CIVIL ENGINEERING

Q. No. 1 to 25 Carry One Mark Each

1. 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

d

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

Key: **(15)**

Exp:

Time	0	1	2	3	4
(1) Ordinate lagged	0	5	12	25	41
(2) Lagged ordinate of 2 hr UH lag by 2hr	0	0	0	5	12
Ordinate 4hr UH $\left(\frac{1+2}{2}\right)$	0	2.5	6	15	26.5

Ordinate of 3 hour UH at 3-hr is $=15m^3/s$

2. 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 line of loading, is

(A) 0.25 (B) 0.5 (C) 2.0 (D) 4.0

Key: **(C)**

Exp: Due to UDL

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

$$\text{at } x=0;\ \text{veritcal stress}(\sigma_z)=\frac{2q}{\pi z}$$

$$\frac{\sigma_{z1}}{\sigma_{z2}}=\frac{z_L}{z_1}=\frac{4}{2}=2$$

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

(A) $\chi_{u,bal}$ depends on the grade of concrete only.

(B) $\chi_{u,bal}$ depends on the grade of steel only.

(C) $\chi_{u,bal}$ depends on both the grade of concrete and grade of steel.

(D) $\chi_{u,bal}$ does not depend on the grade of concrete and grade of steel.

Key: **(B)**

Exp: By limit state method

$$\frac{x_{u,lim}}{d} = \frac{0.0035}{0.0055 + \frac{0.87f_y}{E_S}}$$

For balanced section

$x_{u,bal} = x_u, lim$

$$\frac{x_{u,bal}}{d} = \frac{0.0035}{0.0055 + \frac{0.87f_y}{E_S}}$$

$\therefore x_{u,bal}$ depends upon grade of steel only.

4. Group I lists 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	Group II
P. Regain of strength with time	1. Boiling
Q. Loss of strength due to cyclic loading	2. Liquefaction
R. Loss of strength due to upward seepage	3. Thixotropy
S. Loss of strength due to remolding	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

Key: **(C)**

5. A runway is being constructed in a new airport as per the International Civil Aviation Organization (ICAO) recommendations. The elevation and the airport reference temperature of this 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 conditions 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

Key: **(C)**

Exp: Correction for elevation : 7 % increase per 300 m height

So, correction $= \frac{7}{100} \times \frac{535}{300} \times 2000 = 249.7\text{m}$

$\therefore$ Corrected length $= 2000 + 249.7 = 2249.7$ m

Correction for temperature :

std. Atm temp $= 15 - 0.0065 \times 535 = 11.52°C$

$\Delta T = 22.65 - 11.52 = 11.13°C$

$$\text{Correction} = \frac{2249.7}{100} \times 11.13 = 250.32\text{m}$$

$\therefore$ Corrected length $= 2249.74 + 250.32$

$= 2500.02\,\text{m}$

check : Total correction $= \dfrac{2500.02 - 2000}{2000} \times 100$

$= 25\% < 35\%$

6. A soil sample is subjected 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

Key: **(C)**

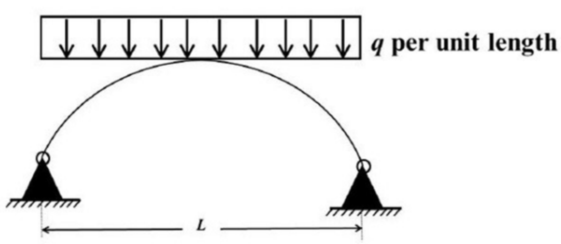
Exp: $\sigma_x = \sigma_y = \sigma_z = \sigma, \tau_{xy} = 0$

For Mohr's Circle

$$\text{Radius (R)} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} = \sqrt{\left(\frac{\sigma - \sigma}{2}\right)^2 + 0^2} = 0$$

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

7. 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) $\dfrac{qL^2}{8}$ (B) $\dfrac{qL^2}{12}$ (C) zero (D) $\dfrac{qL^2}{10}$

Key: **(C)**

Exp: Bending moment at any point for two-hinged parabolic arch with uniformly distributed load is zero.

8. 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 centre

Key: **(B)**

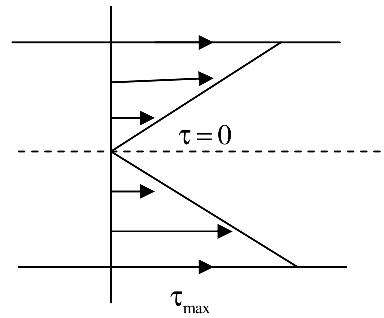
Exp: We know that velocity variation,

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

$$\tau = \mu\frac{\partial u}{\partial y} = \frac{-1}{2}\left(\frac{\partial p}{\partial x}\right)(t - 2y)$$

$$y = 0 \Rightarrow \tau = \tau_{max}$$

$$y = \frac{t}{2} \Rightarrow \tau = 0$$



9. 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) $0.25\alpha\sigma$

Key: **(A)**

Exp:

$$\sigma = E(\alpha\Delta T)$$

σ varies with ΔT and does not depends upon the length of bar.

10. 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

Key: **(B)**

Exp: Probability density functions of univariable exponential distributes

$$f(x) = \lambda e^{-dx} \quad x \geq 0$$
$$= 0 \quad \text{others}$$

where λ is parameter

For Gaussian distribution $f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{2}\right)^2}$

where μ and σ are parameters

11. The wastewater form 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 locations 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.

Key: **(D)**

12. The reaction rate involving reactants A and B is given by $-k[A]^{\alpha}[B]^{\beta}$. Which one of the following statements is valid for the reaction to be 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 $\beta = 2$

Key: **(B)**

Exp: In chemical kinetics, the order of reaction with respect to given substance is defined as the index or exponent to which its concentration term in the rate equation is raised.

$$r = k.[A]^{\alpha}[B]^{\beta}$$

Order of reaction $= \alpha + \beta$

For first order reaction, $\alpha + \beta = 1$

13. 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) $(\pi + 2)C_u$

Key: **(D)**

Exp: Ultimate bearing capacity $= c.N_C$

For pure clay $N_C = 5.14 = (\pi + 2)$

$UBC = (\pi + 2)C$

14. 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.

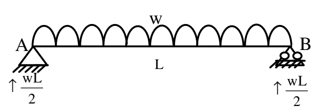
(B) Maximum or minimum bending moment occurs where the shear force is zero.

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

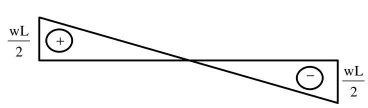
(D) Maximum bending moment and maximum shear force occur at the same section.

Key: **(B)**

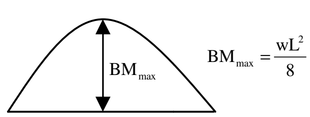
Exp:



SFD

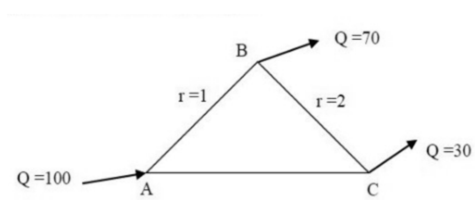


BMD



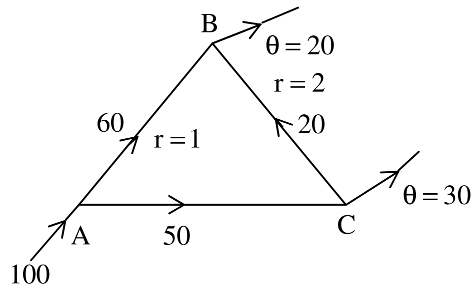
15. A triangular pipe network is shown in the figure.

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_______



Key: (0.62)

Exp: If the discharge supplied at point A is equally divided so $Q_{AB} = Q_{AC} = 50\,m^3/s$



$$\Sigma r\,Q^n = 0$$

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

$$\Rightarrow r\times(50)^{1.8} = 703.84$$

$$\Rightarrow r = 0.62$$

16. $\lim\limits_{x\to 0}\left(\dfrac{\tan x}{x^2 - x}\right)$ is equal to ______

Key: (-1)

Exp: $\text{lt}_{x\to 0}\dfrac{\text{Tan}x}{x^2 - x} = \text{lt}_{x\to 0}\dfrac{\text{Tan}x}{x(x-1)}$

$$= \text{lt}_{x\to 0}\frac{\text{Tan}x}{x}\,.\,\text{lt}_{x\to 0}\frac{1}{(x-1)} = 1\times -1 = -1$$

17. 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 on e can be set

(D) $e = \dfrac{1-(f_{max})^2}{f_{max}}$

Key: (A)

Exp: $\theta = \tan\theta = e$

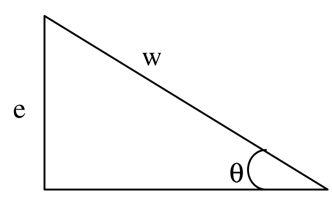
For no sliding

$$\frac{v^2}{gR} \le \frac{\mu + \tan\theta}{1 + \mu\tan\theta}$$

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

For stopped vehicle v=0

$f \ge -e$



18. 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

Key: (D)

19. The accuracy of an Electronic Distance Measuring Instrument (EDMI) is specified as $\pm(a \text{ mm} + b \text{ ppm})$. 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 in proportion to the distance being measured.

Key: (B)

Exp: Accuracy of EDMI is generally stated in terms of constant instrument error and measuring error proportional to distance being measured.

$$\pm(a \text{ mm} + b \text{ ppm})$$

The first part in this expression indicates a constant instrument error that is independent of length of line measured. Second component is distance related error.

20. 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 this equation to be classified as parabolic, the value of B^2 must be_______

Key: (36)

Exp: Given $3\frac{\partial^2\phi}{\partial x^2} + B\frac{\partial^2\phi}{\partial x \partial y} + 3\frac{\partial^2\phi}{\partial y^2} + 4\phi = 0$ is parabolic.

By comparing with general form

$$A\frac{\partial^2\phi}{\partial x^2} + B\frac{\partial^2\phi}{\partial x \partial y} + C\frac{\partial^2\phi}{\partial y^2} + F\left(\phi, x, y, \frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}\right) = 0$$

$A = 3$; $B = B$; $C = 3$

Condition for parabolic is

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

$$B^2 - 4(3\times3) = 0 \Rightarrow B^2 = 36$$

$$\therefore B^2 = 36$$

21. 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) $PQ - QP = I$

Key: (C)

Exp: Given P is inverse of Q

$$\Rightarrow PQ = QP = I$$

22. Vehicles arriving at an intersection from one of the approach road 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______

Key: **(0.1354)**

Exp: By Poission's distribution

$$p(h \geq 8) = e^{-8\lambda}$$

$$\lambda = \frac{900}{36500} = 0.256$$

$$p(h \geq 8) = e^{-8\times 1/4} = 0.1354$$

23. 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}

Key: **(B)**

Exp: $f(x) = e^{-x-e^{-x}}$ $x \in (-\infty, \infty)$ is a continuous variable

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

put $e^{-x} = t$

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

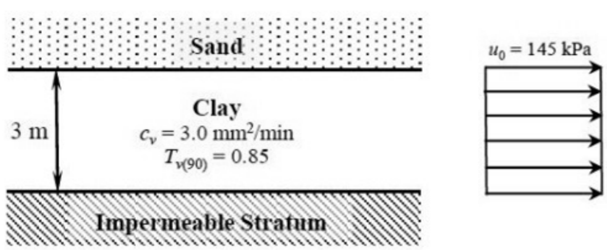
$$\therefore g(x) = \int e^{-t}(-dt) = -\left(\frac{e^{-t}}{-1}\right) = e^{-t} = e^{-e^{-x}}$$

24. 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

Key: **(C)**

25. 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 ________

Key: **(1770.833)**

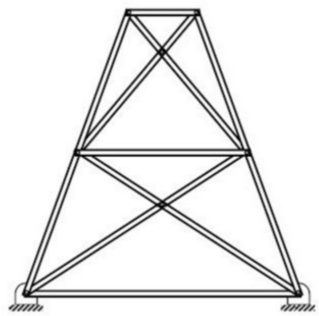
Exp: It is single drainage

$$T_V = \frac{C_V.t}{H^2} \Rightarrow t = \frac{T_V.H^2}{C_V} = \frac{0.85 \times 3000^2}{3\ mm^2/min} = \frac{0.856 \times 9 \times 10^6}{3} min$$

$$= 2.55 \times 10^6 \text{ min} = 1770.833 \text{days}$$

Q. No. 26 to 55 Carry Two Marks Each

26. 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-False; 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

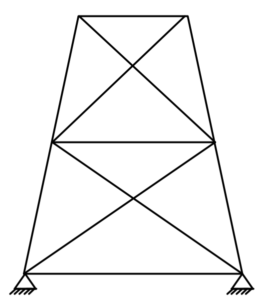
Key: **(A)**

Exp: $D_{se} = r - 3$

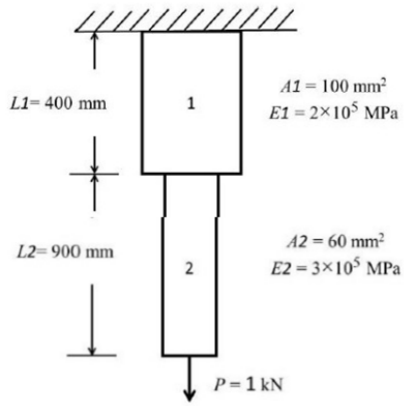
$r = \text{number if support reactions} = 4$

$D_{se} = 4 - 3 = 1$

$D_{si} = \text{number of double diagonals} = 2$



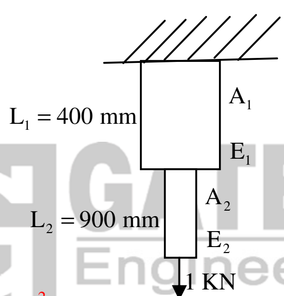
27. Consider the stepped bar made with a linear elastic material and subjected to an axial load of 1 kN, as shown in the figure.

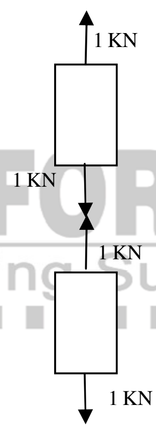


Segments 1 and 2 have cross-sectional are of 100 mm^2 and 60 mm^2, Young's modulus of 2×10^5 MPa and 3×10^5 MPa, and length of 400 mm and 900 mm, respectively. The strain energy (in N-mm, up to one decimal place) in the bar due to the axial load is_____

Key: **(35)**

Exp:





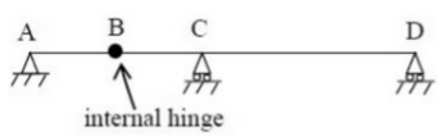
$$\text{Strain energy} = \sum \frac{U^2L}{2AE}$$

$$= \frac{1000^2\times400}{2\times100\times2\times10^5} + \frac{1000^2\times900}{2\times60\times3\times10^5}$$

$$= 10 + 25$$

$$= 35 \text{Nmm}$$

28. Consider the beam ABCD shown in the figure.



AB = BC = 4 m
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______

Key: **(200)**

Exp: By muller Breslau principle

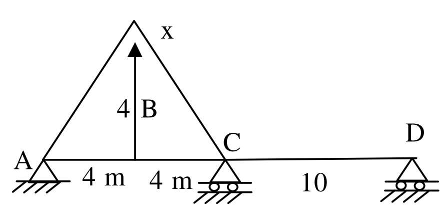
ILD for moment at C

$x - 0 = 4$

$x = 4$

Load is acting at point B

$B.M = 50\times4 = 200 kN - m$



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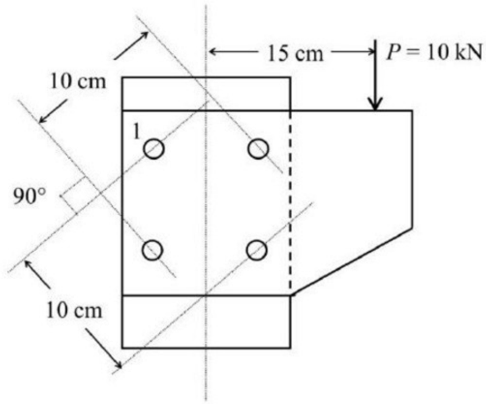
29. A column is subjected to a load through a bracket as shown in the figure.



The resultant force (in kN, up to one decimal place) in the bolt 1 is_____

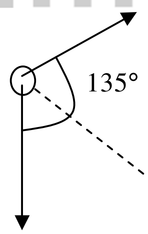
Key: (5.9 to 6.1)

Exp: $P = 10KN, e = 15cm, r_1 = r_2 = r_3 = r_4 = 5\text{ cm}$

$$F_d = \frac{P}{4} = \frac{10}{4} = 2.5KN$$

Force in bolt 1 due to moment

$$F_s = \frac{P_e r_1}{\sum r^2} = \frac{10 \times 15 \times 5}{4 \times (5)^2} = 7.5KN$$



$$FR = \sqrt{(2.5)^2 + (7.5)^2 + 2 \times 2.5 \times 7.5 \cos 135°} \simeq 6\,KN$$

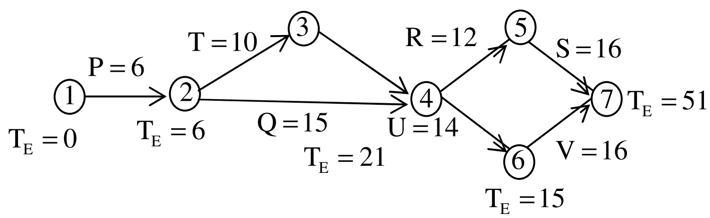
30. The activity details of a project are given below:

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________

Key: **(51)**

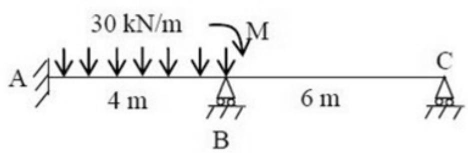
Exp: Activity on arrow (AoA) diagram:



Time along path 1- 2- 4- 6- 7

= 6+15+14+16 = 51 days

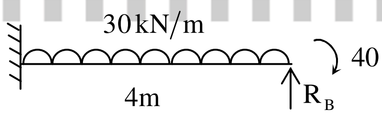
31. The value of M in the beam ABC shown in the figure is such that the joint B does not rotate.



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

Key: **(60)**

Exp: $M_{BA} = \frac{4EI\theta_B}{4} + \frac{2EI\theta_A}{6} + \frac{w\ell^2}{12}$



$\Rightarrow M_{BA} = 0 + 0 + \frac{30 \times 16}{12} = 40$

$M_{BC} = \frac{3EI\theta_B}{6} + \overline{M_{F\,BC}} = 0$

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

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

$\Rightarrow \frac{W\ell^4}{8EI} + \frac{ML^2}{2EI} = \frac{R_B \times L^3}{3EI}$

$\Rightarrow \frac{30 \times 4}{8} + \frac{40}{2 \times 4} = \frac{R_B}{3} \Rightarrow R_B = 60kN$

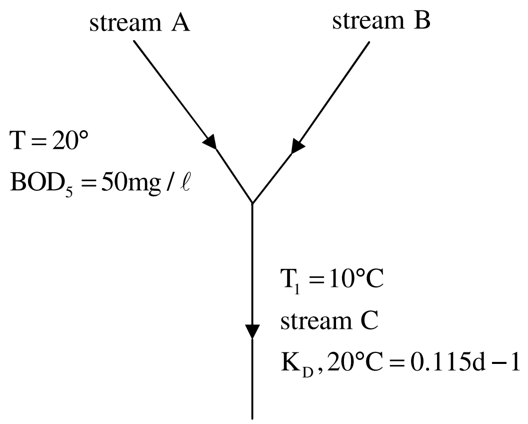
32. Two wastewater streams A and B, having an identical ultimate BOD are getting mixed to form the stream C. The temperature of the stream A is 20°C and the temperature of the stream C is 10°C. It is given that

- The 5-day BOD of the stream A measured at 20°C=50 mg/l
- BOD rate constant (base 10) 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______

Key: **(21.21)**

Exp:



$$BOD_5 = BOD_U \times \left(1 - 10^{-K_D.t}\right)$$

$$\Rightarrow (BOD_U)_A = \frac{50}{1-10^{-0.115\times5}} = 68.13 \text{ mg}/\ell$$

$$K_D, 10°C = K_D, 20°C \times (1.135)^{10-20}$$

$$= 0.115 \times (1.135)^{-10} = 0.0324$$

$$(BOD_U)_A = (BOD_U)_B$$

So, $(BOD_U)_C = 68.13 \text{ mg}/\ell$

For C,

$$(BOD_5)_{10°C} = BOD_U \left(1 - 10^{-K_D.10\times t}\right)$$

$$= 68.13 \times \left(1 - 10^{-0.0324\times5}\right)$$

$$= 21.21 \text{mg}/\ell$$

33. 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________

Key: **(5.5)**

Exp:

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

$$m.Q = 3t^2$$

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

$$m.dv = 3t^2 dt$$

$$m\int_{1.5}^{V} dv = \int_0^2 3t^2 dt$$

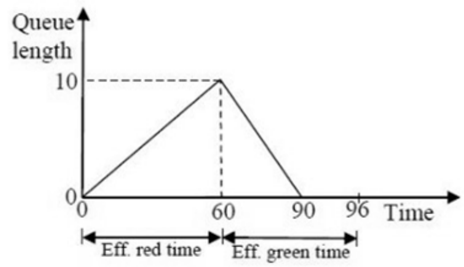
$$2 \times (v - 1.5) = 3.\frac{t^3}{3}\Big|_0^2$$

$$2(v - 1.5) = 3 \times \frac{2}{3} = 8$$

$$v - 1.5 = 4$$

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

34. 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

Key: (B)

35. 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

Key: (B)

Exp: $f(x) = a + bx \quad 0 \le x \le 1$ is a valid probability density function

i.e., $\int_0^1 f(x)dx = 1$

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

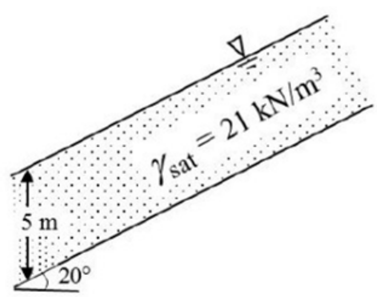
$\left[ax + \frac{bx^2}{2}\right]_0^1 = 1 \Rightarrow a + \frac{b}{2} = 1$

$\Rightarrow 2a + b = 2$

a=0.5, b=1 satisfies the above relation

36. The infinite sand slope shown in the figure is on the verge of sliding failure. The ground water table coincides with the ground surface. Unit weight of water $\gamma_w = 9.81 \text{kN/m}^3$.

The value of the effective angle of internal friction (in degrees, up to one decimal place) of the sand is ________



Key: (34.335)

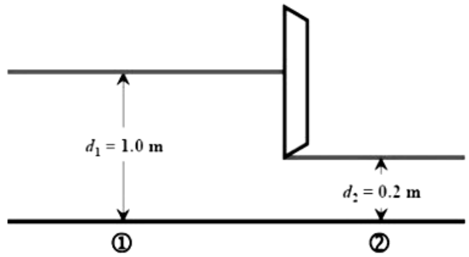
Exp: $\text{F.O.S} = \frac{\gamma_{sub} . \tan \phi}{\gamma_{sat} . \tan \beta}$

$1 = \frac{(21 - 9.8)\tan \phi}{21 \times \tan(20°)} \Rightarrow \tan \phi = \frac{21 \times \tan 20}{(21 - 9.81)}$

$\tan = 0.683$

$\phi = 34.335$

37. 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_______

Key: **(0.82)**

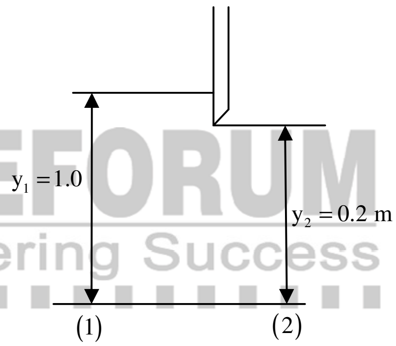
Exp: Given Energy loss is zero $\Rightarrow E_1 = E_2$

$$y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g}$$

$$Q = AV$$

$$V = \frac{Q}{A}$$

$$y_1 + \frac{Q_1^2}{2g.A_1^2} = y_2 + \frac{Q_2^2}{2gA_2^2}$$



$$y_1 - y_2 = \frac{Q_2^2}{2gA_2^2} - \frac{Q_1^2}{2g.A_1^2}$$

$$Q_1 = Q_2 = Q$$

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

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

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

38. 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

Key: **(D)**

39. 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 this matrix?

(A) Eigenvalue 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 eigenvector exists.

(D) Eigenvalues are 3 and -3, and two independent eigenvectors exist.

Key: **(A)**

Exp: Let $A = \begin{bmatrix} 5 & -1 \\ 4 & 1 \end{bmatrix}$

Characteristic equations is $\lambda^2 - 6\lambda + 9 = 0 \Rightarrow \lambda = 3,3$

Eigen value 3 has multiplicity 2.

Eigen vectors corresponding to $\lambda = 3$ is $(A - 3I)X = 0$

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

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

$$R_2 \to R_2 - 2R_1 \Rightarrow \begin{pmatrix} 2 & -1 \\ 0 & 0 \end{pmatrix}\begin{pmatrix} x \\ 4 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$e(A) = 1$

Number of linearly independent eigen vectors corresponding to eigen value $\lambda = 3$ is

n-r=2-1=1 where n= no. of unknowns, r= rank of $(A - \lambda I)$

$\therefore$ One linearly independent eigen vector exists corresponding to $\lambda = 3$

40. The laboratory test 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

Key: **(A)**

Exp: Liquidity Index $(I_L) = 1 - I_C$

$$I_C = \frac{w_L - w}{w_L - w_P}$$

$$= \frac{60-18}{60-25} = \frac{6}{5}$$

$I_L = 1-\frac{6}{5}=\frac{-1}{5}=-0.2$

$\text{Activity}=\frac{I_P}{\%\ \text{clay}}=\frac{w_L-w_P}{\%\ \text{clay}}=\frac{60-25}{25}=\frac{7}{5}=1.4$

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

Key: (D)

Exp: $\frac{d\theta}{dt}+\theta=1$ and $\theta=0$ at $t=0$

Comparing with first order linear differential equations

$\frac{dQ}{dt}+pQ=q$ where $p=1;q=1$

$I.F=\int_e pdt=e^t$

$Q.(IF)=\int 1.(IF)dt+c$

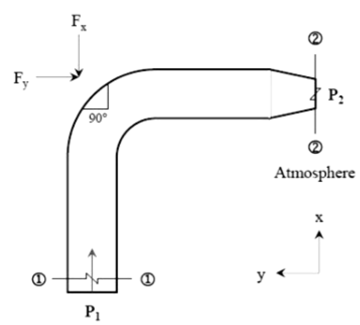
$Q.e^t=\int e^t dt+c$

$Q.e^t=e^t+c$

$Q=0$ at $t=0\Rightarrow 0.1=1+c\Rightarrow c=-1$

$\therefore Q.e^t=e^t-1\Rightarrow Q=1-e^{-t}$

42. 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 at 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 negligible.

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

Key: (2.50 to 3.75)

43. A pre-tensioned rectangular concrete beam 150 mm 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 only is ______.

Key: **(4.8)**

Exp: $\text{Stress} = 1200\ N/mm^2$

$$\frac{P}{A} = 1200$$

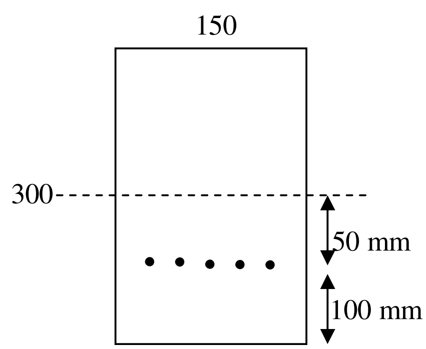
$$P = 1200 \times (3 \times 50)$$

$$= 18 \times 10^4\ N$$

$$f_c = \frac{P}{A} + \frac{Pe}{I}y$$

$$= \frac{18\times10^4}{150\times300} + \frac{18\times10^4\times50\times50}{150\times\frac{300^3}{12}}$$

$$= 4 + 1.33 = 5.33\ N/mm^2$$



Loss due to elastic deformation $= m.f_c = 6\times5.33 = 31.98$

Prestress force $= 31.98\times3\times50 = 4797\ N = 4.8\ KN$

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

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

Assuming laminar conditions, the settling velocity (in mm/s, up to one decimal place) is_____

Key: **(0.436)**

Exp: Kinematic viscocity $= 10^{-6} m^2/s$

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

$$\mu = 10^{-6}\times1000 = 10^{-3} N-S/m^2$$

$$\text{Settling velocity } (V_s) = \frac{(\gamma_s - \gamma_w).d^2}{18\mu}$$

$$V_s = \frac{(9810\times3-9810)\times(2\times0.01\times10^{-3})^2}{18\times10^{-3}} = 4.36\times10^{-4} m/s = 0.436\ mm/s$$

45. 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_______

Key: **(79.9)**

Exp: Equivalent sound power level

$$= 10.\log 10^{\frac{L_1}{10}}$$

$$= 10\log\left[10^{\frac{60}{10}} + 10^{\frac{69}{10}} + 10^{\frac{70}{10}} + 10^{\frac{79}{10}}\right]$$

$$L_{eq} = 79.9\,dB$$

46. Consider the equation $\dfrac{du}{dt} = 3t^2 + 1$ 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_________

Key: (8)

Exp: **Approximation value by Euler's Method:**

$$\frac{du}{dt} = 3t^2 + 1\ ;\ u(0) = 0;\ h = \Delta t = 2$$

$$u(2) = u(0) + hf(0,0),\ f(u,t) = 3t^2 + 1$$

$$= 0 + 2(0+1) = 2$$

Exact value:

$$du = (3t^2 + 1)dt \qquad (\text{variable separable})$$

$$\Rightarrow u = t^3 + t + c \text{ is sloution}$$

$$u(0) = 0 \Rightarrow 0 = c$$

$$u = t^3 + t$$

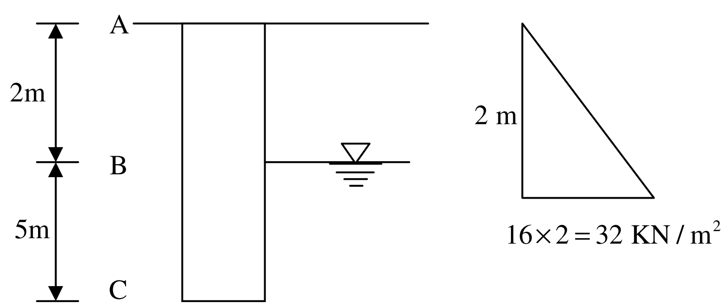
$$u(2) = 8 + 2 = 10$$

$$\therefore \text{ absolute error } = |10 - 2| = 8$$

47. 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 and 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________

Key: (390.7)

Exp:



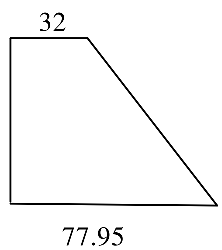
Average stress in $AB = \frac{32}{2} = 16 KN/m^2$

$\theta_{sf} = K \times \sigma_{avg} \times \tan\theta \times AS_1$

$= 1 \times 16 \times \tan 23° \times (3 \times 2) = 40.75\ KN$

BC:

Effective stress variation



$\sigma_{avg} = \frac{32 + 77.95}{2} = 54.97\ kN/m^2$

$A_{BC} = 3 \times 5 = 15\ m^2$

$\theta_{sf} = K\sigma_{avg} \times \tan\theta \times A$

$= 1 \times 54.97 \times \tan 23° \times 15 = 350KN$

Total axial frictional resistance = 350+40.75 = 390.75KN

48. The wastewater having an organic concentration of 54 mg/*l* is flowing at a steady rate of $0.8m^3$/day through a detention tank of dimensions 2m×4m×2m. 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 ______

Key: (17.9 to 18.1)

49. 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 superelevation 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

Key: (C)

Exp: $v = 60 km/hr = 60 \times \frac{5}{18} = 16.67 m/s$

$R = 120 m;\ f = 0.15;\ e + f = \frac{v^2}{gR}$

$$e + 0.15 = \frac{16.67^2}{9.81 \times 120} = 0.236$$

$$e = 0.236 - 0.15 = 0.086 = \frac{1}{11.6}$$

$$\text{at } e = 0;\ e + f = \frac{v^2}{gR}$$

$$f = \frac{v^2}{gR} = 0.236 \cong 0.24$$

50. Consider two axially loaded columns, namely, 1 and 2, made of a 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 ________

Key: (8)

Exp: $P_{cr} = \frac{\pi EI}{\ell^2_{eff}}$

For column -1; One end is fixed and other is free

$\ell_{eff} = 2\ell$

$$P_{cr\,(1)} = \frac{\pi EI}{4\ell^2}$$

For column-2

One end is fixed and other is pinned.

$\ell_{eff} = \ell/\sqrt{2}$

$$P_{cr\,(2)} = \frac{\pi EI}{\left(\ell/\sqrt{2}\right)^2}$$

$$= \frac{2\pi EI}{\ell^2}$$

$$\Rightarrow \frac{P_{cr\,(2)}}{P_{cr\,(1)}} = \frac{\frac{2\pi EI}{\ell^2}}{\frac{\pi EI}{4\ell^2}} = 8$$

51. The observed bearings of a traverse are given below:

Line	Bearing		Line	Bearing
PQ	$46^\circ 15'$		QP	$226^\circ 15'$
QR	$108^\circ 15'$		RQ	$286^\circ 15'$
RS	$201^\circ 30'$		SR	$20^\circ 30'$
ST	$321^\circ 45'$		TS	$141^\circ 45'$

The stations(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

Key: **(A)**

Exp:

Line	Bearing	Back bearing	Diff
PQ	46°15'	226°15'	1800
QR	108°15'	286°15'	1780
RS	201°15'	20°15'	1810
ST	32°15'	141°45'	1800

So, local attraction at only R

52. A 1 m 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 m. At a particular section, gradually varied flow (GVF) is observed and the flow depth is measured as 0.6 m. The GVF profile at that section is classified as

(A) S_1 (B) S_2 (C) M_1 (D) M_2

Key: **(C)**

Exp: $y_n = 0.5\text{m}$

$$y_c = \left(\frac{q^2}{g}\right)^{1/3}$$

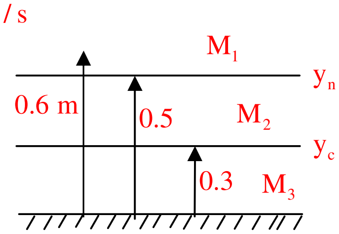
$$Q = \frac{1}{n}.A.R^{2/3}.S^{1/2} \qquad \left(\begin{array}{l}\therefore \text{For wide rectangular Channel} \\ R = \frac{A}{P} = \frac{B.y}{B} = y\end{array}\right)$$

$$= \frac{1}{0.04} \times (1 \times 0.5) \times (0.5)^{2/3}.(0.0016)^{1/2} = 0.315\text{m}^3/\text{s}$$

$$q = \frac{Q}{B} = \frac{0.315}{1} = 0.315$$

$$y_c = \left(\frac{0.315}{9.81}\right)^{1/3} = 0.318\text{m}$$

$y_n > y_c \Rightarrow$ mild slope



53. 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_________

Key: **(26.4)**

Exp: $\sigma_c = 100\text{kPa}; \ \sigma_d = 80\text{kPa}$

$\sigma_1 = \sigma_c + \sigma_d = 100 + 80 = 180\text{kPa}$

$\sigma_3 = \sigma_c = 100\text{kPa}$

$u = 50\text{kPa}$

$\overline{\sigma_1} = 180 - 50 = 130\text{kPa}$

$\overline{\sigma_3} = 100 - 50 = 50\text{kPa}$

For normally consolidated clay c=0

$\overline{\sigma_1} = \overline{\sigma_3} N_\phi + 2c\sqrt{N_\phi}$

$\overline{\sigma_1} = \overline{\sigma_3}\left(\dfrac{1+\sin\phi}{1-\sin\phi}\right)$

$130 = 50\left(\tan^2\left(45+\dfrac{\phi}{2}\right)\right)$

$\tan\left(45+\phi/2\right) = \sqrt{\dfrac{130}{50}} = 1.6124$

$\Rightarrow 45+\dfrac{\phi}{2} = 58.193$

$\phi = 2(58.193-45) = 26.387 = 26.4$

54. An effective rainfall of 2-hour duration produced a flood hydrograph peak of 200 m^3/s. The flood hydrograph 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 hydrograph (in m^3/s-cm, up to one decimal place) is_________

Key: **(150)**

Exp: Food hydrograph peak $= 200\,m^3/s$

Base flow $= 20\,m^3/s$

Excess rainfall $= 2$ cm, $\phi = 0.4$ cm/h

Effective rainfall $= 2 - 0.4\times 2 = 1.2$ cm

Peak of DRH $= 200-20 = 180\,m^3/s$

let peak of UH be Q_p

So $Q_p \times 1.2 = 180$

$\Rightarrow Q_p = 150\,m^3/s$

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

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

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

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 %

Key: **(A)**

Exp: Mass of oven dry aggregate $w_a = 1000g$

Mass of water in saturated surface dry aggregate $= w_w$

So, $w_a + w_w = 1025$

$\Rightarrow w_w = 25g$

Mass of saturated surface dry aggregate under water = 625 g

$\Rightarrow w_a - v_a \rho_w = 625g \left(v_a \text{ vol of aggregate}\right)$

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

$$\text{volume of void}\left(v_v\right) = \text{vol of water} = v_w = \frac{w_w}{\rho_w} = 25\,CC$$

$$\therefore \text{Bulk density of aggregate } \rho_{ba} = \frac{w_a}{v_a + v_v}$$

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

$\therefore$ Bulk specific gravity of aggregate

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

$$\text{water absorption} = \frac{w_w}{w_a} \times 100 = \frac{25}{1000} \times 100 = 2.5\%$$

General Aptitude

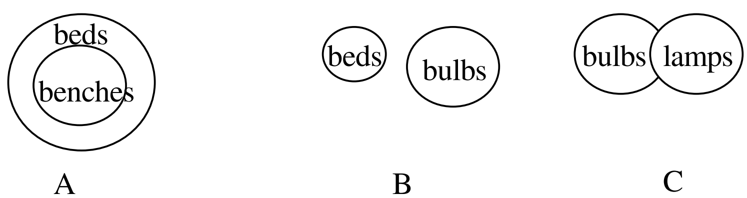
Q. No. 1 - 5 Carry One Mark Each

1. 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

Key: (D)

Exp:



Since there is no direct relation given between lamps and beds. So, neither will be correct

2. 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

Key: (D)

Exp: Given, $\text{Mean} = \text{Median} = 2\text{Mode}$

$\Rightarrow \text{Mean} = \text{Median} = 2x \left[\because \text{Mode} = x\right] \rightarrow (1)$

$\therefore \text{Mean of the data} = \dfrac{3x+2y+44}{9}$

$\Rightarrow 2x = \dfrac{3x+2y+44}{9} \Rightarrow 15x - 2y = 44 \rightarrow (2)$

$\text{Median of the data} = y \rightarrow (3)$

$\therefore y = 2x \rightarrow (4) \left[\because \text{Median} = 2\text{Mode}\right]$

$\text{From } (2); 11x = 44 \Rightarrow x = 4; \quad \therefore y = 8$

3. The bacteria in milk are destroyed when it _________ heated to 80 degree Celsius.

(A) would be (B) will be (C) is (D) was

Key: (C)

4. If the radius of a right circular cone is increased by 50%, its volume increases by

(A) 75% (B) 100% (C) 125%` (D) 237.5%

Key: (C)

Exp: Given, radius of a right circular cone is increased by 50%.

Let, height of the circular cone=(h)

Initially, Volume of the cone(V) $= \dfrac{1}{3}\pi R^2 h$ ....(1)

New volume of the cone(V') $= \dfrac{1}{3}\pi r^2 (1.5R)^2 h$ ....(2)

From (1) and (2); $\dfrac{1}{3}\pi R^2 h = \dfrac{1}{3}\pi (2.25)^2 h = 2.25v$

Hence increases by 125% as $\left[\dfrac{2.25v - v}{v}\right] \times 100 = 125\%$

5. __________ with someone else's email account is now very serious offence.

(A) Involving (B) Assisting (C) Tampering (D) Incubating

Key: (C)

Q. No. 6- 10 Carry Two Marks Each

6. 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. Preferences of lower ranked applicants are ignored during allocation.
Given the data below, which room will Ajit stay in?

Names	Student Seniority	Current room	Room preference list
Amar	1	P	R,S,Q

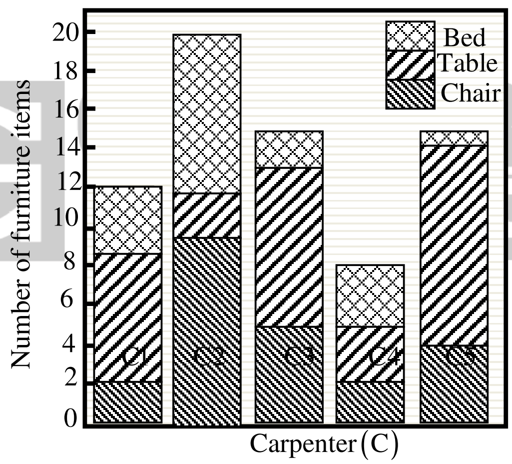
Akbar	2	None	
Anthony	3	Q	P
Ajit	4	S	Q,P,R

(A) P (B) Q (C) R (D) S

Key: **(B)**

Exp: Amar $\rightarrow$ R
Akbar $\rightarrow$ S
Antony $\rightarrow$ P
Ajit $\rightarrow$ Q
As per their preferences given

7. 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 C2 is exactly the same as the same as the number of tables made by carpenter C3.

ii. The total number of chairs made 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

Key: **(C)**

Exp: (i) The number of beds made by carpenter C_2 is exactly the same as the number of tables made by carpenter C_3

i.e., beds made by carpenter $C_2 = 8 =$ tables made by carpenter C_3 $[\because$ From the bar graph$]$

So,(i) is correct.

(ii) Total Number of tables made by all carpenters=31.

Total Number of chairs made by all carpenters=23

$\because 23 < 31$

$\therefore$ (ii) is correct

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

(A) 2 (B) 4 (C) 6 (D) 8

Key: (B)

Exp: The last digit of $(2171)^7 = 1$

The last digit of $(2172)^9 = (2172)^8 (2172)$

$= (2172)^{4n} (2172) \left[\text{Where, } n = 2\right]$

$= 6 \times 2 = 12 \left[\because (2172)^{4n} = \text{Last digit} = 6\right]$

Last digit of $(2172)^{4n} = 6$

The last digit of $(2173)^{11} = (2173)^8 (2173)^3$

$= (2173)^{4n} (2173)^3 \left[\text{Where, } n = 2\right]$

Last digit of $(2173)^{4n} = 1 = 1 \times 7 = 7$

The last digit of $(2174)^{13} = (2174)^{12} (2174)$

$= (2174)^{2n} (2174) \left[\because n = 6\right]$

$= 6 \times 4 \left[\because (2174)^{2n} = \text{last digit} = 6\right]$

Last digit of $(2174)^{2n} = 6 = 24$

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

$= 1 + 2 + 7 + 4 = 14$

9. Two 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

Key: (A)

Exp:

M_1	M_2	
$60 \leftarrow R$	$S \leftarrow 15\,min$	R takes 60 mins;
$30 \leftarrow P$	$S \leftarrow 15\,min$	S takes 15 mins;
$30 \leftarrow P$	$S \leftarrow 15\,min$	Q takes 20 min;
	$S \leftarrow 15\,min$	P takes 30 min;
	$Q \leftarrow 20\,min$	
	$Q \leftarrow 20\,min$	
	$Q \leftarrow 20\,min$	
2hrs	2hrs	

2hrs

(OR)

$P = 30min \times 2 = 60\ min$

$Q = 20min \times 3 = 60\ min$

$R = 60min \times 1 = 60\ min$

$P = 15min \times 4 = 60\ min$

M_1 P Q = 2 hrs

M_2 R S = 2 hrs

10. The old concert hall was demolished because of fears that the foundation would be affected by the 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 in that area.

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

Key: (B)