

Now, $\underbrace{(m+m+m+.....m)}_{\text{n times}}\underbrace{(n+n+n+.....n)}_{\text{m times}} =$

$(nm).(mn) = (mn)^2 = (ab.ab)^2 = a^4b^4$

3. "Although it does contain some pioneering ideas, one would hardly characterize the work as______".

The word the best fills the blank in the above sentence is

(a) Innovative (b) Simple

(c) Dull (d) Boring

Sol–3 : (a)

The word "Although" is a crucial signpost here. The work contains some pioneering ideas, but apparently it is not overall a pioneering work. Hence innovative best fits the sentance.

4. "His face____ with joy when the solution of the puzzle was ____ to him."

The words that best fill the blanks in the above sentence are

(a) shone, sown (b) shone, shone

(c) shown, shone (d) shown, shown

Sol–4 : (a)

5. A three-member committee has to be formed from a group of 9 people. How may such distinct committees can be formed?

(a) 27 (b) 72

(c) 81 (d) 84

Sol–5 : (d)

Three member committee from 9 members = ${}^9C_3 = 84$.

6. In manufacturing industries, loss is usually taken to be proportional to the square of the deviation from a target. If the loss is Rs. 4900 for a deviation of 7 units, what would be the loss in Rupees for a deviation of 4 units from the target?

(a) 400 (b) 1200

(c) 1600 (d) 2800

Sol–6 : (c)

Loss $\propto$ $(\text{Deviation})^2$

i.e., Loss = $K.D^2$

Now, $4900 = K(7)^2 \Rightarrow K = 100$

So, loss is 4 units = $K(4)^2$

= 100 × 16 = 1600

7. Given the $\frac{\log P}{y-z}=\frac{\log Q}{z-x}=\frac{\log R}{x-y}=10$ for $x \neq y \neq z$, what is the value of the product PQR?

(a) 0 (b) 1

(c) xyz (d) 10^{xyz}

Sol–7 : (b)

$$\frac{\log P}{y-z}=\frac{\log Q}{z-x}=\frac{\log R}{x-y}=10$$

$\Rightarrow$ log P = 10(y – z), log Q = (z – x)10, log R = 10(x – y)

So, log P + log Q + log R = 10[(y – z) + (z – x) + (x – y)]

log PQR = 0

$\Rightarrow$ PQR = e^0 = 1

8. A faulty wall clock is known to gain 15 minutes every 24 hours. It is synchronized to the correct time at 9 AM on 11th July. What will be the correct time to the nearest minute when the clock shows 2 PM on 15th July of the same year?

(a) 12:45 PM (b) 12:58 PM

(c) 1:00 PM (d) 2:00 PM

Sol–8 : (b)

From 9 am of 11th July to 2 pm of 15th July

No. of hours = 4 days and 5 hours

Now in 24 hours (1 day) clock gains = 15 minutes

So in 4 days clock will gain = 15 × 4 = 60 mins.

Again in 5 hours clock will gain

$$= \frac{15\times 5}{24}\text{min} = 3\frac{1}{8}\text{min}$$

So, overall clock will gain

$$= 60+3\frac{1}{8} = 63\frac{1}{8}\text{min.}$$

So, correct time = 2:00 pm – $63\frac{1}{8}$ min

$\approx$ 12:57 PM

9. Each of the letters in the figure represents a unique integer from 1 to 9. The letters are positioned in the figure such that each of (A+B+C). (C+D+E), (C+D+G) and (G+H+K) is equal to 13. Which integer does E represent?

A	B	C		
		D		
		E	F	G
				H
				K

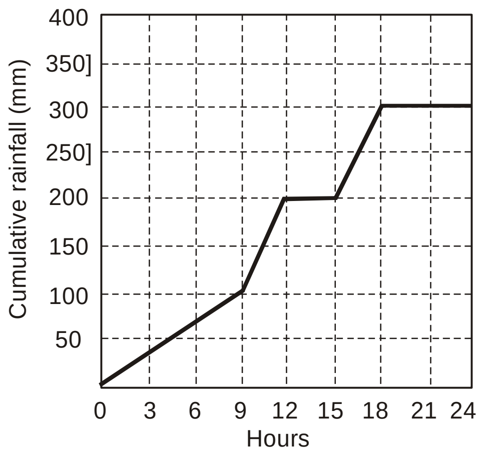
(a) 1 (b) 4

(c) 6 (d) 7

Sol–9 : (b)

A=6	B=5	C=2		
		D=7		
		E=4	F=8	G=1
				H=9
				K=3

10. The annual average rainfall in a tropical city is 1000 mm. On a particular rainy day (24-hour period), the cumulative rainfall experienced by the city is shown in the graph. Over the 24 hours period, 50% of the rainfall falling on a rooftop, which had an obstruction free area of 50 m^2, was harvested into a tank. What is the total volume of water collected in the tank in liters?



(a) 25,000

(b) 18,750

(c) 7,500

(d) 3,125

Sol–10 : (c)

Hours	Rainfall (in mm)
0 – 3	25
3 – 6	50
6 – 9	25
9 – 12	100
12 – 15	–
15 – 18	100
18 – 21	–
21 – 24	–

Hence, total rainfall in 24 hours = 300 mm

So, total rainfall on rooftop = 50% of (300)

= 150 mm = 15 cm

Area of rooftop = 50 m^2

= (50 × 100 × 100) cm^2

So, volume of water collected in a tank

= 15 cm × (50 × 100 × 100) cm^2

= 7500 × 1000 cm^3

= 7500 litres.

Civil Engineering

1. Dupit's assumptions are valid for

(a) artesian aquifer (b) confined aquifer

(c) leaky aquifer (d) unconfined aquifer

Sol–1 : (d)

The Dupit-Forchheimer assumption holds that the groundwater flows horizontally in an unconfined aquifer and that groundwater discharge is proportional to the saturated aquifer thickness.

2. A culvert is designed for a flood frequency of 100 years and a useful life of 20 years. The risk involved in the design of the culvert (in percentage, up to two decimal places) is________

Sol–2 : 18.19%

T = 100 years

$$P = \frac{1}{100} = 0.01$$

q = 0.99

Risk = 1 – $(0.99)^{20}$

$$\boxed{\text{Risk} = 18.19\%}$$

3. Which one of the following statements is NOT correct?

(a) When the water content of soil lies between its liquid limit and plastic limit, the soil is said to be in plastic state.

(b) Boussinesq's theory is used for the analysis of stratified soil.

(c) The inclination of stable slope in cohesive soil can be greater than its angle of internal friction.

(d) For saturated dense fine sand after applying overburden correction, if the standard penetration test value exceeds 15, dilatancy correction is to be applied.

Sol–3 : (b)

Westergaard's theory is used for the analysis of stratified soil not Boussinesq's theory.

4. For a given discharge in an open channel, there are two depths which have the same specific energy. These two depths are known as

(a) alternate depths

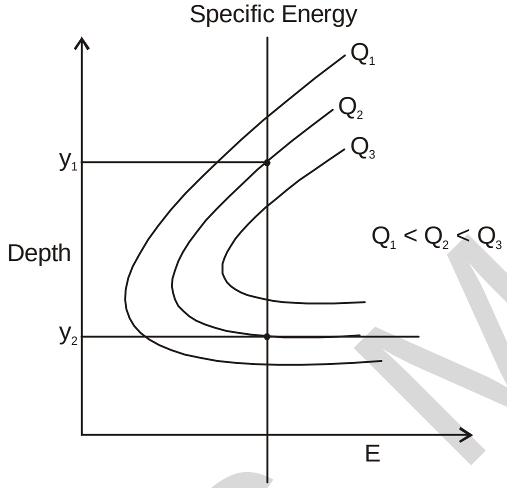
(b) critical depths

(c) normal depths

(d) sequent depths

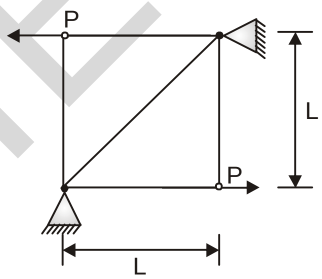
Sol–4 : (a)

For a given discharge in an open channel, alternate depths have the same specific energy.



y_1 and y_2 are alternate depths.

5. All the members of the planar truss (see figure), have the same properties in terms of area of cross-section (A) and modulus of elasticity (E).



For the loads shown on the truss, the statement that correctly represents the nature of forces in the members of the truss is:

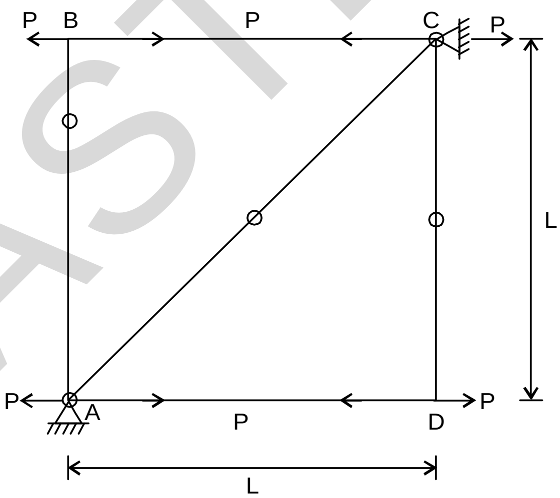
(a) There are 3 members in tension, and 2 members in compression

(b) There are 2 members in tension 2 members in compression and 1 zero-force member

(c) There are 2 members in tension, 1 member in compression, and 2 zero-force members

(d) There are 2 members in tension, and 3 zero-force members.

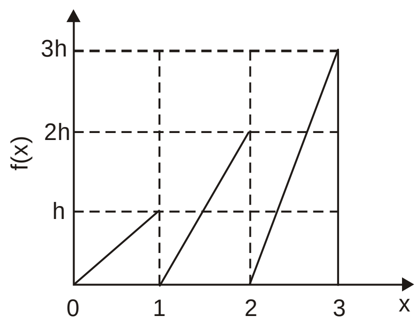
Sol–5 : (d)



AB, CD and AC are zero force members

Force in member AC is zero because the member in between support at A and C which has no tendency to extend due to applied force. Had there been temperature change or lack of fit in AC then only it could have carried any force.

6. The graph of a function f(x) is shown in the figure.



For f(x) to be a valid probability density function, the value of h is

(a) 1/3 (b) 2/3
(c) 1 (d) 3

Sol–6 : (a)

From given graph

$$f(x) = \begin{cases} hx, & 0<x<1 \\ 2h(x-1) & 1<x<2 \\ 3h(x-2) & 2<x<3 \end{cases}$$

$\because$ f(x) is valid p.d.f. so $\int_{-\infty}^{\infty} f(x)dx = 1$

$$\Rightarrow \int_0^1 hx\,dx + \int_1^2 2h(x-1)dx + \int_2^3 3h(x-2)dx = 1$$

$$\frac{h}{2} + 2h\left(\frac{1}{2}\right) + 3h\left(\frac{1}{2}\right) = 1 \Rightarrow h = \frac{1}{3}$$

7. The setting time of cement is determined using
(a) Le Chatelier apparatus
(b) Briquette testing apparatus
(c) Vicat apparatus
(d) Casagrande's apparatus

Sol–7 : (c)

8. A fillet weld is simultaneously subjected to factored normal and shear stress of 120 MPa and 50 MPa, respectively. As per IS 800:2007, the equivalent stress (in MPa, up to two decimal places) is_________

Sol–8 : 147.99

Equivalent stress = $\sqrt{\sigma^2 + 3\tau^2}$
= 147.99 MPa

9. The intensity of irrigation for the Kharif season is 50% for an irrigation project with culturable command area of 50,000 hectares. The duty for the Kharif season is 1000 hectare/cumec. Assuming transmission loss of 10%, the required discharge (in cumec, up to two decimal places) at the head of the canal is________

Sol–9 : (27.78)

Area = 50,000 ha
Area under cultivation = 50% of 50,000 ha
= 25000 ha
Given:

$$\text{Duty} = \frac{\text{Area}}{\text{Discharge}}$$

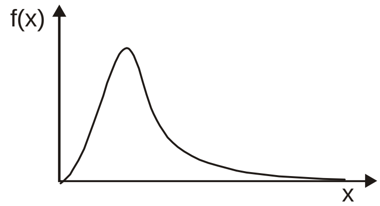
$$\Rightarrow \text{Discharge} = \frac{25000}{1000} m^3/s$$

$\Rightarrow$ Required discharge = 27.78 m^3/s

10. The initial concavity in the load-penetration curve of a CBR test is NOT due to
(a) uneven top surface
(b) high impact at start of loading
(c) inclined penetration plunger
(d) Soft top layer of soaked soil

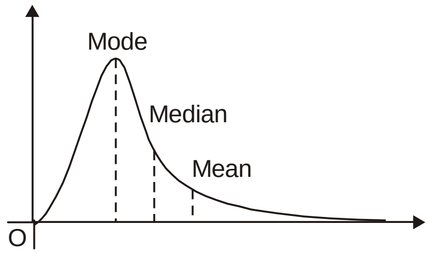
Sol–10 : (b)

11. A probability distribution with right skew is shown in the figure.

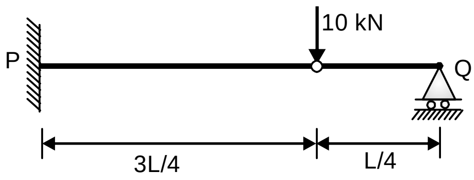


The correct statement for the probability distribution is
(a) Mean is equal to mode
(b) Mean is greater than median but less than mode
(c) Mean is greater than median and mode
(d) Mode is greater than median

Sol–11 : (c)



12. A vertical load of 10 kN acts on a hinge located at a distance of L/4 from the roller support Q of a beam of length L (see figure).

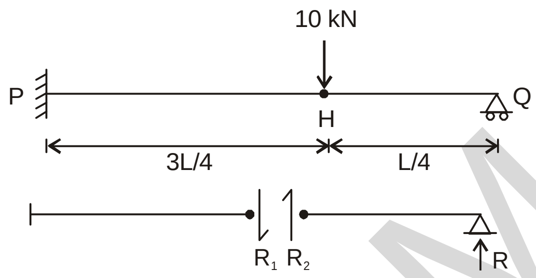


The vertical reaction at support Q is

(a) 0.0 kN (b) 2.5 kN

(c) 7.5 kN (d) 10.0 kN

Sol–12 : (a)



$\Sigma M_H = 0$

$-R \times \frac{L}{4} = 0$

R = 0

13. A structural member subjected to compression, has both translation and rotation restrained at one end, while only translation is restrained at the other end. As per IS 456: 2000, the effective length factor recommended for design is

(a) 0.50 (b) 0.65

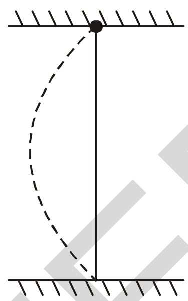
(c) 0.70 (d) 0.80

Sol–13 : (d)

As per IS 456 : 2000, Table 28

(Clause E–3)

Recommended value of effective length = 0.80ℓ



Theoretical value = 0.70ℓ

Recommended value = 0.80ℓ

14. Probability (up to one decimal place) of consecutively picking 3 red balls without replacement from a box containing 5 red balls and 1 white ball is_______

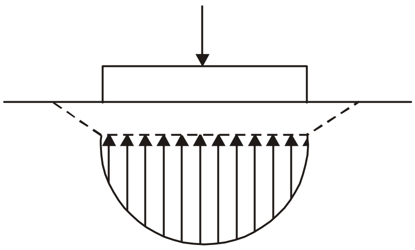
Sol–14 : (0.5)

Required Probability

$$= \frac{{}^5C_1}{{}^6C_1} \times \frac{{}^4C_1}{{}^5C_1} \times \frac{{}^3C_1}{{}^4C_1}$$

$$= \frac{5}{6} \times \frac{4}{5} \times \frac{3}{4} = \frac{1}{2} = 0.5$$

15. The contact pressure and settlement distribution for a footing are shown in the figure.



The figure corresponds to a

(a) rigid footing on granular soil

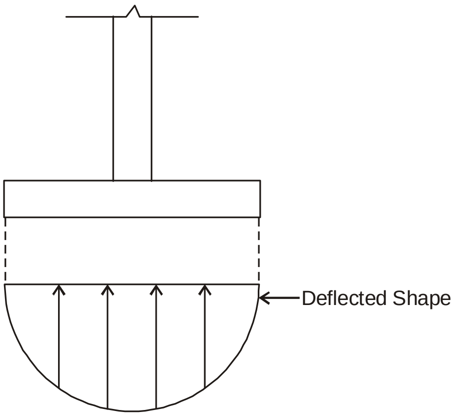
(b) flexible footing on granular soil

(c) flexible footing on saturated clay

(d) rigid footing on cohesive soil.

Sol–15 : (a)

For rigid footing on granular soil



16. The solution of the equation $x\frac{dy}{dx}+y=0$ passing through the point (1, 1) is

(a) x (b) x^2

(c) x^{-1} (d) x^{-2}

Sol–16 : (c)

$$\frac{xdy}{dx}+y = 0;\ y(1) = 1$$

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

On integrating log y = –log x + log c

$$\Rightarrow \boxed{xy = C}$$

Using y(1) = 1 $\Rightarrow$ C = 1 so $\boxed{xy=1}$

i.e., $y = \frac{1}{x} = x^{-1}$

17. As per IS 456:2000, the minimum percentage of tension reinforcement (up to two-decimal places) required in reinforced-concrete beams of rectangular cross-section (considering effective depth in the calculation of area) using Fe500 grade steel is_____

Sol–17 : (0.17)

$$\frac{Ast}{bd} = \frac{0.85}{fy}$$

$$\frac{Ast}{bd} = \frac{0.85}{500}$$

$$\text{Percentage} = \frac{A_{st}}{bd}\times 100$$

$$= \frac{0.85}{500}\times 100$$

$= 0.17$

18. Peak hour factor (PHF) is used to represent the proportion of peak sub-hourly traffic flow within the peak hour. If 15-minute sub-hours are considered, the theoretically possible range of PHF will be

(a) 0 to 1.0 (b) 0.25 to 0.75

(c) 0.25 to 1.0 (d) 0.5 to 1.0

Sol–18 : (c)

$$\text{Peak hourly factor} = \frac{V_{60}}{4\times V_{15}}$$

Peak hourly factor varies from $\Rightarrow$ 0.25 to 1

19. The clay mineral, whose structural units are held together by potassium bond is

(a) Halloysite (b) Illite

(c) Kaolinte (d) Smectite

Sol–19 : (b)

Properties of Illite mineral

1. 2 : 1 clay layer
2. By Potassium bond, the two negative surfaces of silica sheets are held together.

20. As per IS 10500:2012, for drinking water in the absence of alternate source of water, the permissible limits for chloride and sulphate, in mg/L, respectively are

(a) 250 and 200 (b) 1000 and 400

(c) 200 and 250 (d) 500 and 1000

Sol–20: (b)

As per 10500 : 2012, table 2

Permissible Limit of :

Chlorides – 1000 mg/L

Sulphates – 400 mg/L

21. As per IRC:37-2012, in order to control subgrade rutting in flexible pavements, the parameter to be considered is

(a) horizontal tensile strain at the bottom of bituminous layer

(b) vertical compressive strain on top of subgrade

(c) vertical compressive stress on top of granular layer

(d) Vertical deflection at the surface of the pavement.

Sol–21 : (b)

As per clause 6.3.2 of IRC 37:2012

$$N = 4.1656\times10^{-8}\times\left[\frac{1}{\varepsilon_v}\right]^{4.5337}$$

$$N = 1.41\times10^{-8}\times\left[\frac{1}{\varepsilon_v}\right]^{4.5337}$$

where,

N = Number of cumulative standard axle, and

Ev = Vertical strain in the subgrade

As can be seen, the model considers the vertical strain in subgrade as the only variable for rutting, which is a measure of bearing capacity of the subgrade.

22. A flow net below a dam consists of 24 equipotential drops and 7 flow channels. The difference between the upstream and downstream water levels is 6m. the length of the flow line adjacent to the toe of the dam at exit is 1 m. The specific gravity and void ratio of the soil below the dam are 2.70 and 0.70, respectively. The factor of safety against piping is

(a) 1.67 (b) 2.5

(c) 3.4 (d) 4

Sol–22 : (d)

$N_d = 24$

$N_f = 7$

$\Delta H = 6m$

G = 2.70

e = 0.70

Factor of safety against piping

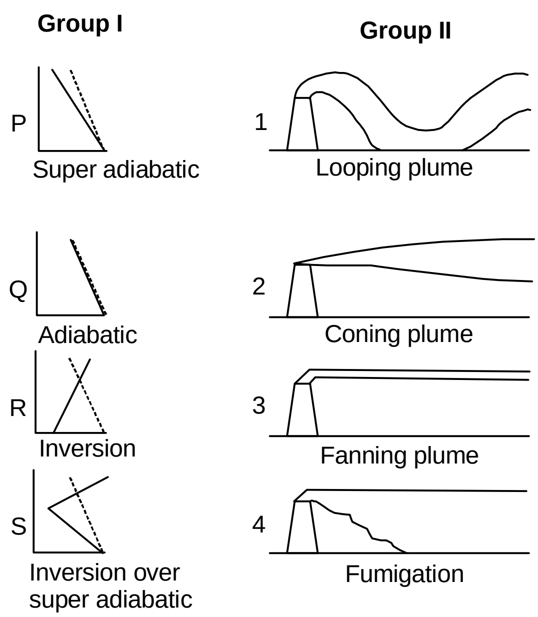
$$FOS = \frac{i_c}{i_e}$$

$$i_c = \frac{G-1}{1+e} = \frac{2.7-1}{1+0.7} = 1$$

$$i_e = \frac{\Delta h}{L} = \left(\frac{H}{N_d\times\ell}\right) = \frac{6m}{24\times1m} = \frac{1}{4}$$

$$FOS = \frac{1}{1/4} = 4$$

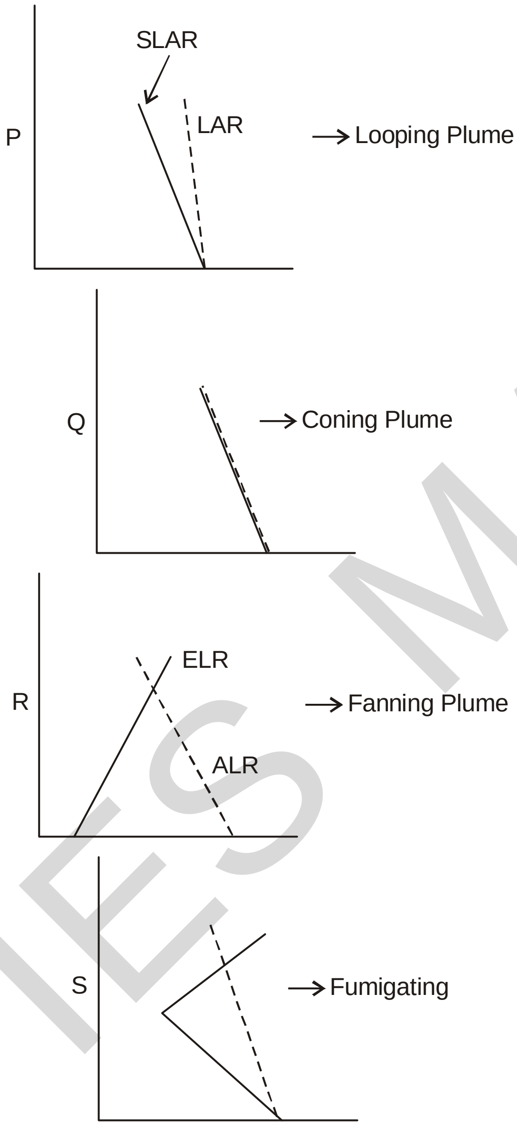
23. In the figures, Group I represents the atmospheric temperature profiles (P, Q, R and S) and Group II represents dispersion of pollutants from a smoke stack (1, 2, 3 and 4). In the figures of group I, the dashed line represents the dry adiabatic lapse rate, where as the horizontal axis represents temperature and the vertical axis represents the altitude.



The correct match is

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

Sol–23 : (a)



24. The quadratic equation $2x^2 - 3x + 3 = 0$ is to be solved numerically starting with an initial guess as x_0 = 2. The new estimate of x after the first iteration using Newton-Raphson method is________

Sol–24 : (1)

Consider $f(x) = 2x^2 - 3x + 3$

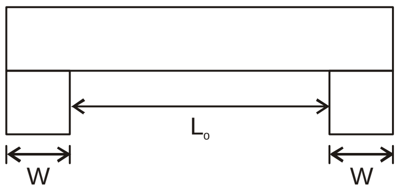
then $f'(x) = 4x - 3$ and $x_0 = 2$

Iteration 1 : $x_1 = x_0 - \dfrac{f(x_0)}{f'(x_0)}$

$= 2 - \dfrac{f(2)}{f'(2)} = 2 - \dfrac{5}{5} = 1$

25. A reinforced-concrete slab with effective depth of 80 mm is simply supported at two opposite ends on 230 mm thick masonry walls. The centre-to-centre distance between the walls is 3.3 m. As per IS 456:2000, the effective span of the slab (in m, up to two decimal places) is________

Sol–25 : (3.15)



$l_{eff} = l_o + \dfrac{W}{2} + \dfrac{W}{2}$

$l_o = 3.3 - \dfrac{w}{2} - \dfrac{w}{2} = 3.3 - 0.23 = 3.07$ m

$l_{eff} = \min \begin{cases} l_o + w \\ l_o + d \end{cases}$

$= \min \begin{cases} 3.07 + 0.23 = 3.30 \text{ m} \\ 3.07 + 0.08 = 3.15 \text{ m} \end{cases}$

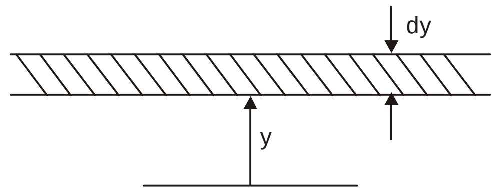
= 3.15 m

26. In a 5 m wide rectangular channel, the velocity u distribution in the vertical direction y is given by $u = 1.25y^{1/6}$. The distance y is measured from the channel bed. If the flow depth is 2m, the discharge per unit width of the channel is

(a) 2.40 m^3/s/m (b) 2.80 m^3/s/m
(c) 3.27 m^3/s/m (d) 12.02 m^3/s/m

Sol–26 : (a)

$u = 1.25y^{1/6}$



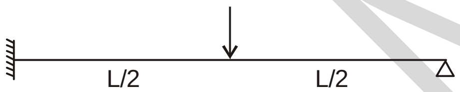
$dq = (1.25y^{1/6})dy$

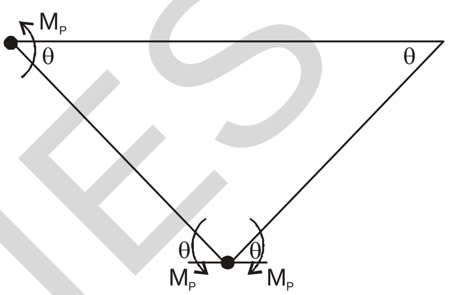
$$q = \int_0^2 (1.25y^{1/6})dy$$

$q = 2.405\ m^3/s/m.$

27. The prismatic propped cantilever beam of span L and plastic moment capacity M_p is subjected to a concentrated load at its mid-span. If the collapse load of the beam is $\alpha \frac{M_p}{L}$ the value of α is____________

Sol–27 : (6)





$$-3M_P\theta = -W\frac{L}{2}\theta$$

$$\frac{6M_P}{L} = W$$

$\therefore\ \alpha = 6$

$\therefore$ Correct answer is 6.

28. The total rainfall in a catchment of area 1000 km^2, during a 6 h storm, is 19 cm. The surface runoff due to this storm computed from triangular direct runoff hydrograph is $1\times10^8\ m^3$.

The ϕ_{index} for this storm (in cm/h, up to one decimal place) is_____

Sol–28 : (1.5)

Area = 1000 km^2

Depth = 19 cm

Runoff = $1 \times 10^8\ m^3$

$$\phi = \frac{\text{Total Rain fall} - \text{Runoff}}{\text{Time}}$$

$$\text{Runoff} = \frac{1\times10^8 m^3}{1000\times10^6 m^2} = 0.1\ m$$

= 10 cm

$$\phi = \frac{\text{Rainfall} - \text{Runoff}}{\text{Time}}$$

$$= \frac{19-10}{6}$$

$$= \frac{9}{6} = 1.5\ \text{cm/hr.}$$

29. A rough pipe of 0.5 m diameter, 300 m length and roughness height of 0.25 mm, carries water (kinematic viscosity = $0.9 \times 10^{-6}\ m^2/s$) with velocity of 3 m/s. Friction factor (f) for

$$\frac{1}{\sqrt{f}} = 2\log_{10}\left(\frac{r}{k}\right) + 1.74,$$ where, R_e = Reynolds number, r = radius of pipe, k = roughness height and g = 9.81 m/s^2. The head loss (in m, up to three decimal places) in the pipe due to friction is_________

Sol–29 : (4.599)

Given, D = 0.5 m

L = 300 m

$\nu = 0.9 \times 10^{-6}\ m^2/sec$

v = 3 m/sec

K = 0.25 mm

Reynolds number, $R_c = \frac{vD}{\nu}$

$= \frac{3 \times 0.5}{9 \times 10^{-6}}$ = 1.667 × 10^6 > 2000

Hence flow is turbulent.

$\therefore \ \frac{1}{\sqrt{f}} = 2\log_{10}\left(\frac{r}{K}\right) + 1.74$

$= 2\log_{10}\left(\frac{0.25}{0.25 \times 10^{-3}}\right) + 1.74$

f = 0.0167

$\therefore$ head loss, $h_f = \frac{fLv^2}{2gD}$

$= \frac{0.0167 \times 300 \times 3^2}{2 \times 9.8 \times 0.5}$

= 4.599 m

30. The value (up to two decimal places) of the line integral $\int_C \vec{F}(\vec{r}).\overrightarrow{dx}$. for $\vec{F}(\vec{r}) = x^2\hat{i} + y^2\hat{j}$ along C which is a straight line joining (0, 0) to (1, 1) is_____

Sol–30 : (0.67)

$\vec{f} = x^2\hat{i} + y^2\hat{j}$ and $d\vec{r} = dx\hat{i} + dy\hat{j}$

So, $\vec{f}.d\vec{r}$ = (x^2 dx + y^2 dy)

Now, along (0, 0) to (1, 1) equation of straight line

y = x

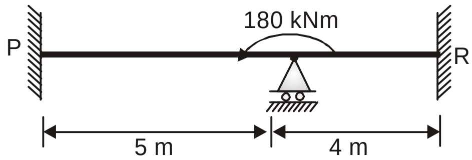
dy = dx

$0 \le x \le 1$

So, $LI = \int_C \vec{f}.d\vec{r} = \int_C (x^2dx + y^2dy)$

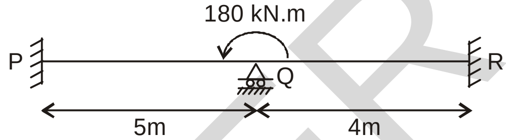
$= \int_0^1 (2x^2dx) = \frac{2}{3} = 0.67$

31. A prismatic beam P-Q-R of flexural rigidity EI = 1×10^4 kNm^2 is subjected to a moment of 180 kNm at Q as shown in the figure.



The rotation at Q (in rad, up to two decimal places) is______

Sol–31 : (0.01)



Fixed end moment

$M_{FQP} = M_{FQR} = 0$

Writing slope deflection equation of QP and QR

$M_{QP} = 0 + \frac{2EI}{5}(2\theta_Q) = \frac{4}{5}EI\theta_Q$

$M_{QR} = \frac{2EI}{4}(2\theta_Q) = EI\theta_Q$

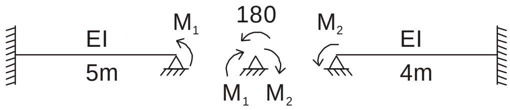
As $M_{QP} + M_{QR}$ = –180 kN.m

$\Rightarrow \frac{4}{5}EI\theta_Q + EI\theta_Q = -180$

$\Rightarrow \theta_Q = \frac{-180 \times 5}{9 \times 10^4}$ = –0.01 rad

Hence, θ_Q = 0.01 rad

Alternative Solution :



$\frac{4EI\theta}{5} = M_1$

$\frac{4EI\theta}{4} = M_2$

$M_1 + M_2 = 180$

$\Rightarrow$ 1.8EIθ = 180

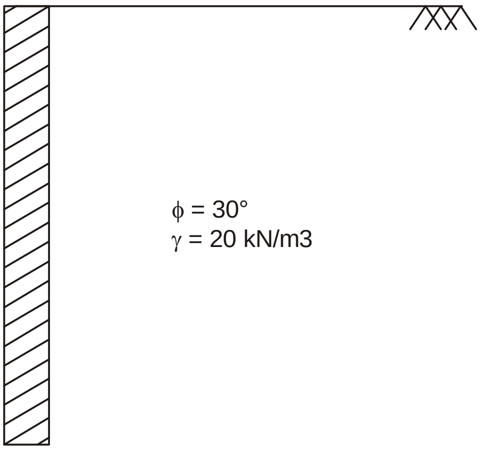
$\theta = \frac{100}{EI} = \frac{100}{10^4}$ = 0.01 rad.

32. The 3 m high vertical earth retaining wall retains a dry granular backfill with angle of internal friction of 30° and unit weight 20 kN/m^3. If the wall is prevented from yielding (no movement) the total horizontal thrust (in kN per unit length) on the wall is

(a) 0 (b) 30

(c) 45 (d) 270

Sol–32 : (c)

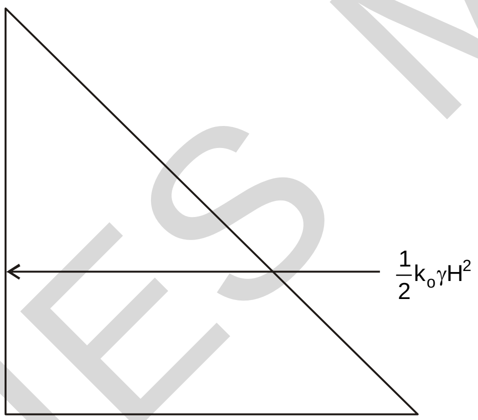


As wall does not move, so wall is at rest.

Coefficient of earth pressure at rest $k_0 = 1 - \sin\phi$

$= 1 - \sin 30^\circ = 0.5$

Earth Pressure Distribution :



Resultant Thrust $(P_o) = \frac{1}{2}(k_o\gamma H)(H)$

$= \frac{1}{2} \times 30 \times 3$

= 45 kN/m

33. A singly reinforced rectangular concrete beam of width 300 mm and effective depth 400 mm is to be designed using M25 grade concrete and Fe500 grade reinforcing steel. For the beam to be under-reinforced, the maximum number of 16 mm diameter reinforcing bars that can be provided is

(a) 3 (b) 4

(c) 5 (d) 6

Sol–33 : (c)

$x_{u,lim}$ for Fe 500 = 0.46 × 400 = 184 mm

For section to be under reinforced $A_{st} \le A_{st,lim}$

$$A_{st,lim} = \frac{0.36 f_{ck} b x_{u lim}}{0.87 f_y} = \frac{0.36 \times 25 \times 300 \times 1.84}{0.87 \times 500}$$

$= 1142.06 \text{ mm}^2$

No. of bars for limited area of steel

$$= \frac{1142.06}{\frac{\pi}{4} \times 16^2} = 5.68$$

So, number of bars will be 5.

34. A level instrument at a height of 1.320 m has been placed at a station having a reduced level (RL) of 112.565 m. The instrument reads –2.835 m on a levelling staff held at the bottom of a bridge deck. The RL (in m) of the bottom of the bridge deck is

(a) 116.720 (b) 116.080

(c) 114.080 (d) 111.050

Sol–34 : (a)

Height of instrument = 112.565 + 1.320

= 113.885 m

RL of bottom of bridge = 113.885 + 2.835

= 116.720 m

35. A flocculation tank contains 1800 m³ of water, which is mixed using paddles at an average velocity gradient G of 100/s. The water temperature and the corresponding dynamic viscosity are 30°C and 0.798×10^{-3} Ns/m², respectively. The theoretical power required to achieve the stated value of G (in kW, up to two decimal places) is__________

Sol–35 : (14.36)

Velocity Gradient, $G = \sqrt{\dfrac{P}{\mu V}}$

Given $G = 100\ S^{-1}$

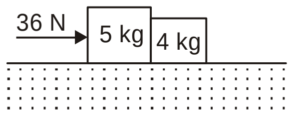
$P = ?$, $\mu = 0.798 \times 10^{-3}\ Ns/m^2$

$V = 1800\ m^3$

$\Rightarrow \quad P = 100^2 \times 0.798 \times 10^{-3} \times 1800$

$= 14.364$ kW

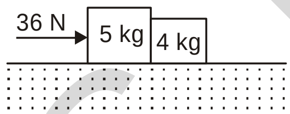
36. Two rigid bodies of mass 5 kg and 4 kg are at rest on a frictionless surface until acted upon by a force of 36 N as shown in the figure. The contact force generated between the two bodies is



(a) 4.0 N (b) 7.2 N

(c) 9.0 N (d) 16.0 N

Sol–36 : (d)



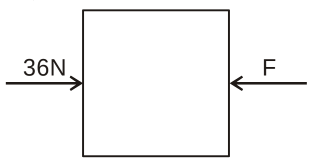
Net force = Net mass × acceleration

$\Rightarrow 36 = 9 \times a$

$\Rightarrow a = 4\ ms^{-2}$

Now, considering 5 kg weight only

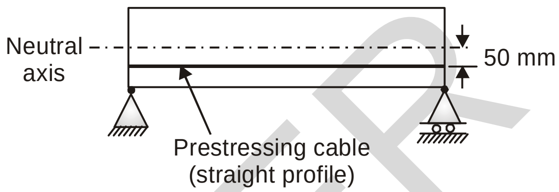
force on 5 kg = 5 × 4 N = 20 N



$\Rightarrow 36N - F = 20N$

$\Rightarrow F = 16N$

37. A 6 m long simply-supported beam is prestressed as shown in the figure.



The beam carries a uniformly distributed load of 6 kN/m over its entire span. If the effective flexural rigidity $EI = 2 \times 10^4\ kNm^2$ and the effective prestressing force is 200 kN, the net increase in length of the prestressing cable (in mm, up to two decimal places) is________

Sol–37 : (0.12)

Downward UDL, w = 6 kN/m

Eccentricity, e = 50 mm

Prestressing force, P = 200 kN

$EI = 2 \times 10^4\ kN\ m^2$

L = 6 m

Rotation due to prestress $= \dfrac{PeL}{2EI}$

$= \dfrac{200 \times 50 \times 10^{-3} \times 6}{2 \times 2 \times 10^4} = 1.5 \times 10^{-3}$

Rotation due to UDL $= \dfrac{wL^3}{24EI}$

$= \dfrac{6 \times (6)^3}{24 \times 2 \times 10^4} = 2.7 \times 10^{-3}$

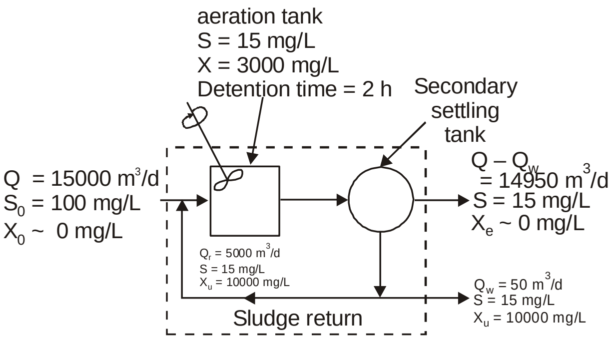
Net rotation $= 2.7 \times 10^{-3} - 1.5 \times 10^{-3}$

$= 1.2 \times 10^{-3}$ radian

Elongation of the cable $= 2 \times 50 \times 1.2 \times 10^{-3}$ mm

= 0.120 mm

38. A schematic flow diagram of a completely mixed biological reactor with provision for recycling of solids is shown in the figure.



So, S = readily biodegradable soluble BOD, mg/L

Q, Q_r, Q_w = flow rates, m^3/d

X_0, X, X_e, X_u = microorganism concentrations (mixed-liquor volatile suspended solids or MLVSS), mg/L

The mean cell residence time (in days, up to one decimal place) is____

Sol–38 : (7.5)

Mean cell residence time is given by

$$\theta_c = \frac{VX}{(Q_o - Q_w)X_e + Q_w X_u}$$

Detention time = 2h

Volume of tank

$$= Q_o t_d = 15000 \times \frac{2}{24} = 1250 \text{ m}^3$$

Since, $X_e = 0$, θ_c will be calculated as follows:

$$\theta_c = \frac{1250 \times 3000}{50 \times 10000} = 7.5 \text{ days}$$

39. The compression curve (void ratio, e vs, effective stress, σ'_v) for a certain clayey soil is a straight line is a semi-logarithmic plot and it passes through the points (e = 1.2; $\sigma'_v = 50$ kPa) and (e = 0.6; $\sigma'_v = 800$ kPa). The compression index (up to two decimal places) of the soil is________

Sol–39 : (0.5)

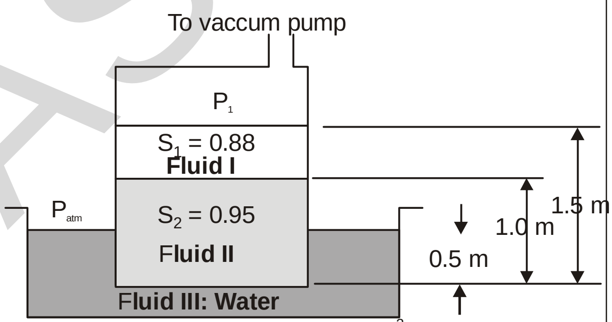
Compression index

$$C_c = \frac{\Delta e}{\log\left(\bar{\sigma}_2 / \bar{\sigma}_1\right)}$$

$$= \frac{1.2 - 0.6}{\log\left(\frac{800}{50}\right)}$$

$$= \frac{0.6}{\log(16)} = 0.50$$

40. A three-fluid system (immiscible) is connected to a vacuum pump. The specific gravity values of the fluids (S_1, S_2) are given in the figure.



Unit weight of water, γ_w = 9.81 kN/m³

Atmospheric pressure P_{atm} = 95.43 kPa

The gauge pressure value (in kN/m². up to two decimal places) of p_1 is

Sol–40 : (–8.73)

Pressure at bottom of fluid II = $P_{atm} + 0.5\gamma_w$

= 95.43 + 0.5 × 9.81

= 100.335 kPa

Also,

$P_1 + 0.88 \times 0.5\gamma_w + 0.95\gamma_w = 100.335$ KPa

P_1 + 13.63 = 100.335

P_1 = 86.69 KPa

$\Rightarrow$ Gauge Pressure = $P_1 - P_{atm}$

$\approx$ –8.73 kN/m

41. A car follows a slow moving truck (travelling at a speed of 10 m/s) on a two-lane two-way highway. The car reduces its speed to 10 m/

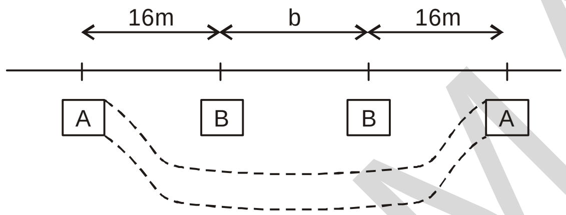
s and follows the truck maintaining a distance of 16 m from the truck. On finding a clear gap in the opposing traffic stream, the car accelerated at an average rate of 4 m/s^2, overtakes the truck and returns to its original lane. When it returns to its original lane, the distance between the car and the truck is 16m. The total distance covered by the car during this period (from the time it leaves its lane and subsequently returns to its lane after overtaking) is

(a) 64 m (b) 72 m

(c) 128 m (d) 144 m

Sol–41 : (b)

Option 2 is correct



Speed of car when he starts overtaking,

v = 10 m/sec

$$\therefore\ (16 + b + 16) = v.t + \frac{1}{2}at^2$$

$32 + b = 10t + 2t^2$ ...(i)

Distanced travelled by slow moving truck during overtaking time t

b = v.t

b = 10t ...(ii)

From (i) & (ii)

$32 + 10t = 10t + 2t^2$

$16 = t^2$

t = 4 sec

$\therefore$ distance covered by car during the period from the time it leaves its lane after overtaking

= 32 + b

= 32 + (10 × 4)

= 72 m

42. A coal containing 2% sulfur is burned completely to ash in a brick kiln at a rate of 30 kg/min. The sulfur content in the ash was found to be 6% of the initial amount of sulfur present in the coal fed to the brick kiln. The molecular weights of S, H and O are 32, 1 and 16 g/mole, respectively. The annual rate of sulfur dioxide (SO_2) emission from the kiln (in tonnes/year, up to two decimal places) is________

Sol–42 : (592.88)

Total coal burnt in the kiln in a year

= 30 × 60 × 24 × 365 kg

= 15768000 kg

Sulphur present in the coal = 0.02 × 15768000 kg

= 315360 kg

Sulphur content in the ash = 0.06 × 315360 kg

= 18921.6 kg

Sulphur oxidized into SO_2 = 194 × 315360 kg

= 296438.4 kg

$$S + O_2 \rightarrow SO_2$$

32 64

32 gm sulphur produce = 64 gm SO_2

$\therefore$ 296438.4 kg sulphur produce =

$$\frac{64}{32} \times 296438.4$$

= 592876.8 kg

= 592.876 tonnes.

43. The Laplace transform F(s) on the exponential function. f(t) = e^{at} when $t \geq 0$, where a is a constant and (s– a) > 0, is

(a) $\frac{1}{s+a}$ (b) $\frac{1}{s-a}$

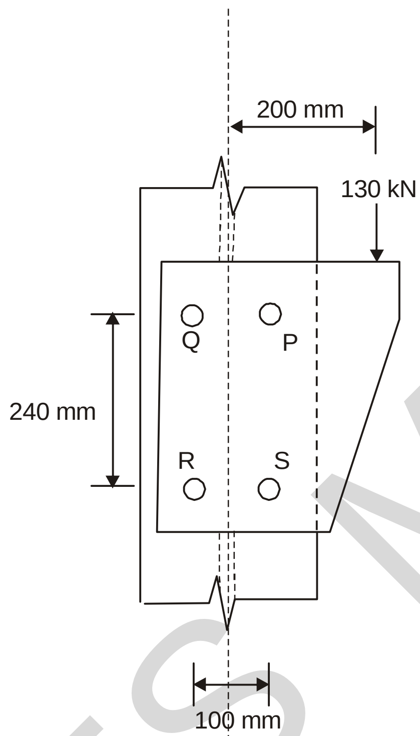
(c) $\frac{1}{a-s}$ (d) ∞

Sol–43 : (b)

$$\because\ L\{f(t)\} = \int_0^\infty e^{-st}.f(t)dt$$

So, $L\{e^{at}\} = \int_0^{\infty} e^{-st}.e^{at}dt = \frac{1}{s-a}$

44. Four bolts P, Q, R and S of equal diameter are used for a bracket subjected to a load of 130 kN as shown in the figure.



The force in bolt P is

(a) 32.50 kN (b) 69.32 kN

(c) 82.50 kN (d) 119.32 kN

Sol–44 : (b)

Option (2) is correct.

Direct shear in bolt P,

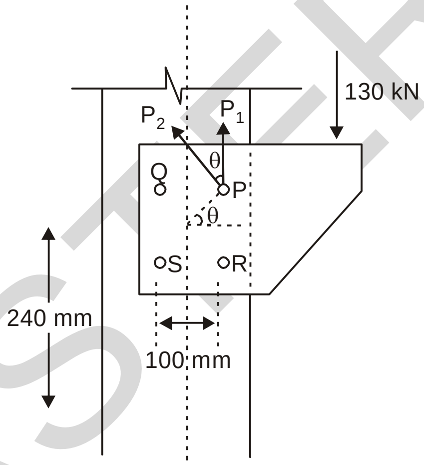
$F_1 = \frac{130}{4} = 32.5\text{KN}$

Shear due to twisting moment

$$= \frac{130 \times 200 \times \sqrt{120^2 + 150^2}}{4(\sqrt{120^2 + 50^2})^2}$$

$F_2 = 50$ KN

$\theta = \tan^{-1}\left(\frac{120}{50}\right) = 67.38°$



∴ Resultant force in bolt P

$= \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$

$= \sqrt{32.5^2 + 50^2 + 2 \times 32.5 \times 50\cos 67.38°}$

= 69.32 kN

45. The total horizontal and vertical stresses at a point X in a saturated sandy medium are 170 kPa and 300 kPa, respectively. The static pore-water pressure is 30 kPa. At failure, the excess pore-water pressure is measured to be 94.50 kPa, and the shear stresses on the vertical and horizontal planes passing through the point X and zero. Effective cohesion is 0 kPa and effective angle of internal friction is 36°. The shear strength (kPa, up to two decimal places) at point X is________

Sol–45 : (52.52)

Major effective principal stress $(\bar{\sigma}_1)$

$= 300 - 30 - 94.5\text{MPa}$

= 175.5 MPa

Minor effective principal stress

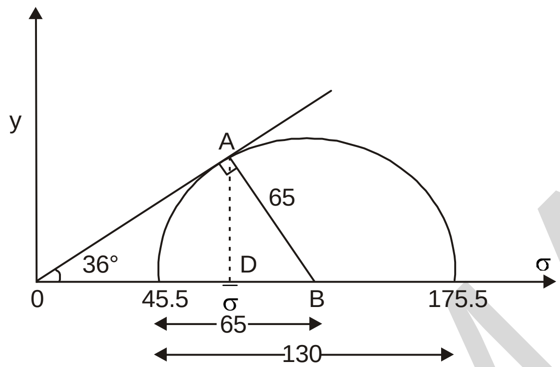
$= 170 - 30 - 94.5 \text{MPa}$

$\bar{\sigma}_3 = 45.5$ MPa

Shear strength = $C + \bar{\sigma}\tan\phi$

C = 0, $\phi = 36°$ (given)

$\bar{\sigma}$ = effective stress at the plane of failure normal.



$\angle OBA = 90 - 36° = 54°$

BD = $65\cos 54° = 38.21$ KPa

$\bar{\sigma} = (45.5 + 65 - 38.21) = 72.3$ KPa

∴ shear strength = $72.3\tan 36°$

= 52.52 KPa

46. The rank of the following matrix is

$$\begin{pmatrix} 1 & 1 & 0 & -2 \\ 2 & 0 & 2 & 2 \\ 4 & 1 & 3 & 1 \end{pmatrix}$$

(a) 1 (b) 2

(c) 3 (d) 4

Sol–46 : (b)

$$A = \begin{bmatrix} 1 & 1 & 0 & -2 \\ 2 & 0 & 2 & 2 \\ 4 & 1 & 3 & 1 \end{bmatrix} \xrightarrow[R_3 \to R_3 - 4R_1]{R_2 \to R_2 - 2R_1}$$

$$\begin{bmatrix} 1 & 1 & 0 & -2 \\ 0 & -2 & 2 & 6 \\ 0 & -3 & 3 & 9 \end{bmatrix} \xrightarrow{R_3 \to R_3 - \frac{3}{2}R_2}$$

$$\begin{bmatrix} 1 & 1 & 0 & -2 \\ 0 & -2 & 2 & 6 \\ 0 & 0 & 0 & 0 \end{bmatrix} \text{ So } \rho(A) = 2.$$

47. An aerial photograph of a terrain having an average elevation of 1400 m is taken at a scale of 1:7500. The focal length of camera is 15 cm. The altitude of the flight above mean sea level (in m. up to one decimal place) is_____

Sol–47 : (2525)

Given; scale, $S = \dfrac{1}{7500}$

elevation of terrain > h = 1400 m

Focal length of the camera, f = 15 cm

altitude of flight, H = ?

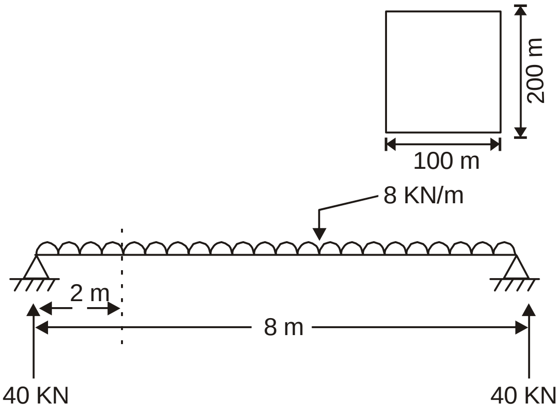
$$S = \frac{f}{H - h}$$

$$\frac{1}{7500} = \frac{15 \times 10^{-2}}{H - 1400}$$

H = 2525 m

48. An 8 m long simply-supported elastic beam of rectangular cross-section (100 mm × 200 mm) is subjected to a uniformly distributed load of 10 kN/m over its entire span. The maximum principal stress (in MPa, up to two decimal places) at a point located at the extreme compression edge of a cross-section and at 2 m from the support is

Sol–48 : (90)



at 2 m from support,

Bending moment, M = $40 \times 2 - 10 \times 2 \times 1$

= 60 KN-m

Shear force, V = $40 - (10 \times 2) = 20KN$

At external compression edge (top fibre)

Shear stress P = 0

Bending stress, $\sigma = \dfrac{MY}{I}$

$$= \frac{(60 \times 10^6 N - mm) \times 100 mm}{\frac{100 \times 200^3}{12} mm^4}$$

$= 90 N/mm^2$

= 90 MPa

Since this edge is free from shear stress, hence it is a principal plane.

Thus maximum principal stress = 90 MPa

49. A 7.5 m wide two-lane road on a plain terrain is to be laid along a horizontal curve of radius 510 m. For a design speed of 100 kmph, super-elevation is provided as per IRC: 73-1980. Considered acceleration due to gravity as 9.81 m/s^2. The level difference between the inner outer edges of the road (in m, up to three decimal places) is___

Sol–49 : (0.525)

Design speed, V = 100 KmpH

Radius of curve, R = 510 m

g = 9.81 m/sec^2

Super elevation $e = \dfrac{(0.75V)^2}{gR}$

$$= \frac{\left(0.75 \times 100 \times \frac{5}{18}\right)^2}{9.81 \times 510}$$

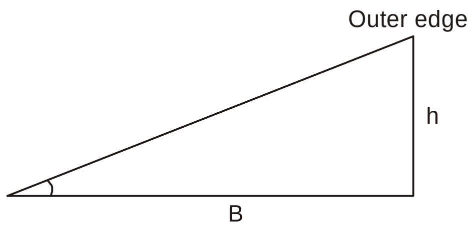
$= 0.08675 > .07$

$\therefore$ e = 0.07

$e = \dfrac{h}{B}$

$.07 = \dfrac{h}{7.5}$

h = 0.525 m



50. At a small water treatment plant which has 4 filters, the rate of filtration and backwashing are 200 m^3/d/m^2 and 1000 m^3/d/m^2, respectively. Backwashing is done for 15 min per day. The maturation, which occurs initially as the filter is put back into service after cleaning, takes 30 min. It is proposed to recover the water being wasted during backwashing and maturation. The percentage increase in the filtered water produced (up to two decimal places) would be _____

Sol–50 : (7.53)

Rate of filteration = $200 m^3/d/m^2$

Backwashing rate = $1000 m^3/d/m^2$

Time for backwashing = 15 min/day

Time wasted in maturation = 30 min

Let the area of filter to be unity

Total water to be produced

$= 200 m^3/d/m^2 \times \frac{23.25}{24}$

= 193.75

Water wasted in backwashing

$\frac{1000 \times 15}{24 \times 60} = 10.4167\ m^3$

Water wasted during maturation

$= \frac{200 \times 30}{24 \times 60}$

$= 4.1667\ m^3$

Total filter water to be produced

= 193.75 + 10.4167 + 4.1667

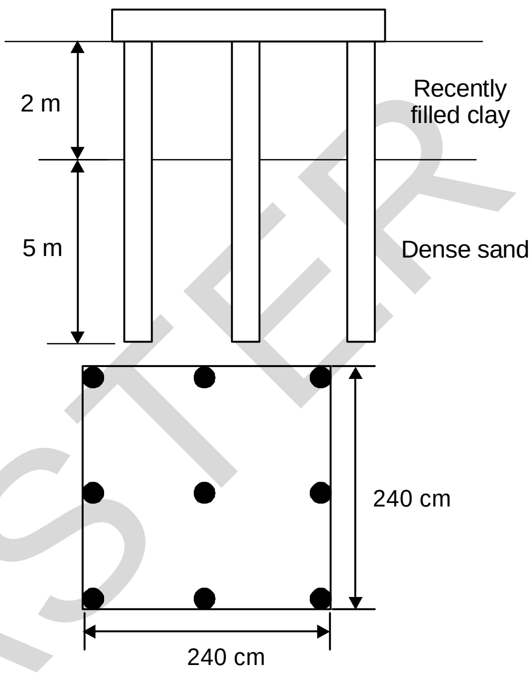
$= 208.3334\ m^3$

Hence percentage increase in filtered water produced

$= \frac{208.3334 - 193.75}{193.75}$

= 7.53%

51. A group of nine piles in a 3 × 3 square pattern in embedded in a soil strata comprising dense sand underlying recently filled clay layer, as shown in the figure. The perimeter of an individual pile is 126 cm. The size of pile group is 240 cm × 240 cm. The recently filled clay has undrained shear strength of 15 kPa and unit weight of 16 kN/m³.



The negative frictional load (in kN, up to two decimal places) acting on the pile group is ______

Sol–51 : (472.32)

Negative skin friction by considering individual pile

$P_{n1} = n[\alpha C_u \times \text{Perimeter of single pile} \times L]$

According to the C_u value of soil it is classified as soft clay. Adhesion factor for soft clay is 1. So,

$P_{n1} = 9 \times [1 \times 15 \times 1.26 \times 2] = 340.2\ kN$

Negative friction load of pile group

$P_{n2} = C_u \cdot P_g \cdot L + \gamma \times [A_{\text{pile group}}] \times L$

= 15 × 4 × 2.4 × 2 + 16 × [2.4 × 2.4] × 2

= 472.32 kN

So, negative skin friction on pile group will be maximum of P_{n1} and P_{n2} and given by 472.32 kN.

52. The matrix $\begin{pmatrix} 2 & -4 \\ 4 & -2 \end{pmatrix}$ has

(a) real eigen values and eigen vectors

(b) real eigen values but complex eigen vectors

(c) complex eigen values but real eigen vectors

(d) complex eigen values and eigen vectors

Sol–52 : (d)

$$A = \begin{bmatrix} 2 & -4 \\ 4 & -2 \end{bmatrix} \begin{cases} \lambda_1 + \lambda_2 = \text{Trace (A)} = 0 \\ \lambda_1 . \lambda_2 = |A| = 12 \end{cases}$$

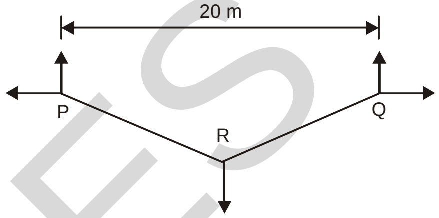
$\Rightarrow \lambda_1 = -\lambda_2$ and $(\lambda_1)(-\lambda_1) = 12$

$\lambda_1^2 = -12 \Rightarrow \lambda_1 = 2\sqrt{3}i$

and $\lambda_2 = -2\sqrt{3}i$

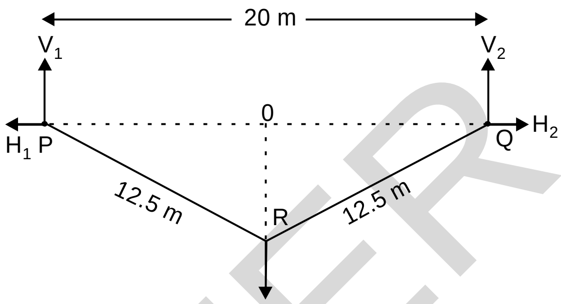
Hence, Eigen values are complex and consequently Eigen Vectors will also complex.

53. A cable PQ of length 25 m is supported at two ends at same level as shown in the figure. The horizontal distance between the supports is 20 m. A point load of 150 kN is applied at point R which divides it into two equal parts.



Neglecting the self-weight of the cable, the tension (in kN, in integer value) in the cable due to applied load will be__

Sol–53 : (125)



$$OR = \sqrt{(12.5)^2 - (10)^2} = 7.5 \text{ m}$$

$V_1 = V_2 = 75$ KN

$\Sigma MR = 0$ (of left hand side)

$$H_1 \times OR = V_1 \times 10$$

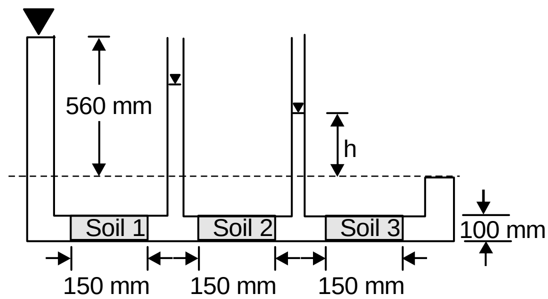
$$H_1 = \frac{75 \times 10}{7.5} = 100 \text{ KN}$$

$\therefore$ Tension in the cable $T = \sqrt{H_1^2 + V_1^2}$

$$= \sqrt{100^2 + 75^2}$$

$= 125$ KN

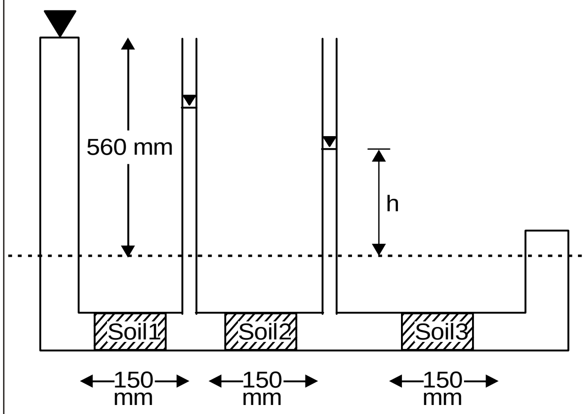
54. Three soil specimens (Soil 1, and Soil 3), each 150 mm long and 100 mm diameter are placed in series in a constant head flow set-up as shown in the figure. Suitable screens are provided at the boundaries of the specimens to keep them intact. The values of coefficient of permeability of Soil 1, Soil 2 and Soil 3 are 0.01, 0.03 and 0.03 cm/s,



The value of h in the set-up is

(a) 0 mm (b) 40 mm
(c) 255 mm (d) 560 mm

Sol–54 : (b)



$K_1 = .01 cm/sec$, $K_2 = 0.003$ cm/sec,

$K_3 = 0.03 cm/sec$

Total head loss, h = 560 mm

Since soil specimen are connected in series, hence discharge through each soil specimen will be same.

$$Q_1 = Q_2 = Q_3$$

$$K_1A_1i_1 = K_2A_2i_2 = K_3A_3i_3$$

$$K_1A_1\frac{h_1}{L_1} = K_2A_2\frac{h_2}{L_2} = K_3A_3\frac{h_3}{L_3}$$

$$K_1h_1 = K_2h_2 = K_3h_3 = x$$

$$(\because L_1 = L_2 = L_3 = 150 mm \; A_1 = A_2 = A_3)$$

$$\therefore \quad h_1 = \frac{x}{.01}, \; h_2 = \frac{x}{0.003}, \; h_3 = \frac{x}{.03}$$

$$\text{Thus } \frac{x}{0.01} + \frac{x}{0.003} + \frac{x}{.03} = 560$$

$$\therefore \; x = 1.2$$

$$\therefore \; h_1 = \frac{1.2}{.01} = 120 \text{ mm},$$

$$h_2 = \frac{1.2}{.003} = 400 mm,$$

$$h_3 = \frac{1.2}{.03} = 40 mm$$

Now h = 560 mm – (head loss between soil 1 & soil 2)

$= 560 - (h_1 + h_2)$

$= 560 - (120 + 400)$

= 40 mm

55. The space mean speed (kmph) and density (vehicles/km) of a traffic stream are linearly related. The free flow speed and jam density are 80 kmph and 100 vehicles/km respectively. The traffic flow (in vehicles/h up to one decimal place) corresponding to a speed of 40 kmph is_____

Sol. (2000)

Free flow speed, $V_f = 80$ Kmph

Jam density, Kj = 100 Veh/km

$$\text{Flow, } q = K\left[V_f - \frac{V_f}{K_j}k\right]$$

$$\text{We know } V = V_f - \frac{V_f.K}{K_j}$$

at V = 40 kmph

$$40 = 80 - \frac{80 \times K}{100}$$

$$K = 50 \text{ Veh/km}$$

$$\therefore \quad q = 50\left[80 - \frac{80}{100} \times 50\right]$$

= 2000 Veh/hr.