Q. No. 1 – 5 Carry One Mark Each

Q.1 Choose the most appropriate word from the options given below to complete the following sentence.

A person suffering from Alzheimer's disease __________ short-term memory loss.

(A) experienced (B) unexperienced

(C) is experiencing (D) experiences

Answer: (D)

Q2. Choose the most appropriate word from the options given below to complete the following sentence.

__________ is the key to their happiness; they are satisfied with what they have.

(A) Contentment (B) Ambition

(C) Perseverance (D) Hunger

Answer: (A)

Q3. Which of the following options is the closest in meaning to the sentence below?

"As a woman, I have no country."

(A) Women have no country

(B) Women are not citizens of any country.

(C) Women's solidarity knows no national boundaries

(D) Women of all countries have equal legal rights.

Answer: (C)

Q.4 In any given year, the probability of an earthquake greater than Magnitude 6 occurring in the Garhwal Himalayas is 0.04. The average time between successive occurrences of such earthquakes is ______ years.

Answer: 25 to 25

Exp:

$P = 0.04 = \frac{4}{100}$

For 1earth quake

Reverse probability

$\frac{100}{4}$ P=1earth quake

25 years

Q.5 The population of a new city is 5 million and is growing at 20% annually. How many years would it take to double at this growth rate?

(A) 3-4 years (B) 4-5 years (C) 5-6 years (D) 6-7 years

Answer: (A)

Exp: $\frac{20}{140} \times 8$

After 1 year

P = 6

2 years = 7.2

After 3= $\frac{20}{100} \times 1.2$

= 8.65

After 4 years= $\frac{20}{100} \times 8.65$

=≈10

Time will be in between 3−4 years.

Q. No. 6 – 10 Carry One Mark Each

Q6. In a group of four children, Som is younger to Riaz. Shiv is elder to Ansu. Ansu is youngest in the group. Which of the following statements is/are required to find the eldest child in the group?

Statements :

1. Shiv is younger to Riaz.
2. Shiv is elder to Som.

(A) Statement 1by itself determines the eldest child.

(B) Statement 2 by itself determines the eldest child.

(C) Statement 1 and 2 are both required to determine the eldest child.

(D) Statement 1 and 2 are not sufficient to determine the eldest child.

Answer: (A)

Q7. Moving into a world of big data will require us to change our thinking about the merits of exactitude. To apply the conventional mindset of measurement to the digital, connected world of the twenty-first century is to miss a crucial point. As mentioned earlier, the obsession with exactness is an artefact of the information-deprived analog era. When data was sparse, every data point was critical, and thus great care was taken to avoid letting any point bias the analysis. From “BIG DATA” Viktor Mayer-Schonberger and Kenneth Cukier

The main point of the paragraph is:

(A) The twenty-first century is a digital world

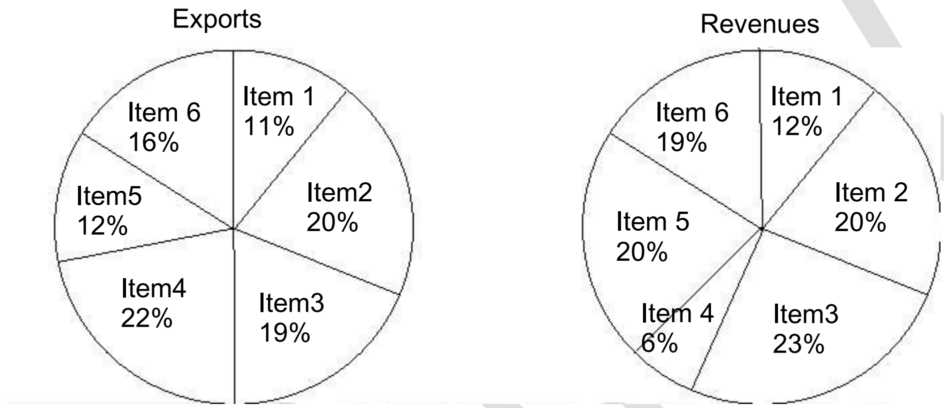
(B) Big data is obsessed with exactness

(C) Exactitude is not critical in dealing with big data

(D) Sparse data leads to a bias in the analysis

Answer: (C)

Q.8 The total exports and revenues from the exports of a country are given in the two pie charts below. The pie chart for exports shows the quantity of each item as a percentage of the total quantity of exports. The pie chart for the revenues shows the percentage of the total revenue generated through export of each item. The total quantity of exports of all the items is 5 lakh tonnes and the total revenues are 250 crore rupees. What is the ratio of the revenue generated through export of Item 1 per kilogram to the revenue generated through export of Item 4 per kilogram?



(A) 1:2 (B) 2:1 (C) 1:4 (D) 4:1

Answer: (D)

Exp: revenue generated through export of item 1 Kg

$\Rightarrow \frac{\text{Item}}{\text{quantity}} = \frac{11}{100} \times 5 = \frac{11}{20}$ (lakhs tows)

revenue gen Item1 $= \frac{12}{100} \times 6 \times 250 \times (C) = \frac{30cr}{11} \times 20$ … (1)

Revenue gen Item 4 $= \frac{6}{100} \times 250.(C)$

$= \frac{15\,cr}{22} \times 20$ Lt. … (2)

1 : 2

$\frac{30}{11} \times \frac{1520 \times \times 2022 =}{4:1}$

Q.9 X is 1 km northeast of Y. Y is 1 km southeast of Z. W is 1 km west of Z. P is 1 km south of W. Q is 1 km east of P. What is the distance between X and Q in km?

(A) 1 (B) $\sqrt{2}$ (C) $\sqrt{3}$ (D) 2

Answer: (C)

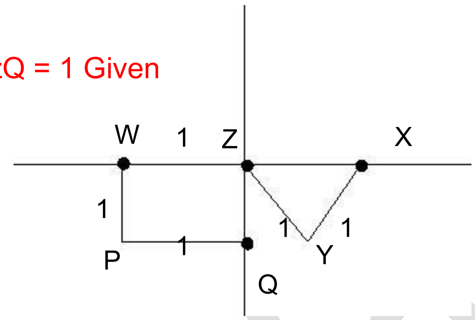
Exp: From the fig: $zx = \sqrt{2}$. [Pythagoras theorem] $zQ = 1$ Given

$\Rightarrow$ Considering ZQX, which is right angle, is

$\Rightarrow Qx^2 = ZQ^2 + Zx^2$

$= \sqrt{1+2}$

$= \sqrt{3}$



Q.10 10% of the population in a town is HIV+. A new diagnostic kit for HIV detection is available; this kit correctly identifies HIV+ individuals 95% of the time, and HIV− individuals 89% of the time. A particular patient is tested using this kit and is found to be positive. The probability that the individual is actually positive is ______

Answer: 0.48 to 0.49

Exp: Let total population = 100

HIV + patients = 10

For the patient to be +Ve, should be either +Ve and test is showing +Ve or the patient should be – Ve but rest is showing +Ve

$$\Rightarrow \frac{0.1\times0.95}{0.1\times0.95+0.9\times0.11}$$

Q. No. 1 – 25 Carry One Mark Each

Q.1 A fair (unbiased) coin was tossed four times in succession and resulted in the following outcomes: (i) Head, (ii) Head, (iii) Head, (iv) Head. The probability of obtaining a 'Tail' when the coin is tossed again is

(A) 0 (B) $\frac{1}{2}$ (C) $\frac{4}{5}$ (D) $\frac{1}{5}$

Answer: (B)

Exp. $P(T) = \frac{1}{2}$

Q.2 The determinant of matrix $\begin{bmatrix} 0 & 1 & 2 & 3 \\ 1 & 0 & 3 & 0 \\ 2 & 3 & 0 & 1 \\ 3 & 0 & 1 & 2 \end{bmatrix}$ is ________

Answer: 88 to 88

Exp. $\begin{vmatrix} 0 & 1 & 2 & 3 \\ 1 & 0 & 3 & 0 \\ 2 & 3 & 0 & 1 \\ 3 & 0 & 1 & 2 \end{vmatrix} = -1\begin{vmatrix} 1 & 2 & 3 \\ 3 & 0 & 1 \\ 0 & 1 & 2 \end{vmatrix} - 3\begin{vmatrix} 0 & 1 & 3 \\ 2 & 3 & 1 \\ 3 & 0 & 2 \end{vmatrix}$

$= -\left[1(0-1)-2(6-0)+3(3-0)\right]$

$= -3\left[0-1(4-3)+3(0-9)\right] = 88$

Q.3 $z=\frac{2-3i}{-5+i}$ can be expressed as

(A) - 0.5 - 0.5i (B) - 0.5 + 0.5i (C) 0.5 - 0.5i (D) 0.5 + 0.5i

Exp. $z=\frac{2-3i}{-5+i}$

$=\frac{2-3i}{-5+i}\times\frac{-5-i}{-5-i}$

$=\frac{-10-2i+15i+3i^2}{5^2-i^2}=\frac{-10+13i-3}{25+1}$

$=\frac{13i-13}{26}=\frac{13(i-1)}{26}=\frac{i-1}{2}=\frac{i}{2}-\frac{i}{2}=0.5i-0.5.$

Q.4 The integrating factor for the differential equation $\frac{dP}{dt}+k_2P=k_1L_0e^{-k_1t}$ is

(A) e^{-k_1t} (B) e^{-k_2t} (C) e^{k_1t} (D) e^{k_2t}

Answer: (D)

Exp. $\frac{dP}{dt}+K_2P=K_1L_0e^{-K_1t}$

The standard form of Linear differential equations is

$\frac{dy}{dx}+py=Q;\ \text{I.F}=e^{\int p\,dx}$

$\Rightarrow \frac{dP}{dt}+K_2P=\left(K_1L_0e^{-K_1t}\right)$

Integrating factor, $\text{I.F}=e^{\int K_2dt}=e^{K_2t}$.

Q.5 If {x} is a continuous, real valued random variable defined over the interval $(-\infty,+\infty)$ and its occurrence is defined by the density function given as: $f(x)=\frac{1}{\sqrt{2\pi}*b}e^{\frac{1}{2}\left(\frac{x-a}{b}\right)^2}$ where 'a' and 'b' are the statistical attributes of the random variable {x}. The value of the integral $\int_{-\infty}^{a}\frac{1}{\sqrt{2\pi}*b}e^{-\frac{1}{2}\left(\frac{x-a}{b}\right)^2}dx$ is

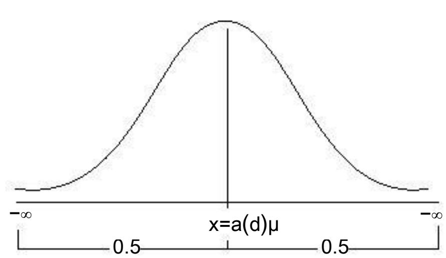
(A) 1 (B) 0.5 (C) π (D) $\frac{\pi}{2}$

Answer: (B)

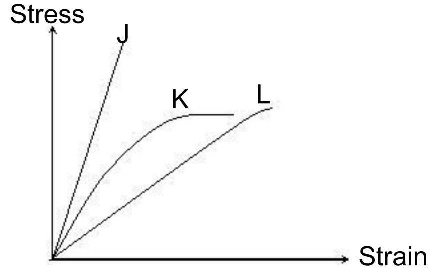
Exp. We have $\int_{-\infty}^{\infty}f(x)\,dx=1$

$\Rightarrow \int_{-\infty}^{a}f(x)\,dx+\int_{a}^{\infty}f(x)\,dx=1$

$\Rightarrow \int_{-\infty}^{a}f(x)\,dx=0.5$



Q.6 Group I contains representative stress-strain curves as shown in the figure, while Group II gives the list of materials. Match the stress-strain curves with the corresponding materials.



Group I	Group II
(p) Curve J	(1) Cement paste
(q) Curve K	(2) Coarse aggregate
(r) Curve L	(3) Concrete

(A) P - 1; Q - 3; R - 2 (B) P - 2; Q - 3; R - 1
(C) P - 3; Q - 1; R - 2 (D) P - 3; Q - 2; R – 1

Answer: (B)

Exp.

Aggregate

concrete

cement paste

So, P=2,
Q=3,
R=1

Q.7 The first moment of area about the axis of bending for a beam cross-section is

(A) moment of inertia (B) section modulus
(C) shape factor (D) polar moment of inertia

Answer: (B)

Exp. $\because$ Sec tion modulus, $z = \frac{I}{r} = \frac{A.r^2}{r} = A.r$, i.e. Moment of Area.

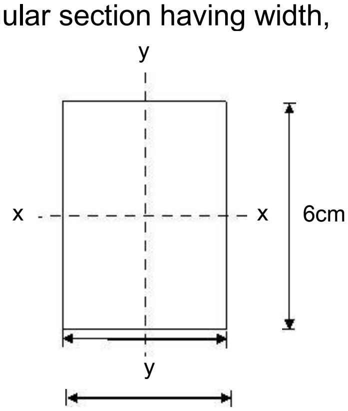
Q.8 Polar moment of inertia (I_p), in cm^4, of a rectangular section having width, b = 2 cm and depth, d = 6 cm is ________________

Answer: 40.00 to 40.00

Exp.

$$I_p = I_{xx} + I_{yy} = \frac{2\times(6)^3}{12} + \frac{6(2)^3}{12}$$

$$= 40 cm^4$$



Q.9 The target mean strength f_{cm} for concrete mix design obtained from the characteristic strength f_{ck} and standard deviation σ, as defined in IS:456-2000, is

(A) $f_{ck}+1.35\sigma$ (B) $f_{ck}+1.45\,\sigma$ (C) $f_{ck}+1.55\,\sigma$ (D) $f_{ck}+1.65\sigma$

Answer: (D)

Exp. $f_m=f_{ck}+1.65\sigma$ (As per IS:456.2000)

Q.10 The flexural tensile strength of M25 grade of concrete, in N/mm^2, as per IS:456-2000 is ________

Answer: 3.5 to 3.5

Exp. Flexural tensile strength, $f_{cr}=0.7\sqrt{f_{ck}}\ N/mm^2$

$=0.7\times\sqrt{25}$

$=3.5N\ /\ mm^2$

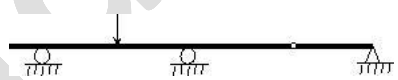
Q.11 The modulus of elasticity, $E=5000\sqrt{f_{ck}}$ where f_{ck} is the characteristic compressive strength of concrete, specified in IS:456-2000 is based on

(A) tangent modulus (B) initial tangent modulus

(C) secant modulus (D) chord modulus

Answer: (B)

Q.12 The static indeterminacy of the two-span continuous beam with an internal hinge, shown below, is ______________



Answer: 0 to 0

Exp. $D_s=3m+r-3j-r_r$

m = no. of members = 4

r = no. of external reactions = 4

j = no. of joints = 5

r_r= no. of reactions released = 2-1 = 1

So, $D_g=3\times4+4-3\times5-1=0$

Q.13 As per Indian Standard Soil Classification System (IS: 1498 - 1970), an expression for A-line is

(A) $I_p = 0.73\ (w_L - 20)$ (B) $I_p = 0.70\ (w_L - 20)$

(C) $I_p = 0.73\ (w_L - 10)$ (D) $I_p = 0.70\ (w_L - 10)$

Answer: (A)

Exp. $I_p=0.73\ (W_L-20)$

Q.14 The clay mineral primarily governing the swelling behavior of Black Cotton soil is

(A) Halloysite (B) Illite (C) Kaolinite (D) Montmorillonite

Answer: (D)

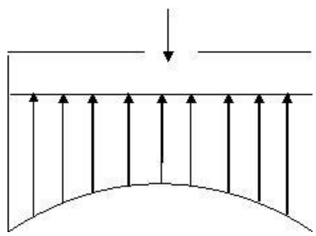
Q.15 The contact pressure for a rigid footing resting on clay at the centre and the edges are respectively

(A) maximum and zero (B) maximum and minimum

(C) zero and maximum (D) minimum and maximum

Answer: (D)

Exp.



Rigid footing: stress distribution for clay
minimum at centre, maximum at edge.

Q.16 A certain soil has the following properties: Gs = 2.71, n = 40% and w = 20%. The degree of saturation of the soil (rounded off to the nearest percent) is _________

Answer: 81.0 to 81.5

Exp. $G_s=2.71$, $n=40\%=0.40$,

$W=20\%$, $S=?$

$$e=\frac{n}{1-n}=\frac{0.4}{0.6}=0.67$$

$$S=\frac{WG}{e}=\frac{0.20\times2.71}{0.67}=0.808=81\%$$

Q.17 A plane flow has velocity components $u=\frac{x}{T_1}$, $v=-\frac{y}{T_2}$ and w = 0 and x, y and z directions respectively, where $T_1(\neq0)$ and $T_2(\neq0)$ are constants having the dimensions of time. The given flow is incompressible if

(A) $T_1=-T_2$ (B) $T_1=-\frac{T_2}{2}$ (C) $T_1=\frac{T_2}{2}$ (D) $T_1=T_2$

Answer: (D)

Exp. $U=\frac{x}{T_1}$, $V=\frac{-y}{T_2}$, $w=0$

For incompressible flow

$$\frac{2v}{2x}+\frac{2v}{2y}+\frac{2w}{2z}=0$$

$$\Rightarrow \frac{1}{T_1}-\frac{1}{T_2}=0 \Rightarrow T_1=T_2$$

Q.18 Group I lists a few devices while Group II provides information about their uses. Match the devices with their corresponding use.

Group I	Group II
(p) Anemometer	(1) Capillary potential of soil water
(q) Hygrometer	(2) Fluid velocity at a specific point in the flow stream
(r) Pitot Tube	(3) Water vapour content of air
(s) Tensiometer	(4) Wind speed

(A) P - 1; Q -2; R - 3; S - 4 (B) P - 2; Q - 1; R - 4; S- 3
(C) P - 4; Q - 2; R - 1; S - 3 (D) P - 4; Q - 3; R - 2; S – 1

Answer: (D)

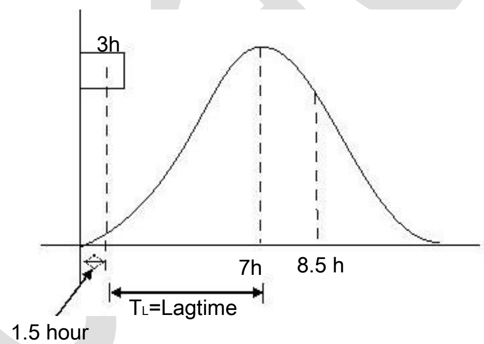
Exp. Aneometer wind speed
Hygrometer water vapour content of air
Pilot tube flow velocity at a specific point in the flow stream
Tensionmeter Capillary potential of soil water

Q.19 An isolated 3-h rainfall event on a small catchment produces a hydrograph peak and point of inflection on the falling limb of the hydrograph at 7 hours and 8.5 hours respectively, after the start of the rainfall. Assuming, no losses and no base flow contribution, the time of concentration (in hours) for this catchment is approximately

(A) 8.5 (B) 7.0 (C) 6.5 (D) 5.5

Answer: (D)

Exp.



For small catchment, time of concentration is equal to lag time of peak flow.
$T_c = 7 - 1.5 = 5.5h$

Q.20 The Muskingum model of routing a flood through a stream reach is expressed as $O_2 = K_0 I_2 + K_1 I_1 + K_2 O_1$, where K_0, K_1 and K_2 are the routing coefficients for the concerned reach, I_1 and I_2 are the inflows to reach, and O_1 and O_2 are the are the outflows from the reach corresponding to time steps 1 and 2 respectively. The sum of K_0, K_1 and K_2 of the model is

(A) -1 (B) -0.5 (C) 0.5 (D) 1

Answer: (D)

Exp. $K_0 + K_1 + K_2 = 1$

Q.21 The dominating microorganisms in an activated sludge process reactor are

(A) aerobic heterotrophs (B) anaerobic heterotrophs
(C) autotrophs (D) phototrophs

Answer: (A)

Q.22 The two air pollution control devices that are usually used to remove very fine particles from the flue gas are

(A) Cyclone and Venturi Scrubber
(B) Cyclone and Packed Scrubber
(C) Electrostatic Precipitator and Fabric Filter
(D) Settling Chamber and Tray Scrubber

Answer: (C)

Q.23 The average spacing between vehicles in a traffic stream is 50 m, then the density (in veh/km) of the stream is___________

Answer: 20.0 to 20.0

Exp. Density, $K=\frac{1000}{s}=\frac{1000}{50}=20 \text{ veh / km}$

Q.24 A road is being designed for a speed of 110 km/hr on a horizontal curve with a super elevation of 8%. If the coefficient of side friction is 0.10, the minimum radius of the curve (in m) required for safe vehicular movement is

(A) 115.0 (B) 152.3 (C) 264.3 (D) 528.5

Answer: (D)

Exp. Ruling gradient = $=\frac{V^2}{127(e+f)}$

$$=\frac{110\times110}{127(0.08+0.10)}=529.30\text{m}$$

Q.25 The survey carried out to delineate natural features, such as hills, rivers, forests and man-made features, such as towns, villages, buildings, roads, transmission lines and canals is classified as

(A) engineering survey (B) geological survey
(C) land survey (D) topographic survey

Answer: (D)

Exp. Topographic survey is carried out to delineate natural features.

Q. No. 26 – 55 Carry Two Marks

Q.26 The expression $\lim_{\alpha\to0}\frac{x^{\alpha}-1}{\alpha}$ is equal to

(A) log x (B) 0 (C) x log x (D) ∞

Answer: (A)

Exp. By L' Hospital rule,

$$L = \frac{\frac{d}{d\alpha}\left(x^{\alpha-1}\right)}{\frac{d}{d\alpha}(\alpha)}$$

$$= \lim_{\alpha\to 0} \frac{x^{\alpha}.\log x}{1} = \log x$$

Q.27 An observer counts 240 veh/h at a specific highway location. Assume that the vehicle arrival at the location is Poisson distributed, the probability of having one vehicle arriving over a 30-second time interval is__________

Answer: 0.25 to 0.28

Exp. Average no. of vehicles per hour,

$\lambda = 240$ / hour

$= \frac{240}{60}$ / min

$= 4$ / min $= 2$ / 30sec

$$P(x=1) = \frac{e^{-2}.2^{1}}{1!} = 0.27$$

Q.28 The rank of matrix $\begin{bmatrix} 6 & 0 & 4 & 4 \\ -2 & 14 & 8 & 18 \end{bmatrix}$ is ____________

Answer: 2.0 to 2.0

Exp. $\begin{bmatrix} 6 & 0 & 4 & 4 \\ -2 & 14 & 8 & 18 \end{bmatrix}$ $R_2 \to 3R_2 + R_1;\ R_3 \to 6R_3 - 14R_1$

$\sim \begin{bmatrix} 6 & 0 & 4 & 4 \\ 0 & 42 & 28 & 58 \\ 0 & -84 & -56 & -116 \end{bmatrix}$ $R_3 \to R_3 + 2R_2$

$\sim \begin{bmatrix} 6 & 0 & 4 & 4 \\ 0 & 42 & 28 & 58 \\ 0 & 0 & 0 & 0 \end{bmatrix}$

Rank = No. of non-zero rows = 2

Q.29 Water is flowing at a steady rate through a homogeneous and saturated horizontal soil strip of 10 m length. The strip is being subjected to a constant water head (H) of 5 m at the beginning and 1 m at the end. If the governing equation of flow in the soil strip is $\frac{d^2H}{dx^2} = 0$ (where x is the distance along the soil strip), the value of H (in m) at the middle of the strip is __________

Answer: 3.0 to 3.0

Exp. $\frac{d^2H}{dx^2} = 0$

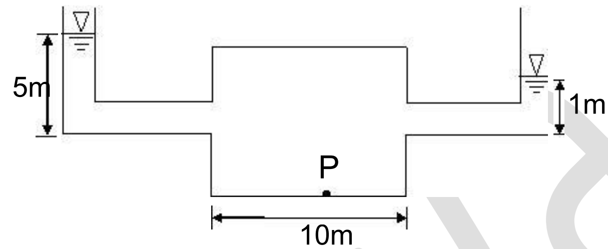
$\Rightarrow \frac{dH}{dX} = K \Rightarrow H = Kx + C$

at x=0, H= 5 $\Rightarrow$ C=5

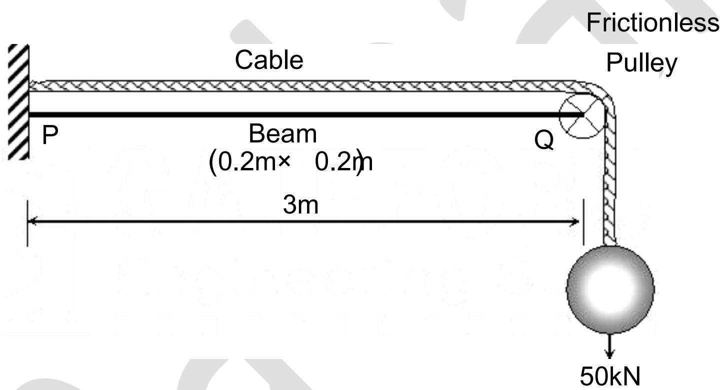
at x=10, H=1 $\Rightarrow$ K=− 0.4

so, H=− 0.4x+ 5

At x=5, H=−.4× 5+5=3m



Q.30 The values of axial stress ( ) in kN/m², bending moment (M) in kNm, and shear force (V) in kN acting at point P for the arrangement shown in the figure are respectively



(A) 1000, 75 and 25
(B) 1250, 150 and 50
(C) 1500, 225 and 75
(D) 1750, 300 and 100

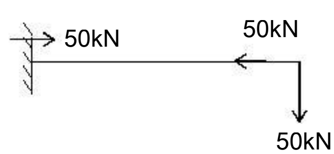
Answer: (B)

Exp. Loading after removing of cable

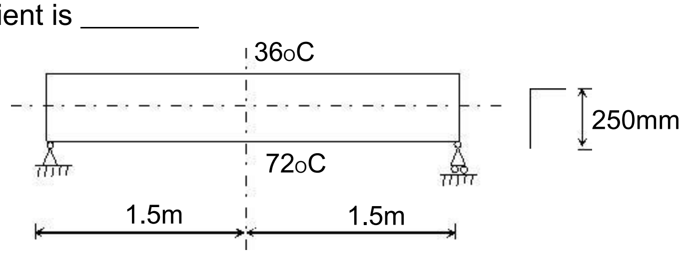
Axial stress $= \frac{50}{0.2 \times 0.2} = 1250\text{kN} / \text{m}^2$

B.M = 50×3 = 150kNm

S.F = 50kN

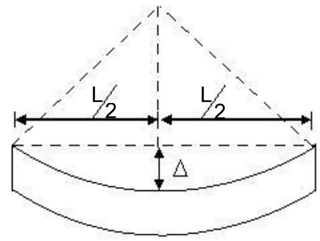


Q.31 The beam of an overall depth 250 mm (shown below) is used in a building subjected to two different thermal environments. The temperatures at the top and bottom surfaces of the beam are 36°C and 72°C respectively. Considering coefficient of thermal expansion ( ) as 1.50×10^{-5} per °C, the vertical deflection of the beam (in mm) at its mid-span due to temperature gradient is ________



Answer: 2.38 to 2.45

Exp.



From properties of circle,

$(2R-\Delta).\Delta = \frac{L}{2} \times \frac{L}{2}$

$\because$ is very small, neglect Δ^2

$2R.\Delta = \frac{L^2}{4}$

$\Rightarrow \Delta = \frac{L^2}{8R}$ But $R = \alpha h T$

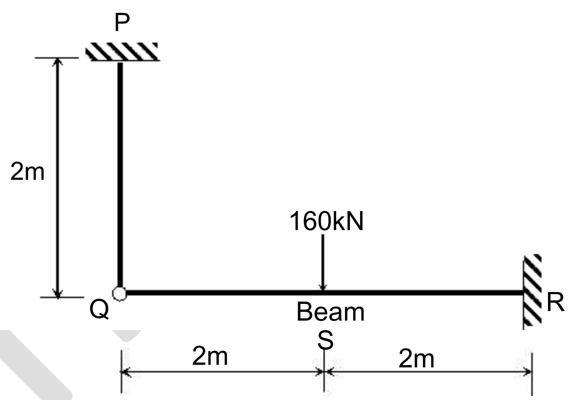
$= \frac{L^2}{8.h}.\alpha T$

Here, L=3m, $\alpha = 1.50 \times 10^{-5}$ /°C,

T=72°−36°=36° C

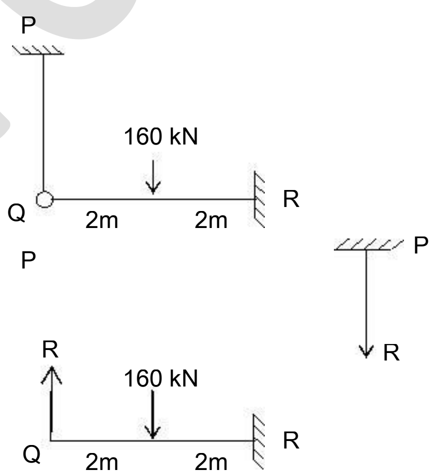
$\Delta = \frac{(3)^2 \times 1.5 \times 10^{-5} \times 36}{8 \times 0.250} = 0.00243\text{m} = 2.43\text{mm}$

Q.32 The axial load (in kN) in the member PQ for the arrangement/assembly shown in the figure given below is ______________



Answer: 50.0 to 50.0

Exp.



Taking PQ to be rigid; so, $\Delta_Q = 0$

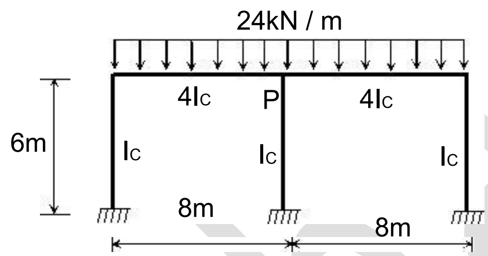
$$\Rightarrow \frac{R(4)^3}{3EI} = \frac{160(2)^3}{3EI} + \frac{160(2)^2}{2EI}\times 2$$

$\Rightarrow 64R = 160\times8 + 160\times4\times3$

$\Rightarrow R = 50kN$

So, Tension in PQ = 50 kN

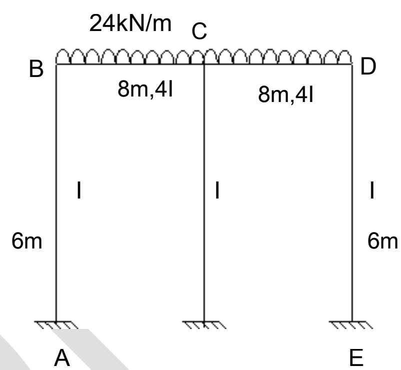
Q.33 Considering the symmetry of a rigid frame as shown below, the magnitude of the bending moment (in kNm) at P (preferably using the moment distribution method) is



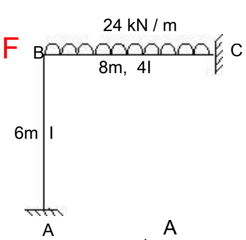
(A) 170 (B) 172 (C) 176 (D) 178

Answer: (C)

Exp.



Axis of symmetry is passing through a column; hence it can be treated as



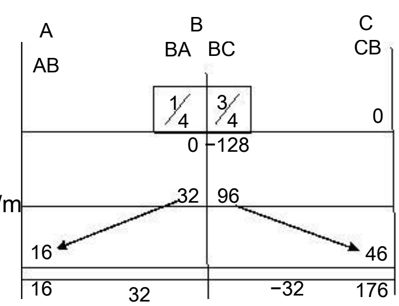
Member	Stiffness	D.F
BA	$\frac{4EI}{6}$	$\frac{1}{4}$
BC	$\frac{4E(4I)}{8}$	$\frac{3}{4}$

FE11:

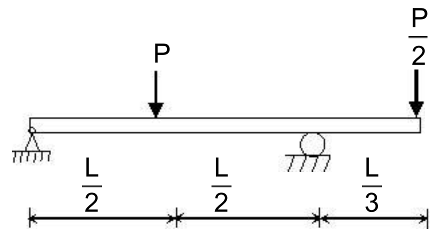
$M_{BC} = -\frac{WL^2}{12} = \frac{-24\times8\times8}{12} = -128kNM$

$M_{CB} = +128$ kNM

B.M at C=176kN/m



Q.34 A prismatic beam (as shown below) has plastic moment capacity of Mp, then the collapse load P of the beam is



(A) $\frac{2M_p}{L}$ (B) $\frac{4M_p}{L}$ (C) $\frac{6M_p}{L}$ (D) $\frac{8M_p}{L}$

Answer: (C)

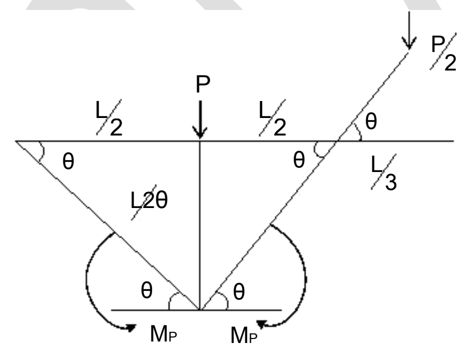
Exp. Degree of static indeterminacy $D_s = 0$

$\therefore$ Number of plastic hinges = $D_s+1 = 1$

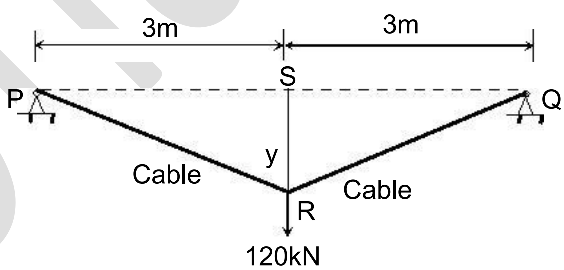
From principal of virtual work

$$-M_p.\theta - M_p.\theta + P.\left(\frac{L}{2}.\theta\right) + \frac{P}{2}\left(\frac{L}{3}.\theta\right) = 0$$

$$\Rightarrow P = \frac{6M_p}{L}$$



Q.35 The tension (in kN) in a 10 m long cable, shown in the figure, neglecting its self-weight is



(A) 120 (B) 75 (C) 60 (D) 45

Answer: (B)

Exp. Taking moment about Q =0

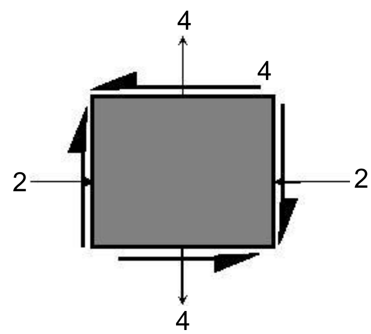
$R \times 6 - 120 \times 3 = 0 \Rightarrow R_A = 60kN$

Taking moment about R = 0

$R \times 3 - H \times 4 = 0 \Rightarrow H = \frac{3}{4} \times 60 = 45kN$

$T = \sqrt{R^2 + H^2} = \sqrt{(60)^2 + (45)^2} = 75kN$

Q.36 For the state of stresses (in MPa) shown in the figure below, the maximum shear stress (in MPa) is ______________



Answer: 5.0 to 5.0

Exp. $\sigma_x = -2, \sigma_y = 4, \tau = 4$

Max shear stress, $\tau_{max} = \dfrac{\sigma_1 - \sigma_2}{2}$

Where, $\sigma_1 = \dfrac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\dfrac{\sigma_x - \sigma_y}{2}\right)^2 + \tau^2}$

$= \dfrac{-2+4}{2} + \sqrt{\left(\dfrac{-2-4}{2}\right)^2 + (4)^2} = 1+5 = 6\text{MPa}$

$\sigma_2 = \dfrac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\dfrac{\sigma_x - \sigma_y}{2}\right)^2 + \tau^2} = 1-5 = -4\text{MPa}$

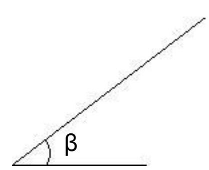
So, $\tau_{max} = \dfrac{6-(-4)}{2} = 5\text{MPa}$

Q.37 An infinitely long slope is made up of a c-φ soil having the properties: cohesion (c) = 20 kPa, and dry unit weight (γ_d) = $16\text{kN}/\text{m}^3$. The angle of inclination and critical height of the slope are 40° and 5 m, respectively. To maintain the limiting equilibrium, the angle of internal friction of the soil (in degrees) is ________________

Answer: 21.0 to 23.0

Exp. Given, $C = 20\text{KPa}, \gamma_d = 16\text{kN}/\text{m}^3$

$\beta = 40°, H = 5\text{m}, \varphi = ?$



$H = \dfrac{C}{\gamma_d(\tan\beta - \tan\varphi)\cos^2\beta}$

$\Rightarrow 5 = \dfrac{20}{16(\tan 40° - \tan\varphi).\cos^2 40°}$

$\Rightarrow \varphi = 22.44°$

Q.38 Group I enlists in-situ field tests carried out for soil exploration, while Group II provides a list of parameters for sub-soil strength characterization. Match the type of tests with the characterization parameters

Group I	Group II
(P) Pressuremeter Test (PMT)	(1) Menard's modulus (E_m)
(Q) Static Cone Penetration Test (SCPT)	(2) Number of blows (N)
(R) Standard Penetration Test (SPT)	(3) Skin resistance (f_c)
(S) Vane Shear Test (VST)	(4) Undrained cohesion (c_x)

(A) P - 1; Q - 3; R - 2; S - 4 (B) P - 1; Q - 2; R - 3; S - 4
(C) P - 2; Q - 3; R - 4; S - 1 (D) P - 4; Q - 1; R - 2; S – 3

Answer: (A)

Q.39 A single vertical friction pile of diameter 500 mm and length 20 m is subjected to a vertical compressive load. The pile is embedded in a homogeneous sandy stratum where: angle of internal friction (ϕ) = 30°, dry unit weight (γ_d) = 20 kN/m^3 and angle of wall friction (δ) = $2\phi/3$. Considering the coefficient of lateral earth pressure (K) = 2.7 and the bearing capacity factor (Nq) = 25, the ultimate bearing capacity of the pile (in kN) is ______________

Answer: 6150 to 6190

Exp. For friction pile

$$Q_U = f_s . A_s$$

Where, $f_s = \frac{1}{2}\sigma_v .K. \tan\delta$

$$\sigma_V = \gamma_d \times L = 20\times20 = 400\,kN/m^2$$

K=2.7

$$\tan\delta = \tan\left(\frac{2}{3}\varphi\right) = \tan\left(\frac{2}{3}\times30\right) = 0.364$$

$$\text{So, } f_s = \frac{1}{2}\times400\times 2.7\times0.364 = 196.56\,kN/m^2$$

$$\text{So, } Q_u = (196.56)\times\pi D.L = 196.56\times\pi\times0.5\times20 = 6175kN$$

Q.40 A circular raft foundation of 20 m diameter and 1.6m thick is provided for a tank that applies a bearing pressure of 110 kPa on sandy soil with Young's modulus, E,' = 30 MPa and Poisson's ration, μ_s = 0.3. The raft is made of concrete (E_C = 30 GPa and μ_C = 0.15). Considering the raft as rigid, the elastic settlement (in mm) is

(A) 50.96 (B) 53.36 (C) 63.72 (D) 66.71

Answer: (B)

Exp. Elastic settlement of rigid footing

$$S = 0.8\left[\frac{qB(1-\mu^2)}{E}\right]$$

Given, $q=110kN/m^2$, $B=20m, \mu = 0.30$

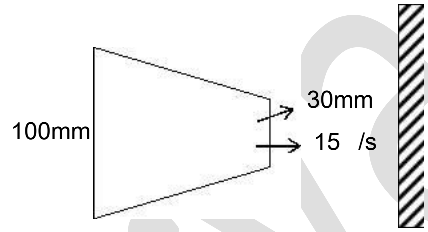
$E_s=30GPa = 30\times10^3\,kN/m^2$

$$S = 0.8\left[\frac{110\times20\times(1-0.09)}{30\times10^3}\right] = 53.38mm$$

Q.41 A horizontal nozzle of 30 mm diameter discharges a steady jet of water into the atmosphere at a rate of 15 litres per second. The diameter of inlet to the nozzle is 100 mm. The jet impinges normal to a flat stationary plate held close to the nozzle end. Neglecting air friction and considering the density of water as 1000 kg/m ^{3}, the force exerted by the jet (in N) on the plate is ________

Answer: 318 to 319

Exp. Velocity of jet, $v = \frac{Q}{A} = \frac{15\times10^{-3}}{\frac{\pi}{4}\times(0.03)^2} m^3/s = 21.22 m/s$



Force on plate, $F = \rho a.v^2$

$= 1000\times\frac{\pi}{4}\times(0.03)^2\times(21.22)^2$

$= 318.29$ N

Q.42 A venturimeter having a throat diameter of 0.1 m is used to estimate the flow rate of a horizontal pipe having a diameter of 0.2 m. For an observed pressure difference of 2 m of water head and coefficient of discharge equal to unity, assuming that the energy losses are negligible, the flow rate (in m^3/s) through the pipe is approximately equal to

(A) 0.500 (B) 0.150 (C) 0.050 (D) 0.015

Answer: (C)

Exp. $Q = C_d.\frac{a_1\times a_2}{\sqrt{a_1^2-a_2^2}}.\sqrt{2gh}$

$a_1 = \frac{\pi}{4}\times(0.2)^2 = 0.0314 m^2$

$a_2 = \frac{\pi}{4}\times(0.1)^2 = 0.0078 m^2$

so, $Q = \frac{1\times0.0314\times0.0078}{\sqrt{(0.0314)^2-(0.0078)^2}}\times\sqrt{2\times9.81\times2} = 0.050 m^3/s$

Q.43 A rectangular channel of 2.5 m width is carrying a discharge of 4 m^3/s. Considering that acceleration due to gravity as 9.81 m/s^2, the velocity of flow (in m/s) corresponding to the critical depth (at which the specific energy is minimum) is _______

Answer: 2.45 to 2.55

Exp. $B=2.5m$, $Q=4m^3/s$, $g=9.81/s^2$

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

$q = \frac{Q}{B} = \frac{4}{2.5} = 1.6 m^2/s$

So, $y_c = \left(\frac{(1.6)^2}{9.81}\right)^{1/3} = 0.64m$

Now, $Q = A.v_c$

$\Rightarrow v_c = \frac{Q}{B.y_c} = \frac{4}{2.5\times0.64} = 2.5 m/s$

Q.44 Irrigation water is to be provided to a crop in a field to bring the moisture content of the soil from the existing 18% to the field capacity of the soil at 28%. The effective root zone of the crop is 70 cm. If the densities of the soil and water are 1.3 g/cm^3 and 1.0 g/cm^3 respectively, the depth of irrigation water (in mm) required for irrigating the crop is ________

Answer: 91 to 91

Exp. Depth of irrigation water

$$d = \frac{\gamma_d}{\gamma_w} d(F.C - W.P)$$

$$= \frac{1.3}{1} \times 70 \times (0.28 - 0.18)$$

$$= 9.1\text{cm} \Rightarrow 91\text{mm}$$

Q.45 With reference to a standard Cartesian (x, y) plane, the parabolic velocity distribution profile of fully developed laminar flow in x-direction between two parallel, stationary and identical plates that are separated by distance, h, is given by the expression

$$u = -\frac{h^2}{8\mu}\frac{dp}{dx}\left[1 - 4\left(\frac{y}{h}\right)^2\right]$$

In this equation, the y = 0 axis lies equidistant between the plates at a distance h/2 from the two plates, p is the pressure variable and μ is the dynamic viscosity term. The maximum and average velocities are, respectively

(A) $u_{max} = -\frac{h^2}{8\mu}\frac{dp}{dx}$ and $u_{average} = \frac{2}{3}u_{max}$

(B) $u_{max} = \frac{h^2}{8\mu}\frac{dp}{dx}$ and $u_{average} = \frac{2}{3}u_{max}$

(C) $u_{max} = -\frac{h^2}{8\mu}\frac{dp}{dx}$ and $u_{average} = \frac{3}{8}u_{max}$

(D) $u_{max} = \frac{h^2}{8\mu}\frac{dp}{dx}$ and $u_{average} = \frac{3}{8}u_{max}$

Answer: (A)

Exp. $U = -\frac{h^2}{8\mu}\left(\frac{dp}{dx}\right)\left[1 - 4\left(\frac{y}{h}\right)^2\right]$

Maximum velocity is at y = 0

$$U_{max} = \frac{-h^2}{8\mu}\left(\frac{dp}{dx}\right)$$

$$U_{avg} = \frac{Q}{A} = \frac{\int U.dA}{A} = \frac{\int U_{max}\left(1 - \frac{4y^2}{h^2}\right).dA}{A}$$

$$= \frac{2\int_0^{h/2} U_{max}\left(1 - \frac{4y^2}{h^2}\right)}{h \times 1} = \frac{2U_{max}}{h}\left[y - \frac{4y^3}{3h^2}\right]_0^{h/2}$$

$$= \frac{2U_{max}}{h}\left[\frac{h}{2} - \frac{4h^3}{24h^2}\right] = \frac{2}{3}U_{max}$$

Q.46 A suspension of sand like particles in water with particles of diameter 0.10 mm and below is flowing into a settling tank at 0.10 m^3/s. Assume g = 9.81 m/s^2, specific gravity of particles = 2.65, and kinematic viscosity of water $=1.0105\times10^{-2}$ cm^2/s. The minimum surface area (in m^2) required for this settling tank to remove particles of size 0.06 mm and above with 100% efficiency is ______________

Answer: 31.0 to 32.0

Exp. Particle size = 0.06m < 0.1 mm

So, Stoke's law is valid

$$\frac{Q}{A} = \text{overflow rate} \le \text{settling velocity of } 0.06\text{mm particle}$$

$$\Rightarrow \frac{Q}{A} \le V_s \Rightarrow A = \frac{Q}{V_s}$$

$$V_s = \frac{1}{18}\cdot\frac{d^2 g}{V}(G_s-1) = \frac{(0.06\times10^{-3})^2\times9.81\times(2.65-1)}{18\times1.0105\times10^{-6}} = 3.20\times10^{-3}\ m/s$$

$$\Rightarrow A \ge \frac{0.1}{3.20\times10^{-3}} = 31.21\ m^2$$

Q.47. A surface water treatment plant operates round the clock with a flow rate of 35 m^3/min. The water temperature is 15□ and jar testing indicated an alum dosage of 25 mg/l with flocculation at a Gt value of 4×10^4 producing optimal results. The alum quantity required for 30 days (in kg) of operation of the plant is _________

Answer: 37800 to 37800

Exp. Given $Q=35m^3/\text{min} = 35\times10^3\times60\times24\ /\text{day}$

Alum dosage = 25 mg/l

Alum quantity required for 30 days

$= 35\times10^3\times60\times24\times25\times10^{-6}\times30 = 37800\text{kg}.$

Q.48

An effluent at a flow rate of 2670 m^3/d from a sewage treatment plant is to be disinfected. The laboratory data of disinfection studies with a chlorine dosage of 15 mg/l yield the model

$N_t = N_o e^{-0.145t}$ where N_t = number of micro-organisms surviving at time t (in min.) and N_O = number of micro-organisms present initially (at t = 0). The volume of disinfection unit (in m^3) required to achieve a 98% kill of micro-organisms is _____________

Answer: 49.0 to 51.0

Exp. $Q=2760\ m^3/\text{day}$, chlorine dose=15mg /

$N_b = N_0.e^{-0.145t}$

If 98% micro organisms are killed, 2% are surviving.

So, $N_t = 0.02$

N_0 = number of microorganisms present at t = 0

ie., 100% = 1

So, $0.02=e^{-0.145.t} \Rightarrow t=26.98\text{minutes}$

$$V = Q\times t_d = \left(2670\frac{m^3}{d}\right)\times\left(\frac{26.98}{60\times24}\right) = 50.02m^3$$

Q.49 A waste water stream (flow = 2 m^3/s, ultimate BOD = 90 mg/l) is joining a small river (flow = 12 m^3/s, ultimate BOD = 5 mg/l). Both water streams get mixed up instantaneously. Cross-sectional area of the river is 50 m^2. Assuming the de-oxygenation rate constant, k' = 0.25/day, the BOD (in mg/l) of the river water, 10 km downstream of the mixing point is

(A) 1.68 (B) 12.63 (C) 15.46 (D) 1.37

Answer: (C)

Exp. $Q_s = 2m^3/s$, BOD ultimate, $L_s = 90mg/\ell$

$Q_R = 12m^3/s$, $L_R = 5mg/\ell$

$$(BOD)_{mix} = \frac{90\times2+12\times5}{2+12} = 17.14mg/\ell$$

$$\text{Velocity of River flow, } V_R = \frac{Q}{A} = \frac{12+2}{50} = 0.28m/s$$

$$\text{Time taken to travel 10km} = \frac{10000}{0.28} = 35714.28s = 0.41d$$

$$L_t = L_0 \times e^{-kt} = 17.14\times e^{-0.25\times0.41} = 15.46\ mg/l$$

Q.50 In a Marshall sample, the bulk specific gravity of mix and aggregates are 2.324 and 2.546 respectively. The sample includes 5% of bitumen (by total weight of mix) of specific gravity 1.10. The theoretical maximum specific gravity of mix is 2.441. The void filled with bitumen (VFB) in the Marshall sample (in %) is _______

Answer: 62 to 66

Exp. $$VFB = \frac{V_b}{V_{MA}}\times100$$

Where, V_b = voids filled with bitumen $= \frac{G_m}{G_4}\times W_4 = \frac{2.324}{1.10}\times5 = 10.564$

$V_{MA} = V_V + V_b$

$$V_V = \text{Volume of voids} = \frac{G_t - G_m}{G_t}\times100 = \frac{2.441-2.324}{2.441}\times100 = 4.79\%$$

$V_{MA} = 10.56 + 4.79 = 15.35$

$$\text{So, } V_{FB} = \frac{10.564}{15.35}\times100 = 68.82\%$$

Q.51 A student riding a bicycle on a 5 km one-way street takes 40 minutes to reach home. The student stopped for 15 minutes during this ride. 60 vehicles overtook the student (assume the number of vehicles overtaken by the student is zero) during the ride and 45 vehicles while the student stopped. The speed of vehicle stream on that road (in km/hr) is

(A) 7.5 (B) 12 (C) 40 (D) 60

Answer: (D)

Q.52 On a section of a highway the speed-density relationship is linear and is given by $v = \left(80 - \frac{2}{3}k\right)$; where v is in km/h and k is in veh/km. The capacity (in veh/h) of this section of the highway would be

(A) 1200 (B) 2400 (C) 4800 (D) 9600

Answer: (B)

Exp. $V = 80 - \frac{2}{3}K$

Capacity $= \frac{V_f \times K_j}{4}$, where V_f = free mean velocity

K_j = Jam density

K_j is when, $V = 0$

$\Rightarrow K_j = 80 \times \frac{3}{2} = 120 \text{ veh / km}$

V_f is at $K=0$, $V_f = 80$ km/h

So, Capacity $= \frac{80 \times 120}{4} = 2400$ veh / h

Q.53 A pre-timed four phase signal has critical lane flow rate for the first three phases as 200, 187 and 210 veh/hr with saturation flow rate of 1800 veh/hr/lane for all phases. The lost time is given as 4 seconds for each phase. If the cycle length is 60 seconds, the effective green time (in seconds) of the fourth phase is ____________

Answer: 14.0 to 18.0

Exp. Total time lost, $t = 4 \times 4 = 16$s; $C = \frac{1.5L+5}{1-Y}$

$Y = y_1 + y_2 + y_3 + y_4$

$= \frac{q_1}{s_1} + \frac{q_2}{s_2} + \frac{q_3}{s_3} + \frac{q_4}{s_4}$

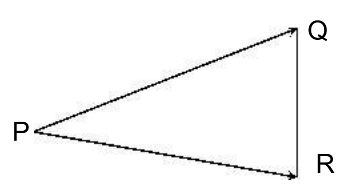
$= \frac{200}{1800} + \frac{187}{1800} + \frac{210}{1800} + y_4 = 0.332 + y_4$

$60 = \frac{1.5 \times 16 + 5}{1 - (0.332 + y_4)} \Rightarrow .668 - y_4 = \frac{29}{60} \Rightarrow y_4 = 0.185$

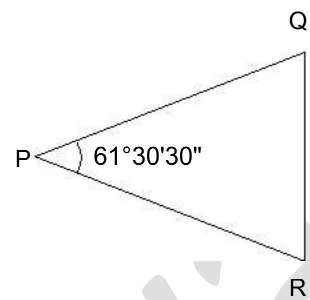
Effective green time for 4_{th} phase

$= \frac{(C_o - L) \times y_4}{y_1 + y_2 + y_3 + y_4} = \frac{(60-16) \times 0.185}{0.332 + 0.185} = 15.74\text{s}$

Q.54 A tacheometer was placed at point P to estimate the horizontal distances PQ and PR. The corresponding stadia intercepts with the telescope kept horizontal, are 0.320 m and 0.210 m, respectively. The $\angle$ QPR is measured to be $61^{o}\ 30'\ 30''$. If the stadia multiplication constant = 100 and stadia addition constant = 0.10 m, the horizontal distance (in m) between the points Q and R is _______________



Answer: 28.0 to 29.0



Exp. Tacheometric equation,

$D = kS + C$

$D_{PQ} = 100 \times 0.32 + 0.10 = 32.1\text{m}$

$D_{PR} = 100 \times 0.210 + 0.10 = 21.1\text{m}$

From Cosine rule in triangle PQR

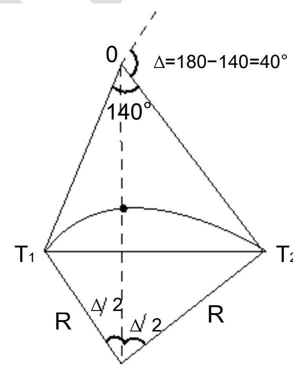
$QR^2 = (PQ)^2 + (PR)^2 - 2(PQ)(PR)\cos 61°30'30''$

$= \sqrt{(32.1)^2 + (21.1)^2 - 2 \times 32.1 \times 21.1 \times \cos 61°30'30''} = 28.8\text{m}$

Q.55 The chainage of the intersection point of two straights is 1585.60 m and the angle of intersection is 140°. If the radius of a circular curve is 600.00 m, the tangent distance (in m) and length of the curve (in m), respectively are

(A) 418.88 and 1466.08
(B) 218.38 and 1648.49
(C) 218.38 and 418.88
(D) 418.88 and 218.38

Answer: (C)



Exp. Length of curve, $L = \frac{\pi}{180} \times \Delta \times R$

$= \frac{\pi}{180} \times 40 \times 600 = 418.88\text{m}$

Tangent distance, $T = R\tan(\Delta/2)$

$= 600\tan\left(\frac{40}{2}\right) = 218.38\text{m}$