IES MASTER
Institute for Engineers (IES/GATE/PSUs)

GATE 2017
Detailed Solution

CIVIL ENGINEERING
SESSION - 1

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GATE—2017

Civil Engineering Questions and Details Solution

Session-1

1. Let x be a continuous variable defined over the interval $(-\infty, \infty)$ and $f(x) = e^{-x-e^{-x}}$. The integral $g(x) = \int f(x)\,dx$ is equal to

(a) $e^{e^{-x}}$ (b) $e^{-e^{-x}}$

(c) $e^{-e^{x}}$ (d) e^{-x}

Sol–1 : (b)

$$g(x) = \int f(x)\,dx$$

$$f(x) = e^{-x-e^{-x}}$$

$$g(x) = \int e^{-x-e^{-x}}\,dx$$

$$= \int \frac{e^{-x}}{e^{e^{-x}}}\,dx$$

Substitude $e^{-x} = t$

$$-e^{-x}\,dx = dt$$

$$g(x) = \int -\frac{dt}{e^{t}}$$

$$= \int -e^{-t}dt$$

$$g(x) = e^{-t}$$

$$g(x) = e^{-e^{-x}}$$

2. Consider the following partial differential equation

$$3\frac{\partial^2\phi}{\partial x^2} + B\frac{\partial^2\phi}{\partial x\partial y} + 3\frac{\partial^2\phi}{\partial y^2} + 4\phi = 0$$

For the equation to be classified as parabolic, the value of B^2 must be _______ .

Sol–2 : 36

$$3\frac{\partial^2\phi}{\partial x^2} + B\frac{\partial^2\phi}{\partial x\partial y} + 3\frac{\partial^2\phi}{\partial y^2} + 4\phi = 0$$

Compare $A\frac{\partial^2\phi}{\partial x^2} + B\frac{\partial^2\phi}{\partial x\partial y} + C\frac{\partial^2\phi}{\partial y^2} + D\phi = 0$

A = 3 B = ? C = 3

Equation to be parabolic

$$B^2 - 4AC = 0$$

$$B^2 - 4 \times 3 \times 3 =$$

$$B^2 = 36$$

3. A strip footing is resting on the ground surface of a pure clay bed having an undrained cohesion c_u. The ultimate bearing capacity of the footing is equal to

(a) $2\pi c_u$ (b) πc_u

(c) $(\pi+1)c_u$ (d) $(\pi+2)c_u$

Sol–3 : (d)

Ultimate bearing capacity on pure clay

$$= c_u N_c$$

$$= 5.14\ c_u$$

$$= (\pi+2)\ c_u$$

4. Group I list the type of gain or loss of strength in soils, Group II lists the property or process responsible for the loss or gain of strength in soils

Group I

P. Regain of strength with time

Q. Loss of strength due to cyclic loading

R. Loss of strength due to upward seepage

S. Loss of strength due to remolding

Group II

1. Boiling
2. Liquefaction
3. Thixotropy
4. Sensitivity

The correct match between Group I and Group II is

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

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

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

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

Sol–4 : (c)

- Thixotropy is that property of soil due to which loss of strength on remoulding can be regained if left undisturbed for some time.
- If rate of loading is larger and soil is saturated +ve pore water pressure will develope. This will reduces effective stress and hence strength. If effective stress reduces to zero. The soil will loss all its shear strength. This is known as liquefaction. It occurs during pile driving vibration of machine, explore blasting, earthquake shock.

  There can be cumulative increase in pore water pressure under successive cycle of loading.
- When upward flow is taking place at critical hydraulic gradient a soil such as sand losses all its shearing strength. This condition is called quick sand condition or boiling of sand.
- Degree of disturbance achieved on remoulding is expressed by sensitivity.

5. A runway is being constructed in a new airport as per the International Civil Aviation Organisation (ICAO) recommendations. The elevation and the airport reference temperature of the airport are 535 m above the mean sea level and 22.65°C, respectively. Consider the effective gradient of runway as 1%. The length of runway required for a design-aircraft under the standard condition is 2000 m. Within the framework of applying sequential corrections as per the ICAO recommendations, the length of runway corrected for the temperature is

(a) 2223 m (b) 2250 m

(c) 2500 m (d) 2750 m

Sol–5 : (c)

Correction for elevation :

7% increase per 300 m

So, correction = $\frac{7}{100}\times\frac{535}{300}\times 2000$

= 249.66 m

Corrected length = 2000 + 249.66

= 2249.66 m

Correction for temperature :

Standard atmospheric temperature

= 15 – 0.0065 × 535 = 11.5225°C

Rise of temp. = 22.65°C – 11.523°C = 11.127°C

Correction = $\frac{2249.66}{100}\times 11.127$ = 250.320 m

Correct length = 2249.66 + 250.320

= 2499.98m

Check for total correction for elevation plus temperature

Total correction % = $\frac{2299.98-2000}{2000}\times 100$

= 24.99%

According to ICAO, this should not exceed by 35%.

6. $\lim_{x\to 0}\left(\frac{\tan x}{x^2-x}\right)$ is equal to ____________ .

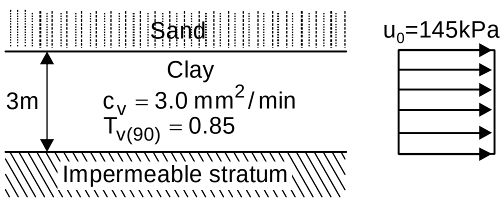
Sol–6: –1

$$\lim_{x\to 0}\left(\frac{\tan x}{x^2-x}\right)$$

$\frac{0}{0}$ form so applying L-Hospital's Rule

$$= \lim_{x\to 0}\frac{\sec^2 x}{2x-1} = \frac{1}{-1} = -1$$

7. A 3 m thick clay layer is subjected to an initial uniform pore pressure of 145 kPa as shown in the figure.



For the given ground conditions the time (in days, rounded to the nearest integer) required for 90% consolidation would be __________

Sol–7: 1771

It is one way drainage case so

H = 3 m = 3000 mm

$T_v = \frac{c_v t}{H^2}$

$t = \frac{0.85 \times 3000^2}{3}$ = 2250000 minutes

= 1770.83 days

≈ 1771 days

8. A soil sample is subected to a hydrostatic pressure σ. The Mohr circle for any point in the soil sample would be

(a) a circle of radius σ and center at the origin

(b) a circle of radius σ and center at a distance σ from the origin

(c) a point at a distance σ from the origin

(d) a circle of diameter σ and center at the origin

Sol–8 : (c)

Radius of Mohr circle = $\sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau^2}$

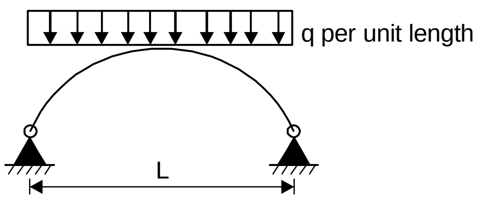
Given : $\sigma_x = \sigma_y = \sigma_z = \sigma \quad \tau = 0$

$$R = \sqrt{\left(\frac{\sigma - \sigma}{2}\right)^2 + 0^2} = 0$$

$$\text{Centre} = \frac{\sigma_x + \sigma_y}{2} = \frac{\sigma + \sigma}{2} = \sigma$$

Mohr circle a point at a distance of σ form origin.

9. The figure shows a two-hinged parabolic arch of span L subjected to a uniformly distributed load of intensity q per unit length



The maximum bending moment in the arch is equal to

(a) $\frac{qL^2}{8}$ (b) $\frac{qL^2}{12}$

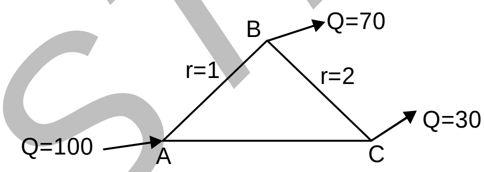
(c) Zero (d) $\frac{qL^2}{10}$

Sol–9 : (c)

If two-hinged parabolic is subjected to uniformly distributed load of intensity q per unit length.

The bending moment at every where in the arch is zero. So, Maximum bending moment in arch is equal to zero.

10. A triangular pipe network is shown in the figure.

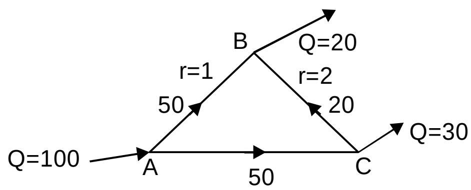


The head loss in each pipe is given by $h_f = rQ^{1.8}$, with the variables expressed in a consistent set of units. The value of r for the pipe AB is 1 and for the pipe BC is 2. If the discharge supplied at the point A (i.e., 100) is equally divided between the pipes AB and AC, the value of r (up to two decimal places) for the pipe AC should be __________

Sol–10 : 0.62

If the discharge supplied at point A is equally divided so Q_{AB} = 50 m^3/s

Q_{AC} = 50 m^3/s



Head loss in closed loop is zero

$\sum rQ^n = 0$

$\sum rQ^{1.8} = 0$

$1 \times 50^{1.8} - 2 \times 20^{1.8} - r \times 50^{1.8} = 0$

$r \times 50^{1.8} = 703.838$

r = 0.615

≈ 0.62

11. For a steady incompressible laminar flow between two infinite parallel stationary plates, the shear stress variation is

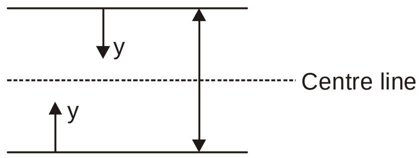
(a) linear with zero value at the plates

(b) linear with zero value at the center

(c) quadratic with zero value at the plates

(d) quadratic with zero value at the center

Sol–11: (b)



Velocity variation

$$v = \frac{1}{2\mu}\left(\frac{-\partial p}{\partial x}\right)(By - y^2)$$

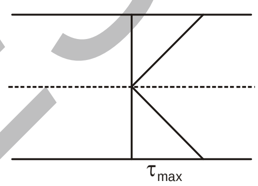
Shear stress

$$\tau = \mu\frac{du}{dy}$$

$$= \frac{1}{2}\times\left(-\frac{\partial p}{\partial x}\right)(B-2y)$$

$$y = \frac{B}{2}, \quad \tau = 0$$

$$y = 0, \quad \tau = \tau_{max}$$



Shear variation

12. The reaction rate involving reactions A and B is given by $-k[A]^{\alpha}[B]^{\beta}$. Which one of the the following statements is valid for the reaction to be a first-order reaction?

(a) $\alpha = 0$ and $\beta = 0$ (b) $\alpha = 1$ and $\beta = 0$

(c) $\alpha = 1$ and $\beta = 1$ (d) $\alpha = 1$ and $\beta = 2$

Sol–12: (b)

In chemical kinetics, the order of reaction with respect to a given substance (reactant, catalyst or product) is defined as the index or exponent to which its concentration term in the rate equation is raised. For typical rate equation of form

$$r = k[A]^x [B]^y$$

Overall reaction order = x + y

So first order reaction

$$\alpha + \beta = 1$$

Hence option (b).

13. A uniformly distributed line load of 500 kN-m is acting on the ground surface based on Boussinesq's theory, the ratio of vertical stress at a depth 2 m to that at 4 m right below the limit of loading is

(a) 0.25 (b) 0.5

(c) 2.0 (d) 4.0

Sol–13: (c)

Due to uniformly distributed line load vertical stress

$$= \frac{2q}{\pi z}\left[\frac{1}{1+\left(\frac{x}{z}\right)^2}\right]^2$$

Vertically below line load x = 0

$$\sigma_z = \frac{2q}{\pi z}$$

$$\frac{\sigma_1}{\sigma_2} = \frac{z_2}{z_1} = \frac{4}{2} = 2$$

14. A super-elevation e is provided on a circular horizontal curve such that a vehicle can be stopped on the curve without sliding. Assuming a design speed v and maximum coefficient of side friction f_{max}, which one of the following criteria should be satisfied?

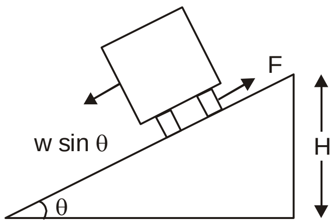
(a) $e \le f_{max}$

(b) $e > f_{max}$

(c) no limit of e can be set

(d) $e = \frac{1-(f_{max})^2}{f_{max}}$

Sol–14: (a)



Let the weight of vehicle = W

in stopping condition the friction force F should be greater than $w \sin\theta$ to prevent the sliding

$F > w\sin\theta$

for smaller value of Q

$\tan\theta = e = \sin\theta$

$F = w \times f$

$w \times f \geq w \times e$

$f > e$

15. The matrix P is the inverse of a matrix Q. If I denotes the identity matrix, which one of the following options is correct?

(a) $PQ = I$ but $QP \neq I$

(b) $QP = I$ but $PQ \neq I$

(c) $PQ = I$ and $QP = I$

(d) $PQ - QP = I$

Sol–15: (c)

Given, $P = Q^{-1}$

Post multiply by Q

$PQ = Q^{-1}Q$ (we know $Q^{-1}Q = I$)

$PQ = I$

Again premultiply by Q

$QP = QQ^{-1}$

$QP = I$ ($QQ^{-1} = I$)

So, $PQ = I$ and $QP = I$

16. The number of spectral bands in the Enhanced Thematic Mapper sensor on the remote sensing satellite Landsat-7 is

(a) 64 (b) 10

(c) 8 (d) 15

Sol–16: (c)

Landsat enhanced Thematic Mapper sensor on the remote sensing satellite Landsat-7 has 8 number of spectral bands.

Band 1 – Blue

Band 2 – Green

Band 3 – Red

Band 4 – Near Infrared (NIR)

Band 5 – Shortwave Infrared $(SWIR)_1$

Band 6 – Thermal

Band 7 – Shortwave Infrared $(SWIR)_2$

Band 8 – Panchromatic

17. The number of parameters in the univariate exponential and Gaussian distributions, respectively are

(a) 2 and 2 (b) 1 and 2

(c) 2 and 1 (d) 1 and 1

Sol–17: (b)

Probability distribution function (PDF) of an exponential distribution is

$$f(x,\lambda) = \begin{cases} \lambda e^{-\lambda x} & x \geq 0 \\ 0 & x < 0 \end{cases}$$

Cumulative distribution function of an exponential distribution is

$$f(x,\lambda) = \begin{cases} 1-e^{-\lambda x} & x \geq 0 \\ 0 & x < 0 \end{cases}$$

where $\lambda > 0$ is the parameter of distribution. So only one parameter in exponential distribtuion.

The normal (or Gaussion) distribution is a very common continuous probability distribtuion.

The probability density of normal distribution is

$$\delta\left(\frac{x}{\mu}, \sigma^2\right) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

So there are two parameters i.e. (μ and σ^2) in gaussian distribution.

18. Vehicles arriving at an intersection from one of the approach roads follow the Poisson distribution. The mean rate of arrival is 900 vehicles per hour. If a gap is defined as the time difference between two successive vehicle arrivals (with vehicles assumed to be points), the probability (up to four decimal places) that the gap is greater than 8 seconds is ______

Sol–18: (0.1353)

Probability of time headway being greater than 8 sec.

$$P(h \geq 8) = e^{-8\lambda} = e^{-8\times\frac{900}{3600}}$$
$$= e^{-2} = 0.1353$$

19. The wastewater from a city, containing a high concentration of biodegradable organics, is being steadily discharged into a flowing river at a location S. If the rate of aeration of the river water is lower than the rate of degradation of the organics, then the dissolved oxygen of the river water

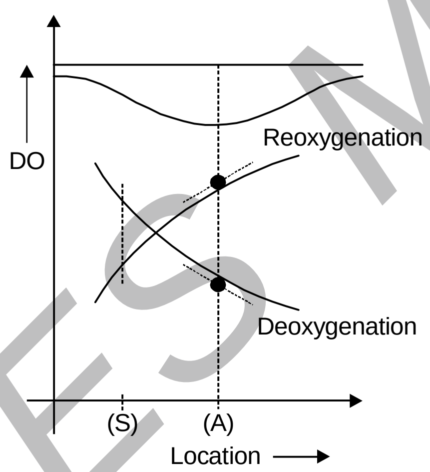
(a) is lowest at the location S

(b) is lowest at a point upstream of the location S

(c) remains constant all along the length of the river

(d) is lowest at a point downstream of the location S

Sol–19: (d)



At (A) rate of reoxygenation is equal to rate of deoxygenation.

Before (A) rate of reoxygenation is less that rate of deoxygenation. The DO continuously decreases when rate of deoxygenation > Rate of reoxygenation

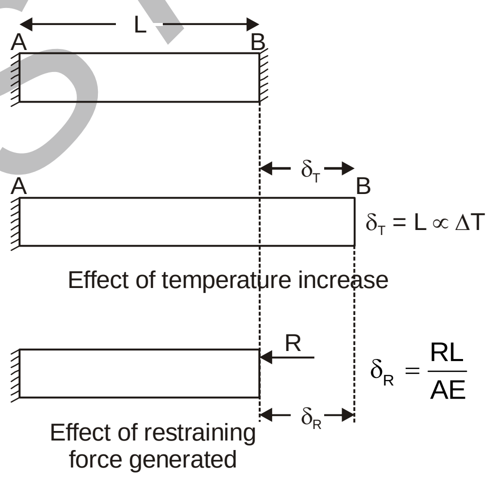
It reaches a minimum when the two rates because equal in magnitude and after that when rate of reoxygenation > rate of deoxygenation, DO increases. In the figure, the point (S) is at upstream of minimum DO location or minimum location is downstream of (S).

20. An elastic bar of length L, uniform cross sectional area A, coefficient of thermal expansion α and Young's modulus E is fixed at the two ends. The temperature of the bar is increased by T, resulting in an axial stress σ. Keeping all other parameters unchanged, if the length of the bar is doubled, the axial stress would be

(a) σ (b) 2σ

(c) 0.5σ (d) $0.25\,\alpha\sigma$

Sol–20: (a)



From compatibility

$$\delta_T = \delta_R = 0$$

$$\Rightarrow \quad L\propto\Delta T = \frac{RL}{AE}$$

$$\Rightarrow \quad \sigma = \frac{R}{A} = \text{Stress}$$

$$= E\propto\Delta T$$

Hence stress is independent of length of bar.

21. A simply supported beam is subjected to a uniformly distributed load. Which one of the following statements is true?

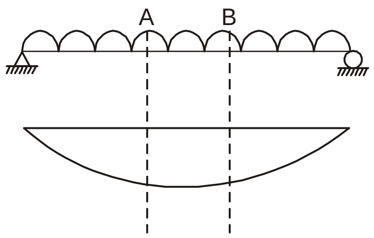
(a) Maximum or minimum shear force occurs where the curvature is zero.

(b) Maximum or minimum bending moment occurs where the shear force is zero

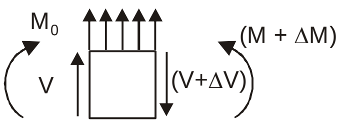
(c) Maximum or minimum bending moment occurs where the curvature is zero

(d) Maximum bending moment and maximum shear force occur at the same section

Sol–21 : (b)



For section AB



For equilibrium, $\sum M_0 = 0$

$$M + V\Delta x + W_x\Delta_x\frac{\Delta x}{2} - (M + \Delta M) = 0$$

$$\Delta M = V\Delta x + W_x\frac{(\Delta x)^2}{2}$$

$$\lim_{\Delta x\to 0}\frac{\Delta M}{\Delta x} = \lim_{\Delta x\to 0}\left(V + W_x\frac{(\Delta x)}{2}\right)$$

$$\Rightarrow \frac{dM}{dx} = V \quad \text{...(i)}$$

and we know that for any function to the maximum or minimum it's differential should be equal to zero.

Hence is equation (i) for bending moment (M) to be maximum or minimum $\Rightarrow \frac{dM}{dx} = 0$

Hence $\boxed{\frac{dM}{dx} = 0 =}$ V = 0

22. The ordinates of a 2-hour unit hydrograph for a catchment are given as

Time (h)	0	1	2	3	4
Ordinate (m^3/s)	0	5	12	25	41

The ordinate (in m^3/s) of a 4-hour unit hydrograph for this catchment at the time of 3 h would be ________

Sol–22 : (15)

Lagging 2-hr ordinate unit hydrograph by 2-hr and adding it with 2-hr unit hydrograph.

Time	A Ordinate	B Lagged ordinate	A + B	$\frac{A+B}{2}$
0	0		0	0
1	5		5	2.5
2	12	0	12	6
3	25	5	30	15
4	41	12	53	26.5

Hence ordinate of resulting hydrograph at 3hrs would be = 15 m^3/s

23. According to IS 456–2000, which one of the following statements about the depth of neutral axis $x_{u,bal}$ for a balanced reinforced concrete section is correct?

(a) $x_{u,bal}$ depends on the grade of concrete only

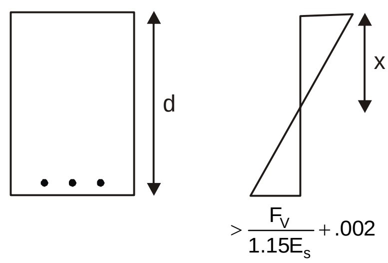
(b) $x_{u,bal}$ depends on the grade of steel only

(c) $x_{u,bal}$ depends on both the grade of concrete and grade of steel

(d) $x_{u,bal}$ does not depend on the grade of concrete and grade of steel

Sol–23 : (b)

For limiting or balanced depth of neutral axis.



For the recommendation that,

$$E_{st} \geq \frac{.87f_y}{E_s} + .002$$

and strain in concrete at collapse, should be max of .0035

$$\frac{0.0035(d - x_u)}{x_0} \geq \frac{0.87f_y}{E_s} + 0.002$$

$$\left(\frac{d}{x_0}-1\right) \geq \frac{\frac{0.87f_y}{E_s}+0.002}{0.0035}$$

$$\frac{d}{x_u} \geq \frac{\frac{0.87f_y}{E_s}+0.0055}{0.0035}$$

$$\frac{x_u}{d} \leq \frac{0.0035}{\frac{0.87f_y}{E_s}+0.0055}$$

Thus limiting value of netural axis depth is given by.

$$\boxed{\left(\frac{x_u}{d}\right)_{lim} = \frac{0.0035}{0.0055+\frac{0.87f_y}{E_s}}}$$

Hence, balanced or limiting depth of neutral axis is dependent on grade of steel only.

24. Which one of the following is NOT present in the acid rain?

(a) HNO_3 (b) H_2SO_4

(c) H_2CO_3 (d) CH_3COOH

Sol–24 : (d)

Acid rain results due to conversion of atmospheric gases into strong acidic compounds. NO_x, SO_x and CO_2 present in the atmospheic reacts with the water vapour and sunlight forming HNO_3, H_2SO_4 and H_2CO_3 which are present in the acid rain.

25. The accuracy of an Electronic Distance Measuring Instrument (EDMI) is specified as ±(a mm + b ppm). Which one of the following statements is correct?

(a) Both a and b remain constant, irrespective of the distance being measured.

(b) a remains constant and b varies in proportion to the distance being measured.

(c) a varies in proportion to the distance being measured and b remains constant.

(d) Both a and b vary is proportion to the distance being measured.

Sol–25 : (b)

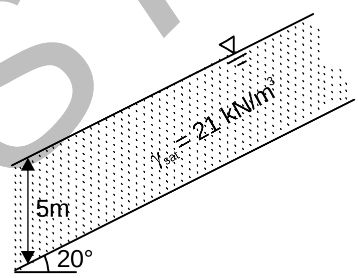
Accuracy of EDMI is generally stated in terms of constants instruments error and measuring error proportional to the distance being measured.

± (a mm + b ppm)

The first part in this expression indicates a constant instrument error that is independent of the length of line measured.

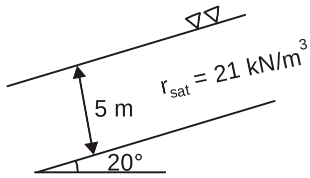
Second component is distance related error.

26. The infinite sand slope shown in the figure is one the verge of sliding failure. The ground water table coincides with the ground surface. Unit weight of water γ_w = 9.81 kN/m^3.



The value of the effective angle of internal friction (in degrees upto one decimal place) of the sand is _________

Sol–26 : 34.33°



$$\text{F.O.S.} = \frac{\text{Effect stress}}{\text{Total stress}}$$

$$\text{F.O.S} = \frac{\gamma_{sub} H\cos^2\beta\tan\phi}{\gamma_{sat} H\cos\beta\sin\beta}$$

$$1 = \frac{\gamma_{sub}\tan\phi}{\gamma_{sat}\tan\beta}$$

$$1 = \frac{(21-9.81)\tan\phi}{21\tan 20°}$$

$$\tan\phi = \frac{21\times\tan 20^\circ}{11.19}$$

$$\boxed{\phi = 34.33}$$

27. The wastewater having an organic concentration of 54 mg/l is flowing at a steady rate of 0.8 m^3/day through a detention tank of dimensions 2 m × 4 m × 2 m. If the contents of the tank are well mixed and the decay constant is 0.1 per day, the outlet concentration (in mg/l, up to one decimal place) is ____________

Sol–27 : 0.54 mg/l

Given $\Rightarrow$ Initial concentration (L_0) = $54 \frac{mg}{l}$

Q = 0.8 m^3/day

V = 2 × 4 × 2 = 16 m^3

Detention Time (t_d) = $\frac{16}{0.8}$ = 20 day

Outlet concentration $L_t = L_0 - Kt_d$

Note: If decay constanmt is between 0.1 to 0.2 per day then we take base as 10.

If decay constant is greater then 0.2 then we take base as e.

$L_t = L_0 \times 10^{-0.1 \times 20}$

$= 54 \times 10^{-0.1 \times 20}$

= 0.54 mg/*l*

Note that if decay constant is assumed to have been given at base 'e'

$L_t = L_0 e^{-Kt} = 54e^{-0.1 \times 20} = 7.3$ mg/*l*

28. The laboratory tests on a soil sample yields the following results: natural moisture content = 18%, liquid limit = 60%, plastic limit = 25%, percentage of clay sized fraction = 25%. The liquidity index and activity (as per the expression proposed by Skempton) of the soil, respectively, are

(a) –0.2 and 1.4 (b) 0.2 and 1.4

(c) –1.2 and 0.714 (d) 1.2 and 0.714

Sol–28 : (a)

Given $\Rightarrow$ W_{LL} = 60% = 0.6

W_{PL} = 25% = 0.25

% of clay sized fraction 25% = 0.25

W_n = 18% = 0.18

$$I_L = \frac{W_n - W_{PL}}{W_{LL} - W_{PL}}$$

$$= \frac{0.18 - 0.25}{0.6 - 0.25} = -0.2$$

$$\text{Activity} = \frac{I_P}{\text{\% of clay sized fraction}}$$

$$= \frac{W_{LL} - W_{PL}}{0.25} = \frac{0.6 - 0.25}{0.25} = 1.4$$

29. The following observations are made while testing aggregate for its suitability in pavement construction:

(i) Mass of oven-dry aggregate in air = 1000g

(ii) Mass of saturated surface-dry aggregate in air = 1025g

(iii) Mass of saturated surface-dry aggregate under water = 625 g

Based on the above observations, the correct statement is

(a) bulk specific gravity of aggregate = 2.5 and water absorption = 2.5%

(b) bulk specific gravity of aggregate = 2.5 and water absorption = 2.4%

(c) apparent specific gravity of aggregate = 2.5 and water absorption = 2.5%

(d) apparent specific gravity of aggregate = 2.5 and water absorption = 2.4%

Sol–29 : (a)

Mass of oven dry aggregate = W_a = 1000g

Mass of water in saturated surface dry aggregate = W_w

Mass of saturated surface dry aggregate = 1025g = $W_a + W_w$

$\therefore$ W_w = 1025 – 1000 = 25g

Mass of saturated surface dry aggregate under water

= 625g

$\Rightarrow$ $W_a - (V_a)\rho_w$ = 625g (Va = Volume of aggregate)

$$\Rightarrow V_a = \frac{1000-625}{1} = 375 \text{ CC.}$$

Volume of void (V_v) = volume of water = V_w =

$$\frac{W_w}{\rho_w} = \frac{25}{1} = 25\text{cc}$$

$\therefore$ Bulk density of aggregate = $\rho_{ba} = \dfrac{W_a}{V_a + V_v}$

$$= \frac{1000}{375+25}\text{g/cc}$$

$\therefore$ Bulk specific gravity of aggregate

$$= \frac{\rho_{ba}}{\rho_w} = \frac{2.5}{1} = 2.5$$

$$\text{Water absorption} = \frac{W_w}{W_a}\times 100 = \frac{25}{1000}\times 100$$

= 2.5%

30. The radius of a horizontal circular curve on a highway is 120 m. The design speed is 60 km/hour, and the design coefficient of lateral friction between the tyre and the road surface is 0.15. The estimated value of superelevation required (if full lateral friction is assumed to develop), and the value of coefficient of friction needed (if no superrelevation is provided) will, respectively, be

(a) $\frac{1}{11.6}$ and 0.10 (b) $\frac{1}{10.5}$ and 0.37

(c) $\frac{1}{11.6}$ and 0.24 (d) $\frac{1}{12.9}$ and 0.24

Sol–30 : (c)

Given $\Rightarrow$ R = 120m

$$V_{design} = 60\ \frac{\text{km}}{\text{hr}}$$

f = 0.15

$$e + f = \frac{v^2}{gR}$$

$$\Rightarrow e + 0.15 = \frac{(60\times 5/18)^2}{9.81\times 120}$$

$$e = \frac{(60\times 5/18)^2}{9.81\times 120} - 0.15 = \frac{1}{11.6}$$

$$e + f = \frac{v^2}{gR}$$

$\Rightarrow$ e = 0

$$\Rightarrow f = \frac{(60\times 5/15)^2}{9.81\times 120}$$

= 0.2359 = 0.24

31. For the function f(x) = a + bx, $0 \le x \le 1$, to be a valid probability density function, which one of the following statements is correct?

(a) a = 1, b = 4 (b) a = 0.5, b = 1

(c) a = 0, b = 1 (d) a = 1, b = –1

Sol–31 : (b)

For probability density function = f(x) to be valid $\int_{-\infty}^{\infty} f(x) = 1$

$$\int_{-\infty}^{\infty} a + bx = 1$$

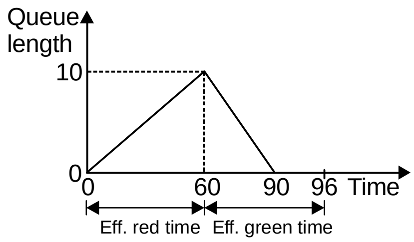
$$\int_0^{1} (a+bx)dx = 1$$

$$\left. ax + \frac{bx^2}{2}\right]_0^1 = 1$$

$$a + \frac{b}{2} = 1$$

for equation to be satisfied a = 0.5 b = 1

32. The queue length (in number of vehicles) versus time (in seconds) plot for an approach to a signalized intersection with the cycle length of 96 seconds is shown in the figure (not drawn to scale).



At time t = 0, the light has just turned red. The effective green time is 36 seconds, during which vehicles discharge at the saturation flow rate, s (in vph). Vehicles arrive at a uniform rate, v (in vph), throughout the cycle. Which one of the following statements is TRUE?

(a) v = 600 vph, and for this cycle, the average stopped delay per vehicle = 30 seconds

(b) s = 1800 vph, and for this cycle, the average stopped delay per vehicle = 28.125 seconds

(c) v = 600 vph, and for this cycle, the average stopped delay per vehicle = 45 seconds

(d) s = 1200 vph, and for this cycle, the average stopped delay per vehicle = 28.125 seconds

Sol–32 : (b)

Vehicle arrived upto 60 sec (Red time) = 10

arrival rate = $\frac{10}{60}\times 3600 = 600$ V/h

$\boxed{V = 600 \text{ V/h}}$

$\rightarrow$ departure at vehicle starts at 60 second and ends at 90 seconds.

So, between 60 second to 90 second total vehicle departed

= Vehicle arrived upto 60 second + Vehicle arriving between 60 sec to 90 sec

$= 10 + \frac{600}{3600}\times 30$

= 10 + 5

= 15

So, departure rate = Saturation flow

$= S = \frac{15}{30}\times 3600$

$\boxed{S = 1800 \text{ v/h}}$

Average delay time is given by

$$t_d = \frac{\frac{C}{2}\left(1-\frac{g}{c}\right)^2}{1-\frac{V}{S}}$$

C = 96 seconds

g = 96 – 60 = 36 seconds

V = 600 Vph

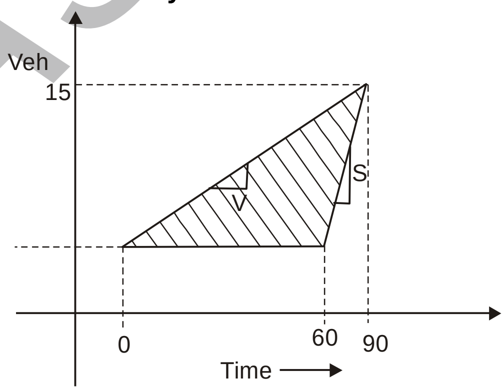
S = 1800 Vph

$$t_d = \frac{\frac{96}{2}\left(1-\frac{36}{96}\right)^2}{1-\frac{600}{1800}}$$

$\boxed{t_d = 28.125 \text{ seconds}}$

So, (b) option is true

Alternatively



Total no. of vehicles arriving in 90 sec

$= \frac{10}{60}\times 90 = 15$

V = Vehicle arrival rate

$= \frac{15}{90}\times 3600 = 600$ veh/hr

S = Vehicle discharge rate

$= \frac{15}{30}\times 3600 = 1800$ veh/hr

Aggregate delay = Area under shaded diagram

$= \frac{1}{2}\times 15\times 60 = 450$ veh sec

Av. Stop delay per veh = $\frac{450 \text{ veh sec}}{\text{no. of veh. arriving (in one cycle time)}}$

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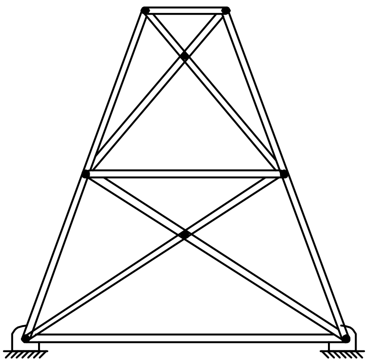
$$= \frac{450}{\frac{15}{90}\times 96} = 28.125 \text{ sec}$$

Hence option (b) is correct

33. A planar truss tower structure is shown in the figure.



Consider the following statements about the external and internal determinacies of the truss.

P. Externally determinate

Q. External static indeterminacy = 1

R. External Static Indeterminacy = 2

S. Internally Determinate

T. Internal Static Indeterminacy = 1

U. Internal Static Indeterminacy = 2

Which one of the following options is correct?

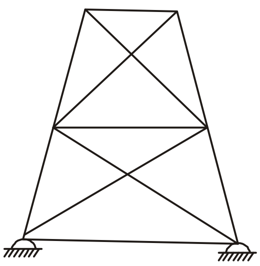
(a) P-Flase; Q-True; R-False; S-False; T-False; U-True

(b) P-False; Q-True; R-False; S-False; T-True; U-False

(c) P-False; Q-False; R-True; S-False; T-False; U-True

(d) P-True; Q-True; R-False; S-True; T-False; U-True

Sol–33 : (a)



For truss,

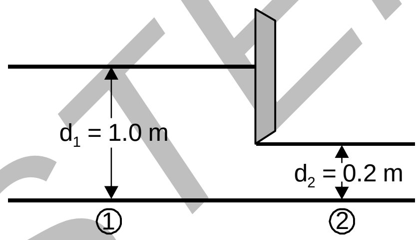
External Indeterminacy = r – 3

r = no of support reactions

External Indeterminacy = 4 – 3 = 1

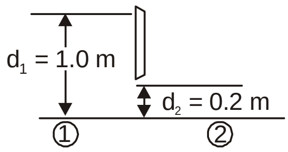
Internal Indeterminacy = no. of panels of double diagonal = 1 + 1 = 2 .

34. A sluice gate used to control the flow in a horizontal channel of unit width is shown in the figure.



It is observed that the depth of flow is 1.0 m upstream of the gate, while the depth is 0.2 m downstream of the gate. Assuming a smooth flow transition across the sluice gate, i.e., without any energy loss, and the acceleration due to gravity as 10 m/s^2, the discharge (in m^3/s, up to two decimal places) passing under the sluice gate is ____________

Sol–34 : 0.82 m^3/s per metre width



There is no energy loss so

$$E_1 = E_2$$

$$y_1 + \frac{v_1^2}{2g} = y_2 + \frac{v_2^2}{2g}$$

$$1 + \frac{Q}{2gA_1^2} = 0.2 + \frac{Q}{2gA_2^2}$$

$$\frac{Q^2}{2g}\left[\frac{1}{A_2^2} - \frac{1}{A_1^2}\right] = 1 - 0.2$$

$$\frac{Q^2}{2\times 10}\left[\frac{1}{0.2^2} - \frac{1}{1^2}\right] = 0.8$$

$$Q^2 = \frac{16}{24}$$

$$Q^2 = \frac{2}{3}$$

$$Q = 0.82\ m^3/s$$

35. Group I contains three broad classes of irrigation supply canal outlets. Group II presents hydraulic performance attributes.

Group-I	Group-II
P. Non-modular outlet	1. Outlet discharge depends on the water levels in both the supply canal as well as the receiving water course
Q. Semi-modular outlet	2. Outlet discharge is fixed and is independent of the water levels in both the supply canal as well as the receiving water course
R. Modular outlet	3. Outlet discharge depends only on the water level in the supply canal.

The correct match of the items in Group I with the items in Group II is

(a) P-1; Q-2; R-3 (b) P-3; Q-1; R-2

(c) P-2; Q-3; R-1 (d) P-1; Q-3; R-2

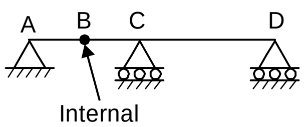
Sol–35: (d)

Non modulor outlet : These are outlets through which the discharge depends upon the difference of head between the distributary and the water course.

Semi modulator outlet : These are outlets through which the discharge is independent of the distribitary so long as a minimum working head is available and depends upond distributary water surface level.

Modular outlet : these are outlets through which discharge is constant and fixed within limits irrespective of the fluctuations of the water levels of either the distributary or of the water course or of both.

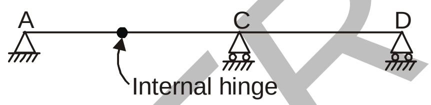
36. Consider the beam ABCD shown in the figure.



AB = BC = 4m
CD = 10 m

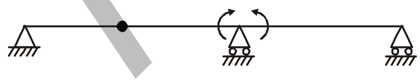
For a moving concentrated load of 50 kN on the beam, the magnitude of the maximum bending moment (in kN-m) obtained at the support C will be equal to ____________

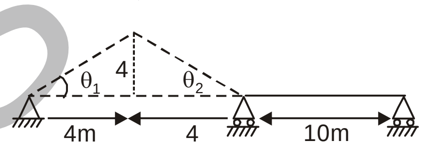
Sol–36: (200)



AB = BC = 4m
CD = 10m

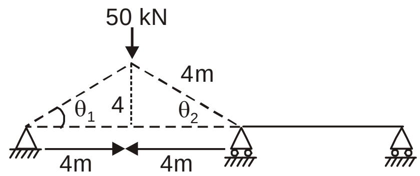
⇒ According to Muller Breslau Principel ILD for moment at C





$$\theta_1 = \tan 45°$$

For maximum bending moment



Hence, $M_{max} = 50 \times 4$

$= 200$ kNm

37. A consolidated undrained $(\overline{CU})$ triaxial compression test is conducted on a normally consolidated clay at a confining pressure of 100 kPa. The deviator stress at failure is 80 kPa, and the pore-water pressure measured at failure is 50 kPa. The effective angle of internal friction (in degrees, up to one decimal place) of the soil is __________

Sol–37: (26.4)

Confining pressure = $\sigma_3 = 100kP_a$

Deviator stress = $\sigma_1 - \sigma_3 = 80kP_a$

$$\sigma_1 = 80 + \sigma_3$$

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ESE-2017 Conventional Test Schedule, Civil Engineering

Date		Topic
19th Feb 2017	**N.T.** :	M-1, M-3, M-4, SM-1, SM-3, SM-8
	R.T. :	
26th Feb 2017	**N.T.** :	SA-1, SA-2, SA-5, HY-1, HY-4, HY-5, M-5
	R.T. :	SM-1, M-1
5th Mar 2017	**N.T.** :	DSS-4, DSS-5, FM-1, FM-4, FM-6
	R.T. :	M-3, SA-1, SA-2
11th Mar 2017	**N.T.** :	SA-6, SA-4, SA-3, EE-6, EE-5, EE-4
	R.T. :	FM-4, FM-6, M-1, M-4, M-3, HY-1
19th Mar 2017	**N.T.** :	FM-7, RCC-1, RCC-2, RCC-3, HY-2
	R.T. :	SA-1, SA-2, SM-3, FM-6, EE-6
26th Mar 2017	**N.T.** :	SM-4, DSS-1, DSS-2, DSS-3, RCC-4, RCC-5, RCC-6
	R.T. :	SM-1, SA-3, EE-5
2nd Apr 2017	**N.T.** :	SU-1, SU-2, SU-3, SM-2, SM-5, SM-6, SM-7, HY-3, SU-5
	R.T. :	FM-7, RCC-1, RCC-2, RCC-3, HY-1, EE-6
9th Apr 2017	**N.T.** :	TF-1, TF-2, TF-3, TF-4, FM-5, M-2
	R.T. :	RCC-5, DSS-1, DSS-2, SM-4, M-1, M-3, M-4, FM-4, SA-1
16th Apr 2017	**N.T.** :	IR-1, IR-2, IR-3, IR-4, EE-7
	R.T. :	SM-5, SM-6, FM-1, EE-5, DSS-3, DSS-4, HY-3, HY-4, HY-5, SU-1, SU-2
23rd Apr 2017	**N.T.** :	CPM-1, CPM-2, EE-1, EE-2, EE-3, SU-4 (Railway & Airport)
	R.T. :	SM-4, FM-5, TF-1, TF-2, FM-7, SA-3, SU-3, SU-5, RCC-5
30th Apr 2017	**N.T.** :	FM-2, FM-3, FM-8, Building Material, Ports & Harbors/Tunneling
	R.T. :	IR-1, IR-2, HY-2, DSS-4, DSS-2, SA-1, SA-2, SA-3, RCC-6, EE-2, FM-6
07th May 2017		Full Length (Test Paper-1 + Test Paper-2)

Test Type	Timing	Day
Conventional Test	10:00 A.M. to 1:00 P.M.	Sunday
Conventional Full Length Test Paper-1	10:00 A.M. to 1:00 P.M.	Sunday
Conventional Full Length Test Paper-2	02:00 P.M. to 5:00 P.M.	Sunday

Note : The timing of the test may change on certain dates. Prior information will be given in this regard.

***N.T. :** New Topic. ***R.T. :** Revision Topic

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Subject Code Details

Structural Analysis (SA)

SA-1	SA-2	SA-3	SA-4	SA-5	SA-6
Slope Deflection Method	Moment Distribution Method	Truss, Cables	Force Method, • Consistent Deformation Method • Method of Least work • Castigliano's Method	Determinacy/ indeterminacy/ stability	Stiffness Matrix Method, Influence Line Diagram/ Moving Load

SOM (M)

M-1	M-2	M-3	M-4	M-5
Concept of Stress and Strain	Shear Force & Bending Moment, Deflection of Beams	Transformation of Stress & Strains, Theory of Failure, Combined Bending & Torsion/ Combined bending & Transverse shear stress/ combined bending & Axial stress, Torsion	Bending Stress, Shear Stress	Columns, Springs, Thick & Thin Shells, Moment of inertia

RCC & PSC (RCC)

RCC-1	RCC-2	RCC-3	RCC-4	RCC-5		RCC-6
Working stress Method of RCC Design	Limit State Method	Earthquake resistant structures, Beams (LS, WS), Lintels	Slab-One way, (LS, WS) Staircase	Column, (LS, WS) Tanks	Fooling (LS, WS), Retaining Wall	Cement & Concrete, Masonry Structures, PSC-Pre stressed Concrete

Design of Steel Structure (DSS)

DSS-1	DSS-2	DSS-3	DSS-4	DSS-5	DSS-6
Compression member	Plastic Analysis	Beams	Connections (Direct, Eccentric)	Tension Member	Plate girders, Industrial building

Pert & CPM (CPM)

CPM-1	CPM-2
Network analysis, Pert, CPM, Crashing, Resource allogaction, Levelling, Smoothing, Rate Analysis	Construction equipments, Engineering Economy, Tendering Process and Contract Management

Building Material (BM)

BM-1	BM-2
Cement, Concrete, Stone, Lime, Glass, Steel	Brick Mortar Timber, Plastics, FRP, Ceramics, Aluminium

Environmental (EE)

EE-1	EE-2	EE-3	EE-4	EE-5	EE-6	EE-7
Characteristics of water, Treatment of water	Distribution of water	Characteristics of Sewage	Disposal of Sewage	Sewer design	Treatment of Sewage	Air Pollution, Noise Pollution, Miscellaneous topics

Fluid Mechanics (FM)

FM-1	FM-2	FM-3	FM-4	FM-5	FM-6	FM-7	FM-8
Fluid properties, Hydrostatic Pressure, Liquid in relative equilibrium, Buoyancy & Flotation	Fluid Kinematics	Fluid Dynamics, Weirs & Notches	Laminar flow, Turbulent flow, Boundary layer theory, Drag & lift	Flow through Pipes	Open channel flow	Hydraulic Machines	Modal Analysis & Dimensional Analysis

Soil Mechanics (SM)

SM-1	SM-2	SM-3	SM-4	SM-5	SM-6	SM-7	SM-8
Classification of Soil, Soil water relationships, index properties of Soil, Compaction of Soil	Effective stress, Seepage	Consolidation	Shear Stress/ Vertical Stress	Earth Pressure, Stability of Slopes	Bearing capacity- Shallow Foundation	Deep foundation - Piles	Exploration of Soil, Expansive Soil, Geosynthetics

Transportation (TF)

TF-1	TF-2	TF-3	TF-4
Geometric Design	Pavement Design	Materials, Construction, Maintenance, Hill roads etc.	Traffic Engineering

Surveying (SU)

SU-1	SU-2	SU-3	SU-4	SU-5
Scale/ Accuracy, Measurements of horizontal distances	Angular Measurements	Levelling, Contouring	Triangulation & Traversing Plane, tabling, Geology	Photogrammetry, Field Astronomy, GPS, Remote Sensing

Irrigation (IR)

IR-1	IR-2	IR-3	IR-4
Soil water relationships, irrigation requirements of crops (Duty, Delta)	Design of Canals (Lacey & Kennedy)	Gravity dams	Cross drainage works, Weirs & Barrages, Seepage theory, Canal Falls/ Canal Regulators, Energy dissipators, River training works,

Hydrology (HY)

HY-1	HY-2	HY-3	HY-4	HY-5
Hydrographs	Flood Routing	Ground Water	Evapo-transpiration, Run off	Abstraction from Precipitation, Hydrological cycle, Precipitation

Railways / Airports / Ports & Harbours / Tunneling

$= 180$ kPa

Pore pressure = u = 50 kPa

$$\bar{\sigma}_1 = \sigma_1 - u$$
$$= 180 - 50$$
$$= 130 \text{ kPa}$$

$$\bar{\sigma}_3 = \sigma_3 - u$$
$$= 100 - 50$$
$$= 50 \text{ kPa}$$

For NC soil $C' = 0$

$$\bar{\sigma}_1 = \bar{\sigma}_3\left(\frac{1+\sin\phi}{1-\sin\phi}\right)$$

$$130 = 50\left(\frac{1+\sin\phi}{1-\sin\phi}\right)$$

$$\sin\phi = \frac{8}{18}$$

$$\phi = 26.38°$$

38. Consider the equation $\frac{du}{dt} = 3t^2 + 1$ with u = 0 at t = 0. This is numerically solved by using the forward Euler method with a step size, $\Delta t = 2$. The absolute error in the solution at the end of the first time step is ________

Sol–38: (8)

$$\frac{du}{dt} = 3t^2 + 1$$

Forward Eular Method

$$y_1 = y_0 + hf(t)$$

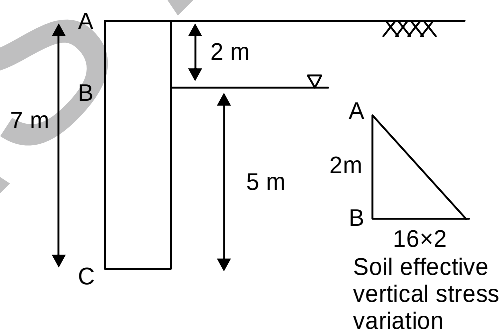
at $t = 0, u = 0$

$$y_1 = 0 + 2(3 \times 0^2 + 1)$$
$$u_1 = 2$$
$$\frac{du}{dt} = 3t^2 + 1$$
$$du = \int_0^2 (3t^2 + 1)dt$$
$$u_1 = t^3 + t]_0^2$$
$$u_1 = 10$$

Absolute error = 10 – 2 = 8

39. It is proposed to drive H-piles up to a depth of 7 m at a construction site. The average surface area of the H-pile is 3 m^2 per meter length. The soil at the site is homogeneous sand, having an effective friction angle of 32°. The ground water table (GWT) is at a depth of 2 m below the ground surface. The unit weights of the soil above the below the GWT are 16 kN/m^3 and 19 kN/m^3, respectively. Assume the earth pressure coefficient, K = 1.0, and the angle of wall friction, $\delta = 23°$. The total axial frictional resistance (in kN, up to one decimal place) mobilized on the pile against the driving is ________

Sol–39: (390.8)



Stress of B level = 16 × 2 = 32 $kN.m^2$

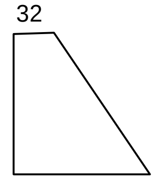
Average stress in AB = 16 kN/m^2

Axial frictional resistance in

$$AB = (K\sigma_{avg}\tan\delta)A_{AB}$$
$$A_{AB} = \text{Area of AB}$$
$$= 3 \times 2 = 6 \text{ m}^2$$
$$= (K\sigma_{avg}\tan\delta) \times 6$$
$$= (1 \times 16 \times \tan 23°) \times 6$$
$$= 40.75 \text{ kN}$$

In part BC :

Effective vertical stress variation



$$\sigma_{avg} = \frac{32+77.95}{2}$$

$= 54.975\ kN/m^2$

$A_{BC} = 3 \times 5$

$= 15\ m^2$

Axial frictional resistance in part BC

$= (K\sigma_{avg} \tan\delta)A$

$= (1\times 54.975 \times \tan 23°) \times 15$

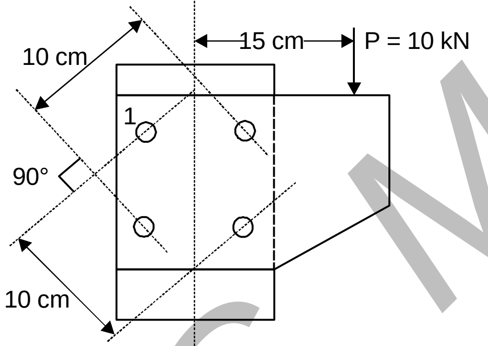
$= 350.03$ kN

Tota axial frictional resitance

$= 350.03 + 40.75$

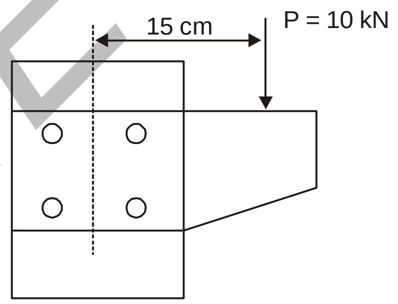
$= 390.78$ kN

40. A column is subjected to a load through a bracket as shown in the figure.



The resultant force (in kN, up to one decimal place) in the bolt is __________

Sol–40: (5.99)



P = 10 kN, e = 15 cm

$r_1 = r_2 = r_3 = r_4 = 5$ cm

Direct load to bolt (1) $= \frac{P}{4}$

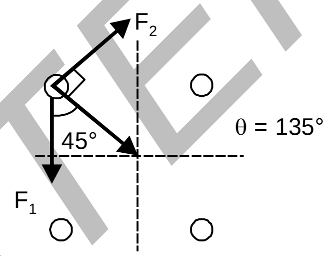
$$F_1 = \frac{10}{4} = 2.5\ kN$$

Force in bolt (1) due to moment

$$= \frac{Per_1}{\Sigma r_1^2}$$

$$F_2 = \frac{10\times 15\times 5}{4\times 5^2}$$

$= 7.5$ kN



Angle between force F_1 and F_2 = 135°

$$R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos(135°)}$$

$$= \sqrt{2.5^2 + 7.5^2 + 2\times 2.5 \times 7.5\times\cos(135°)}$$

$= 5.99$ kN

41. The solution of the equation $\frac{dQ}{dt} + Q = 1$ with Q = 0 at t = 0 is

(a) $Q(t) = e^{-t} - 1$ (b) $Q(t) = 1 + e^{-t}$

(c) $Q(t) = 1 - e^{t}$ (d) $Q(t) = 1 - e^{-t}$

Sol–41 : (d)

$$\frac{dQ}{dt} + Q = 1$$

$$1\cdot F = e^{\int \rho dt} = e^{\int 1\cdot dt} = e^t$$

$$Q(t)e^t = \int e^t dt$$

$$Q(t)e^t = e^t + C$$

At t = 0 Q = 0

$0 = 1 + C$

$C = -1$

$Q(t) = 1 - e^{-t}$

42. Consider the matrix $\begin{bmatrix} 5 & -1 \\ 4 & 1 \end{bmatrix}$ which one of the following statements is TRUE for the eigenvalues and eigenvectors of the matrix?

(a) Eighenvalue 3 has a multiplicity of 2 and only one independent eigenvector exists

(b) Eigenvalue 3 has a multiplicity of 2 and two independent eigenvectors exist

(c) Eigenvalue 3 has a multiplicity of 2 and no independent eigentvector exists

(d) Eigenvalues are 3 and –3 and two independent eighenvectors exist.

Sol–42 : (a)

$$[A] = \begin{bmatrix} 5 & -1 \\ 4 & 1 \end{bmatrix}$$

For eigen value

$$[A - \lambda I] = \begin{bmatrix} 5-\lambda & -1 \\ 4 & 1-\lambda \end{bmatrix}$$

$$(5-\lambda)(1-\lambda)+4=0$$

$$5-5\lambda-\lambda+\lambda^2+4=0$$

$$\lambda^2-6\lambda+9=0$$

$$(\lambda-3)^2=0$$

$$\lambda=3$$

For eigen vector

$$[A-\lambda I]\begin{bmatrix} x \\ y \end{bmatrix}=0$$

$$\begin{bmatrix} 5-3 & -1 \\ 4 & 1-3 \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix}=0$$

2x – y = 0

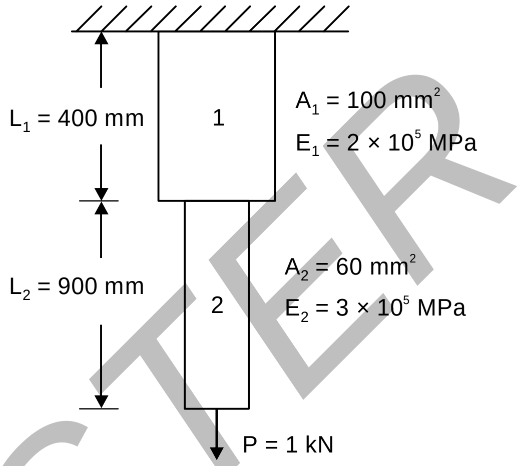
$$\begin{bmatrix} x \\ y \end{bmatrix}=\begin{bmatrix} 2 \\ 1 \end{bmatrix}$$

4x – 2y = 0

$$\begin{bmatrix} x \\ y \end{bmatrix}=\begin{bmatrix} 2 \\ 1 \end{bmatrix}$$

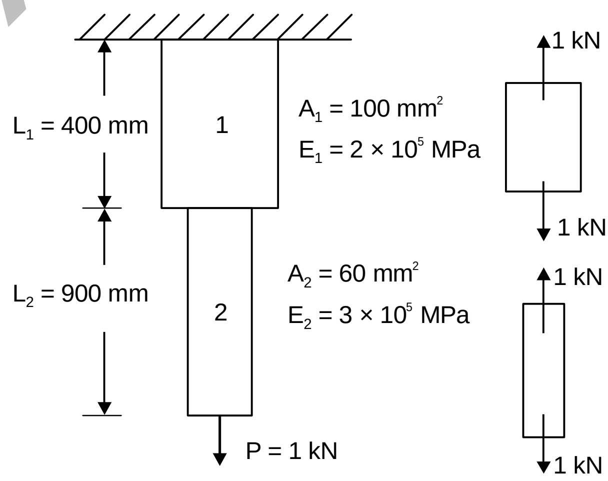
So, only one independent eigen vector.

43. Consider the stepped bar made with a linear elastic material and subjected to an axial load of 1 kN as shown in the figure/



Segments 1 and 2 have cross sectional area of 100 mm^2 and 60 mm^2 Young's modulus of 2×10^5 Mpa and 3×10^5 Mpa and length of 400 mm and 900 mm respectively. The strain energy in N-mm up to one decimal place in the bar due to the axial load is_______

Sol–43 : 35



$$U = \sum \frac{P^2 L_1}{2A_1E_1}$$

$$= \frac{(1000)^2 \times 400}{2\times100\times2\times10^5}+\frac{(1000)^2\times900}{2\times60\times3\times10^5}$$

= 10 + 25 = 35 Nmm

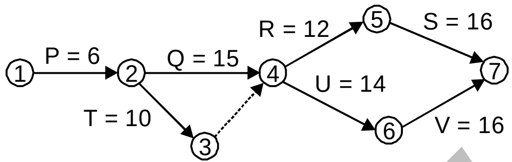
44. The activity details of a project are given below:

Activity	Depends on	Duration (in days)
P	—	6
Q	P	15
R	Q, T	12
S	R	16
T	P	10
U	Q, T	14
V	U	16

The estimated minimum time (in days) for the completion of the project will be_______

Sol–44 : 51

Activity on Arrow (AOA) diagram :



Time along path 1 – 2 – 4 – 5 – 7

= 6 + 15 + 12 + 16 = 49 days

Time along path 1 – 2 – 3 – 4 – 6 – 7

= 6 + 10 + 14 + 16 = 46 days

Time along path 1 – 2 – 4 – 6 – 7

= 6 + 15 + 14 + 16 = 51 days

Minimum time for the completion of the project will be = 51 days.

45. An effective rainfall of 2 hour duration produced a flood hydrograph peak of 200 m^3/s. The flood hygrograph has a base flow of 20 m^3/s if the spatial average rainfall in the watershed for the duration of storm is 2 cm and the average loss rate is 0.4 cm/hour the peak of 2-hour unit hygrograph (in m^3/s-cm up to one decimal place) is ______

Sol–45 : 150

Flood hydrograph peak = 200 m^3/s

Base flow = 20 m^3/s

Excess rainfall = 2 cm

ϕ = 0.4 cm/hr

Effective rainfall = 2 – 0.4 × 2 = 1.2 cm

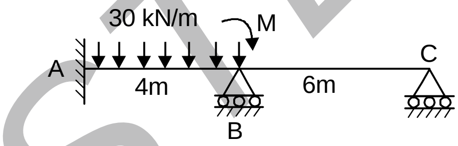
Peak of DRH = 200 – 20 = 180 m^3/s

Peak of 2-h unit hydrograph

$$= \frac{\text{Peak of DRH}}{\text{Effective rainfall}}$$

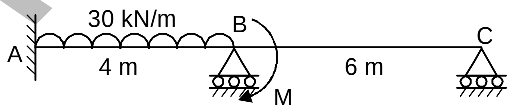
$$= \frac{180}{1.2} = 150\ \text{m}^3/\text{s}$$

46. The value of M in the beam ABC shown in the figure is such that the joint B does not rotate



The value of support reaction (in kN) at B should be equal to ______

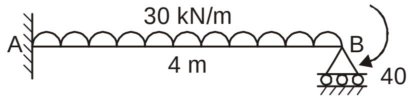
Sol–46 : 60

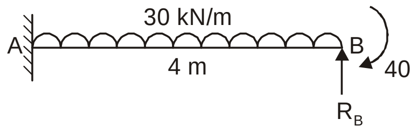


$$M_{BA} = M_{FBA} + \frac{2EI}{l}\left(2\theta_B + \theta_A - \frac{3\Delta}{l}\right)$$

$$\theta_B = 0 \qquad \theta_A = 0, \qquad \Delta = 0$$

$$M_{BA} = M_{FBA} = \frac{wl^2}{12} = \frac{30 \times 4^2}{12} = 40\ \text{kNm}$$





$$M_{BC} = \overline{M_{FBC}} + \frac{3EI}{6}\left(\theta_B - \frac{\Delta}{l}\right),$$

$$\Delta = 0, \theta_B = 0, \overline{M_{FBC}} = 0, M_{BC} = 0$$

$$M = M_{BA} + M_{BC}$$

$$\Rightarrow M = M_{BA} = 40$$

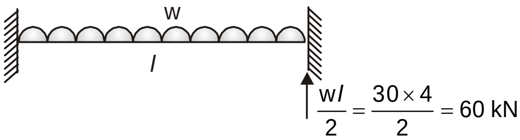
$$\Rightarrow \frac{wl^4}{8EI} + \frac{Ml^2}{2EI} = \frac{R_B \times l^3}{3EI}$$

$$\frac{30 \times 4}{8} + \frac{40}{2 \times 4} = \frac{R_B}{3}$$

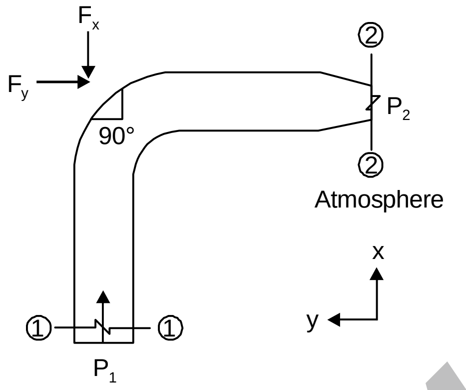
$$15 + 5 = \frac{R_B}{3}$$

$$R_B = 60 \text{ kN}$$

Alternatively



47. Water flows through a 90° bend in a horizontal plane as depicted in the figure.



A pressure of 140 kpa is measured at section 1-1. The inlet diameter marked at section 1-1 is $\frac{27}{\sqrt{\pi}}$ cm. While the nozzle diameter marked as section 2-2 is $\frac{14}{\sqrt{\pi}}$ cm. Assume the following

(i) Acceleration due to gravity = 10 m/s^2

(ii) Weights of both the bent pipe segment as well as water are negligible

(iii) Friction across the bend is neglibile

The magnitude of the force (in kN up to two decimal places) that would be required to hold the pipe section is _____

Sol–47 : 3.29

Pressure at the exit of nozzle is taken as zero because water at the outlet of nozzle will be discharging to atmosphere.

$$\frac{P_1}{\gamma_w} + Z_1 + \frac{V_1^2}{g} = \frac{P_2}{\gamma_w} + Z_2 + \frac{V_2^2}{2g}$$

$$\frac{140\times 10^3}{9810} + 0 = 0 + 0 + \frac{Q^2}{2g}\left(\frac{1}{A_2^2} - \frac{1}{A_1^2}\right)$$

$$280 = Q^2\left(\frac{1}{\left(\frac{\pi}{4}\times\frac{0.14^2}{\pi}\right)^2} - \frac{1}{\left(\frac{\pi}{4}\times\frac{0.27^2}{\pi}\right)^2}\right)$$

$$Q = 0.085 \text{ m}^3/\text{s}$$

In x-direction momentum equation is given by

$$P_1A_1 - F_x = \rho Q(V_2 - V_1),\ V_2 = 0,\quad V_1 = \frac{Q}{A_1}$$

$$= 140\times 10^3 \times \frac{\pi}{4}\times\frac{0.27^2}{\pi} + \frac{1000\times 0.085^2}{\frac{\pi}{4}\times\frac{0.27^2}{\pi}}$$

$$= 2.947 \text{ kN}$$

In y-direction momentum

$$F_y = \rho Q V_2$$

$$= 1000\times 0.085\times\frac{0.085}{\frac{\pi}{4}\times\frac{0.14^2}{\pi}}$$

$$= 1.47 \text{ kN}$$

$$\text{Resultant force} = \sqrt{2.947^2 + 1.47^2}$$

$$= 3.29 \text{ kN}$$

48. A particle of mass 2 kg is travelling at a velocity of 1.5 m/s. A force f(t) = $3t^2$ (in N) is applied to it in the direction of motion for a duration of 2 seconds. Where t denotes time in seconds. The velocity (in m/s up to one decimal place) of the particle immediately after the removal of the force is ______.

Sol–48 : 5.5 m/s

$$f(t) = 3t^2$$

$$mQ = 3t^2$$

$$m\frac{dv}{dt} = 3t^2$$

$$2\int_{1.5}^{v} dv = \int_0^2 3t^2\, dt$$

$$2(v - 1.5) = 8$$

$$v = 5.5 \text{ m/s}$$

49. Consider two axially loaded columns namely 1 and 2, made of linear elastic material with young's modulus 2×10^5 MPa, square cross-section with side 10 mm and length 1 m. For column 1. One end is fixed and the other end is free. For column 2 one end is fixed and the other end is pinned. Based on the Euler's theory the ratio (up to one decimal place) of the buckling load of column 2 to the buckling load of column 1 is ______

Sol–49 : 8

Euler's Buckling load = $\frac{\pi EI}{l_e^2}$

$l_{effective}$ for column 1 = $2l$

$l_{effective}$ for column 2 = $\frac{l}{\sqrt{2}}$

$$\frac{P_2}{P_1} = \left(\frac{l_1}{l_2}\right)_{effective} = \left(\frac{2l}{\frac{l}{\sqrt{2}}}\right)^2$$

$$= \left(2\sqrt{2}\right)^2 = 8$$

50. The observed bearings of a traverse are given below.

Line	Bearing	Line	Bearing
PQ	46°15′	QP	226°15′
QR	108°15′	RQ	286°15′
RS	201°15′	SR	20°30′
ST	321°15′	TS	141°45′

The station(s) most likely to be affected by the local attraction is/are

(a) Only R (b) Only S

(c) R and S (d) P and Q

Sol–50 : (a)

Line	Bearing	Back Bearing	Difference
PQ	46°15′	226°15′	180°
QR	108°15′	286°15′	180°
RS	201°15′	20°15′	181°
ST	321°15′	141°45′	180°

For bearing and back bearing difference for PQ, QR and ST is 180°. So, P, Q, S, T are free from any local attraction.

51. The equivalent sound power level (in dB) of the four sources with the noise levels of 60 dB 69 dB 70 dB and 79 dB is _______.

Sol–51 : 79.928 dB

Sound in decibals = $20\log\left(\frac{P_{rms}}{20}\right)$

$$\Rightarrow \quad 60 = 20\log\left(\frac{P_{rms1}}{20}\right)$$

$$\Rightarrow \quad \left(\frac{P_{rms}}{20}\right)_1 = 10^{60/20} = 1000$$

$$\left(\frac{P_{rms}}{20}\right)_2 = 10^{69/20} = 2818.3829$$

$$\left(\frac{P_{rms}}{20}\right)_3 = 10^{70/20} = 3162.2776$$

$$\left(\frac{P_{rms}}{20}\right)_4 = 10^{79/20} = 8912.50938$$

$$\Rightarrow \left(\frac{P_{rms}}{20}\right)_{equivalent} = \sqrt{(1000)^2 + (2818.3829)^2 + (3162.2776)^2 + (8912.50938)^2}$$

$$= 9918.4729$$

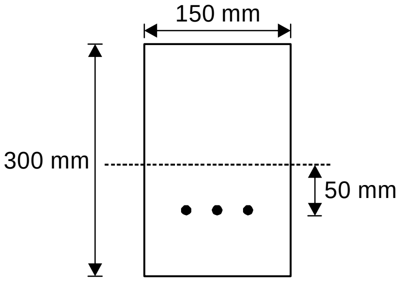
$\therefore$ Equivalent sound in dB = $20\log\left(\left(\frac{P_{rms}}{20}\right)_{eq}\right)$

= 20 log (9918.4729)

= 79.928 dB

52. A pre-tensional rectangular beam 150mm wide and 300 mm depth is prestressed with three straight tendons each having a cross-sectional area of 50 mm^2 to an initial stress of 1200 N/mm^2. The tendons are located at 100 mm from the soffit of the beam if the modular ratio is 6 the loss of prestressing force (in kN up to one decimal place) due to the elastic deformation of concrete is ______

Sol–52 : 4.8



Loss due to elastic deformation = $mf_c = 6f_c$

$$f_c = \frac{P}{A} + \frac{P\,e^2}{I}$$

$$P = 1200 \times 3 \times 50 \text{ N}$$

$$A = 150 \times 300$$

$$e = 50 \text{ mm}$$

$$f_c = \frac{1200 \times 3 \times 50}{150 \times 300} + \frac{1200 \times 3 \times 50 \times 50^2}{\frac{150 \times 300^3}{12}}$$

$$= 4 + \frac{4}{3} = \frac{16}{3} \text{ N/mm}^2$$

$$\text{Loss} = 6 \times \frac{16}{3} = 32 \text{ N/mm}^2$$

$$\text{Loss in force} = 32 \times 3 \times 50$$

$$= 4800 \text{ N} = 4.8 \text{ kN}$$

53. The spherical grit particles having a radius of 0.01 mm and specific gravity of 3.0 need to be separated in a settling chamber it is given that

- $g = 9.81 \text{ m/s}^2$
- The density of the liquid in the settling chamber = 1000 kg/m^3
- The kinematic viscosity of the liquid in the setting chamber = 10^{-6} m^2/s

Assuming laminar conditions the setting velocity on mm/sec up to one decimal place is ___________.

Sol–53 : 0.44

$$\text{Settling velocity} = \frac{(\gamma_s - \gamma_l)\, d^2}{18\,\mu}$$

$$\frac{\mu}{\rho} = 10^{-6} \text{ m}^2/\text{s}$$

$$\mu = 10^{-3} \text{ N-s/m}^2$$

$$d = 0.02 \text{ mm} = 2 \times 10^{-5} \text{ m}$$

$$V_s = \frac{(3 \times 9810 - 9810) \times (2 \times 10^{-5})^2}{18 \times 10^{-3}}$$

$$= 4.36 \times 10^{-4} \text{ m/s}$$

$$= 0.436 \text{ mm/s}$$

54. A 1m wide rectangular channel has a bed slope of 0.0016 and the Manning's roughness coefficient is 0.04. Uniform flow takes place in the channel at a flow depth of 0.5. At a particular section gradually varied flow GVF is observed and the flow depth is measured as 0.6m. The GVF profile at that section is classified as

(a) S (b) S_2

(c) M_1 (d) M_2

Sol–54 : (c)

Given :

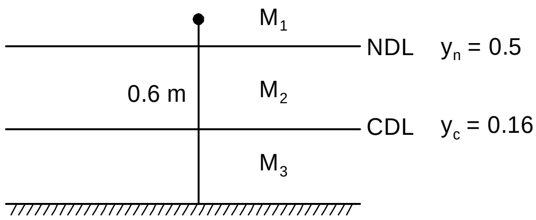
Normal depth (y_n) = 0.5 m

$$Q = \frac{1}{n} A R^{2/3} \sqrt{S}$$

$$= \frac{1}{0.04} \times 1 \times 0.5 \times \left(\frac{1 \times 0.5}{1 + 2 \times 0.5}\right)^{2/3} \sqrt{0.0016}$$

$$= 0.198 \text{ m}^3/\text{s}$$

$$y_c = \left(\frac{q^2}{g}\right)^{1/3} = \left(\frac{0.198^2}{9.81}\right)^{1/3} = 0.1586 \text{ m}$$



So, M_1 profile.

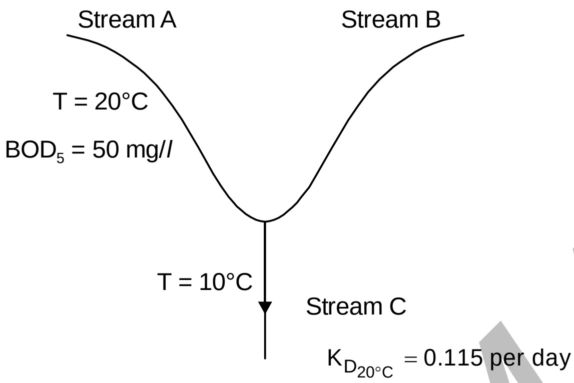
55. Two wastewater streams A and B having an idential ultimate BOD are getting mixed to form the stream C. The temperature of the stream A is 20° C and the temperature of the stream C is 10°C. It is given that

- The 5-day BOD of the stream A measured at 20°C = 50 mg/l
- BOD rate constant (base10) at 20° C = 0.115 per day
- Temperature coefficient = 1.135

The 5-day BOD (in mg/l up to one decimal place) of the stream C. Calculated at 10°C is ______.

Sol–55 : 21.2 mg/l

Given :



$(BOD_u)_A = ?$

$\Rightarrow \; BOD_5 = (BOD_u) \times (1-10^{-K_D t})$

$\Rightarrow \; (BOD_u)_A = \dfrac{50}{1-10^{-0.115\times 5}}$

= 68.13 mg/l

$K_{D_{10°}} = K_{D_{20°}} \times [1.135]^{10-20}$

= 0.115 × $(1.135)^{-10}$ = 0.0324

$(BOD_u)_A = (BOD_u)_B$

Hence, $(BOD_u)_C$ = 68.13 mg/l

For C; $(BOD_5)_{10°C} = BOD_u\left[1-10^{-K_{D_{10}} \times t}\right]$

= 68.13 $[1 - 10^{-0.0324 \times 5}]$

= 21.21 mg/l

1. The following sequence of numbers is arranged in increasing order 1,x,x,x,y,y,9,16,18 given that the mean and median are equal and are also equal to twice the mode, the value of y is

(a) 5 (b) 6

(c) 7 (d) 8

Sol–1 : (d)

Numbers in increasing order 1, x, x, x, y, y, 9, 16, 18

$$\text{Mean} = \frac{1+x+x+x+y+y+9+16+18}{9}$$

$$= \frac{3x+2y+44}{9}$$

Median = y

Mode = x

Given : Mean = Median

$$\frac{3x+2y+44}{9} = y$$

$\Rightarrow$ 3x + 2y + 44 = 9y

$\Rightarrow$ 3x – 7y + 44 = 0 ...(i)

Median = 2x Mode

y = 2x ...(ii)

By Eq. (i) and (ii)

3x – 7 × (2x) + 44 = 0

$\Rightarrow$ –11x = –44

$\Rightarrow$ x = 4

Putting value x in equation (ii)

y = 2 × 4 = 8

2. _____ with someone else's email account is now a very serious offence.

(a) Involving (b) Assisting

(c) Tampering (d) Incubating

Sol–2 : (c)

Tampering with someone else's email account is now a very serious offence.

3. If the radius of a right circular cone is increased by 50% its volume increase by

(a) 75% (b) 100%

(c) 125% (d) 237.5%

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- AIR 33 CE — SPARSH BHARDWAJ

- AIR 1 ME — MOHAMMAD IDUL AHMED
- AIR 3 ME — CHIRAG SRIVASTAV
- AIR 5 ME — DEEPAK VIJAY
- AIR 12 ME — SACHIN JAIN
- AIR 13 ME — KHILENDRA SINGH CHAUHAN
- AIR 14 ME — VINAY KUMAR
- AIR 17 ME — SAMARTH AGARWAL

- AIR 18 ME — ROOPAK TIWARI
- AIR 40 ME — ANIL KUMAR
- AIR 51 ME — ANKUR SINGH CHAUHAN
- AIR 63 ME — NIMIT AGRAWAL
- AIR 71 ME — SURYANK GUPTA
- AIR 106 ME — ARPIT KUMAR
- AIR 108 ME — P.S. MANI KUMAR
- AIR 131 ME — RAHUL RAJPAL SINGH
- AIR 132 ME — SACHINI KUMAR
- AIR 156 ME — ARVIND KUMAR
- AIR 38 EE — VIDYA
- AIR 94 EE — RITA NAGDEVE

- AIR 106 EE — RAJIV DAS
- AIR 35 CE — RAVI MITTAL
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- AIR 46 CE — VAIBHAV PODDAR
- AIR 47 CE — AJIT KR. PALSANIA
- AIR 48 CE — VIKRAM MITTU
- AIR 51 CE — HARSHIT CHOUHAN

- AIR 52 CE — VIKAS KR. SEHRA
- AIR 53 CE — AYUSH TIWARI
- AIR 55 CE — SAGAR MAHESHWARI
- AIR 59 CE — AKHILESH
- AIR 61 CE — ABHIPRERNA AWANA
- AIR 62 CE — MAYANK AGRAWAL
- AIR 63 CE — THATI SONY
- AIR 65 CE — SUSHIL KR. SINGH
- AIR 66 CE — ANANT YADAV
- AIR 67 CE — P JAMSHEER
- AIR 68 CE — AVINASH SAHANI
- AIR 69 CE — PAYAL GOYAL

- AIR 70 CE — PRANAV
- AIR 71 CE — DEEPAK NEGI
- AIR 72 CE — KULDEEP SINGH
- AIR 74 CE — NAVEEN YADAV
- AIR 75 CE — VIVEK RANJAN PANDEY
- AIR 76 CE — ANKUR GOYAL
- AIR 77 CE — VIPUL KUMAR
- AIR 78 CE — AMIT GUPTA
- AIR 80 CE — DHAWAL SRIVASTAVA
- AIR 81 CE — NITIN MANGWAL
- AIR 87 CE — SHYAMAL KUMAR
- AIR 88 CE — RAJAT KOTHARI

- AIR 93 CE — AJAY KR. CHAUDHARY
- AIR 95 CE — MADHURIMA BHATTACHARYA
- AIR 97 CE — DIGVIJAY CHAUHAN
- AIR 99 CE — ABHISHEK
- AIR 105 CE — CHITRANSHU
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- AIR 113 CE — ANKIT
- AIR 115 CE — KUNWAR CHRAYA

- AIR 116 CE — SIDDHARTH SONI
- AIR 119 CE — AJAY SHARMA
- AIR 120 CE — ASHISH PANDEY
- AIR 121 CE — DANISH KHAN
- AIR 122 CE — OM NATH BIHARI
- AIR 125 CE — GOPAL PATRALEKH
- AIR 126 CE — AKASH ROUT
- AIR 130 CE — RANVIJAY AZAD
- AIR 132 CE — GYANPRAKASH SONI
- AIR 136 CE — MOHIT KUMAR
- AIR 137 CE — NIRAJ KUMAR YADAV
- AIR 138 CE — MOHNISH KR. SINHA

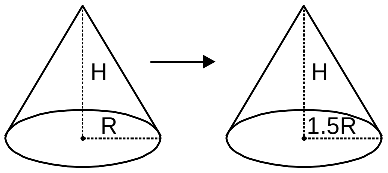
- AIR 142 CE — ABHISHEK KUMAR YADAV
- AIR 143 CE — VIJAY ANAND VERMA
- AIR 145 CE — DIVIJ SAHANI
- AIR 147 CE — MANISHA K. MEENA
- AIR 150 CE — SATYAPAL SANNU
- AIR 151 CE — AHTESHAMUL HAQ
- AIR 153 CE — SURAJ PRATAP SINGH
- AIR 154 CE — ALOK KUMAR VERMA
- AIR 161 CE — JAY KARAN YADAV
- AIR 165 CE — PRASANT KUMAR
- AIR 166 CE — PUKHA RAM
- AIR 168 CE — MAHENDRA SINGH JATAV

- AIR 169 CE — ABHISHEK
- AIR 171 CE — BUDDI PRAKASH MEENA
- AIR 173 CE — DHEERESH KR.
- AIR 174 CE — VINITA
- AIR 175 CE — SAURAV SHIVHARE
- AIR 179 CE — LALIT KUMAR
- AIR 180 CE — NAVALPREET KAUR
- AIR 183 CE — SANTOSH KR. MEENA
- AIR 184 CE — ABHISHEK KUMAR
- AIR 187 CE — RAHUL JAJORIA
- AIR 188 CE — BHARTI MEENA
- AIR 189 CE — JITENDRA KR. MEENA

- AIR 190 CE — SAURAV DEO
- AIR 193 CE — PRADEEP KR. MEENA
- AIR 194 CE — NITESH KR. SINGH
- AIR 199 CE — AMIT KR. MEENA
- AIR 203 CE — ACHAL KUMAR
- AIR 207 CE — LALIT MOHAN MEENA
- AIR 210 CE — SUNIL KR. MEENA
- AIR 212 CE — AKASH CHANDRA
- AIR 213 CE — MAHENDRA KR. MEENA
- AIR 216 CE — SUMAN JEE
- AIR 221 CE — ALOK OJHA
- AIR 224 CE — ANKIT KR. SHUKLA

Received so far..... [If found any discrepancy please bring it to our notice.]

Sol–3 : (c)



Percentage increase in volume

$$= \frac{V_1 - V}{V} \times 100$$

$$= \frac{\frac{1}{3}\pi R^2 H \times 2.25 - \frac{1}{3}\pi R^2 H}{\frac{1}{3}\pi R^2 H} \times 100$$

$$= \frac{2.25 - 1}{1} \times 100 = 125\%$$

4. Consider the following sentences:

All benches are beds.

No bed is a bulb.

Some bulbs are lamps.

Which of the following can be inferred?

(i) Some beds are lamps

(ii) Some lamps are beds.

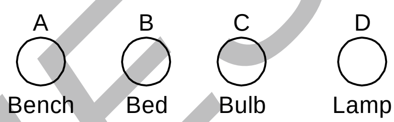
(a) Only (i)

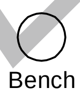
(b) Only (ii)

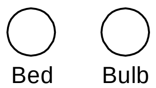
(c) Both (i) and (ii)

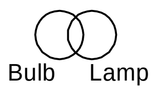
(d) Neither (i) nor (ii)

Sol–4 : (d)

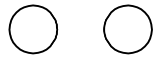


$A \cup B$ = 

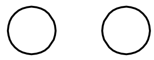
$B \cap C = B \neq C$ 

$C \cap D$ = 

(i) Since $C \cap B = 0$

Hence $B \cap D$ =  = 0

(ii) Since $C \cap B = 0$

Hence $D \cap C$ =  = 0

5. The bacteria in milk are destroyed when it____ heated to 80 degree celsius.

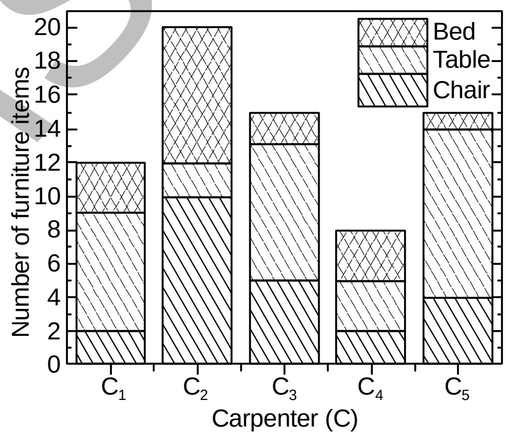
(a) Would be (b) will be

(c) is (d) was

Sol–5 : (c)

The bacteria in milk are destroyed when it **is** heated to 80°C.

6. The bar graph below shows the output of five carpenters over one month each of whom made different items of furniture chairs, tables and beds.



Consider the following statements.

(i) The number of beds made by carpenter 2 is exactly the same as the number of tables made by carpenter C_3

(ii) The total number of chair by all carpenters is less than the total number of tables.

Which one of the following is true?

(a) Only (i) (b) Only (ii)

(c) Both (i) and (ii) (d) Neither (i) nor (ii)

Sol–6 : (c)

No. of Beds by carpenter C_2 = 20 – 12 = 8

No. of Tables by carpenter C_3 = 13 – 2 = 8

Total no. of Chairs made = 2 + 10 + 5 + 2 + 4 = 23

Total no. of Tables = 7 + 2 + 8 + 3 + 10 = 30

Total no. of Tables > Total no. of Chairs

(No. of Beds) C_2 = (No. of Tables)C_3

7. The last digit of $(2171)^7 + (2172)^9 + (2173)^{11} + (2174)^{13}$ is

(a) 2 (b) 4

(c) 6 (d) 8

Sol–7 : (b)

$(2171)^7 + (2172)^9 + (2173)^{11} + (2174)^{13}$

$1^1 + 2^1 + 3^3 + 4^1$

Last digit = 1 + 2 + 7 + 4 = 14

Last digit = 4

8. Students applying for hostel rooms are allotted rooms in order of seniority. Students already staying in a room will move if they get a room in their preferred list. Preference of lower ranked applicant are ignored during allocation.

Names	Student seniority	Current room	Room preference List
Amar	1	P	R, S,Q
Akbar	2	None	R,S
Anthony	3	Q	P
Ajit	4	S	Q,P,R

Given the data below. Which room will Ajit stay in?

(a) P (b) Q

(c) R (d) S

Sol–8 : (b)

Amar → R

Akbar → S

Anthony → P

Ajit → Q

9. Tow machines M1 and M2 are able to execute any of four jobs P, Q, R and S the machines can perform one job on one object at a time jobs P, Q, R and S take 30 minutes 20 minutes 60 minutes and 15 minutes each respectively. There are 10 objects each requiring exactly 1 job. Job P is to be performed on 2 objects. Job Q on 3 objects, job R on 1 object and job S on 4 objects. What is the minimum time needed to complete all the jobs?

(a) 2 hours (b) 2.5 hours

(c) 3 hours (d) 3.5 hours

Sol–9 : (a)

	Job P		Job Q
M_1	30 × 2	+	20 × 3 = 2 hrs
	Job R		Job S
M_2	60 × 1	+	15 × 4 = 2 hrs

M_1 and M_2 both require 2 hrs

Hence, minimum time is 2 hrs.

10. The old concert hall was demolished because of fears that the foundation would be affected by the construction of the new metro line in the area. Modern technology for underground metro construction tried to mitigate the impact of pressurized air pockets created by the excavation of large amounts of soil but even with these safeguards. It was feared that the soil below the concert hall would not be stable.

From this, one can infer that

(a) The foundations of old buildings create pressurized air pockets underground. which are difficult to handle during metro construction.

(b) Metro construction has to be done carefully considering its impact on the foundations of existing buildings.

(c) Old buildings in an area form an impossible hurdle to metro construction as that area

(d) Pressurized air can be used to excavate large amounts of soil form underground areas.

Sol–10 : (b)