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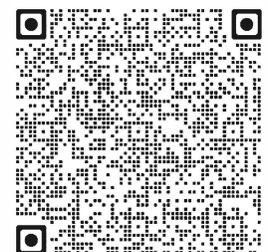
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MATHEMATICS

SECTION - A

Multiple Choice Questions: This section contains 20 multiple choice questions. Each question has 4 choices (1), (2), (3) and (4), out of which **ONLY ONE** is correct.

Choose the correct answer :

1. Let $f(x) = \int \frac{dx}{x^{\left(\frac{2}{3}\right)} + 2x^{\left(\frac{1}{2}\right)}}$ be such that

$f(0) = -26 + 24 \log_e(2)$. If $f(1) = a + b \log_e(3)$, where

$a, b \in \mathbb{Z}$, then $a + b$ is equal to:

- (1) -26
- (2) -5
- (3) -18
- (4) -11

Answer (4)

Sol. $f(x) = \int \frac{dx}{x^{2/3} + 2x^{1/2}}$

Let $x = t^6$

$f(x) = \int \frac{6t^5 dt}{t^4 + 2t^3}$

$= \int \frac{6t^2 dt}{t + 2}$

$= 6 \int \left(t - 2 + \frac{4}{t + 2} \right) dt$

$= 6 \left(\frac{t^2}{2} - 2t + 4 \ln|t + 2| \right) + C$, where $t = x^{1/6}$

$f(0) = 24 \ln 2 + C$

When $x = 0$ then $t = 0$ and

When $x = 1$ then $t = 1$.

$-26 + 24 \ln 2 = 24 \ln 2 + C$

$\therefore C = -26$

Now, $f(1) = 6 \left(\frac{1}{2} - 2 + 4 \ln 3 \right) - 26$

$f(1) = -35 + 24 \ln 3$

Here $a = -35$, $b = 24$

$\therefore a + b = -11$

2. Given below are two statements:

Statement I: $25^{13} + 20^{13} + 8^{13} + 3^{13}$ is divisible by 7.

Statement II: The integral part of $(7 + 4\sqrt{3})^{25}$ is an odd number.

In the light of the above statements, choose the correct answer from the options given below:

- (1) Both Statement I and Statement II are false
- (2) Statement I is true but Statement II is false
- (3) Both Statement I and Statement II are true
- (4) Statement I is false but Statement II is true

Answer (3)

Sol. Statement 1 :

$(25^{13} + 3^{13}) + (20^{13} + 8^{13})$ is divisible by 28 as

$(a + b) | a^n + b^n$ for $n \in$ odd natural numbers

or using congruence modular arithmetic,

$25^{13} + 3^{13} + 20^{13} + 8^{13}$

$\equiv (4^{13} + 3^{13} + (-1)^{13} + 1^{13}) \pmod{7}$

$\equiv ((-3)^{13} + 3^{13}) \pmod{7}$

$\equiv 0 \pmod{7} \implies 7$ divides the sum

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Sol. $f(x) = \lim_{\theta \rightarrow 0} \frac{\cos \pi x - x \left(\frac{2}{\theta}\right) \sin(x-1)}{1 + x \left(\frac{2}{\theta}\right) (x-1)}$

$$f(x) = \begin{cases} \cos \pi x, & , x < 1 \\ -1, & , x = 1 \\ -\frac{\sin(x-1)}{x-1}, & , x > 1 \end{cases}$$

Hence, $\lim_{x \rightarrow 1^-} f(x) = -1$

and $\lim_{x \rightarrow 1^+} f(x) = -1$

and $f(x) = -1$

$\therefore f(x)$ is continuous at $x = 1$

$$f(x) = \begin{cases} -\frac{\sin(x-1)}{x-1} & x < -1 \\ -1 + \sin 2 & x = -1 \\ \frac{1 - \sin 2}{\cos \pi x} & x > -1 \end{cases} = 1$$

LHL \neq RHL

\therefore option (4) true

8. Considering the principal values of inverse trigonometric functions, the value of the expression

$\tan\left(2\sin^{-1}\left(\frac{2}{\sqrt{13}}\right) - 2\cos^{-1}\left(\frac{3}{\sqrt{10}}\right)\right)$ is equal to :

(1) $-\frac{16}{63}$

(2) $\frac{16}{63}$

(3) $\frac{33}{56}$

(4) $-\frac{33}{56}$

Answer (3)

Sol. $\therefore \tan\left(2\sin^{-1}\left(\frac{2}{\sqrt{13}}\right) - 2\cos^{-1}\left(\frac{3}{\sqrt{10}}\right)\right)$

$= \tan\left(2\tan^{-1}\left(\frac{2}{3}\right) - 2\tan^{-1}\left(\frac{1}{3}\right)\right)$

$= \tan\left(2\tan^{-1}\left(\frac{\frac{2}{3} - \frac{1}{3}}{1 + \frac{2}{9}}\right)\right)$

$= \tan\left(2\tan^{-1}\left(\frac{3}{11}\right)\right)$

$= \tan\left(\tan^{-1}\left(\frac{\frac{6}{11}}{1 - \frac{9}{14}}\right)\right)$

$= \frac{66}{112} = \frac{33}{56}$

9. Let the arithmetic mean of $\frac{1}{a}$ and $\frac{1}{b}$ be $\frac{5}{16}$, $a > 2$.

If α is such that $a, 4, \alpha, b$ are in A.P., then the equation $\alpha x^2 - ax + 2(\alpha - 2b) = 0$ has:

(1) Complex roots of magnitude less than 2

(2) One root in (1, 4) and another in (-2, 0)

(3) Both roots in the interval (-2, 0)

(4) One root in (0, 2) and another in (-4, -2)

Answer (2)

Sol. Let $4 - d, 4, 4 + d, 4 + 2d$ are in A.P.

$\Rightarrow \frac{1}{2}\left(\frac{1}{4-d} + \frac{1}{4+2d}\right) = \frac{5}{10}$

$\Rightarrow 5d^2 - 6d - 8 = 0$

$\Rightarrow d = 2, \frac{-4}{5}$

$\Rightarrow d = 2$

$a = 2, \beta = 8, \alpha = 6$

$6x^2 - 2x + 2(6 - 16) = 0$

$\Rightarrow 3x^2 - x - 10 = 0$

$\Rightarrow x = 2, \frac{-5}{3}$

10. Let

$A = \{z \in \mathbb{C} : |z - 2| \leq 4\}$ and

$B = \{z \in \mathbb{C} : |z - 2| + |z + 2| = 5\}$.

Then the max $\{|z_1 - z_2| : z_1 \in A \text{ and } z_2 \in B\}$ is :

(1) $\frac{15}{2}$

(2) 9

(3) $\frac{17}{2}$

(4) 8

Answer (3)

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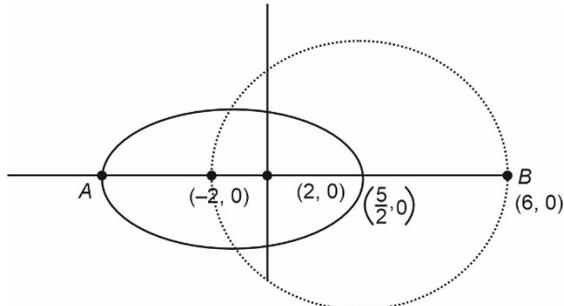
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Sol. $2a = 4$

$2a = 5$

$\Rightarrow a = \frac{5}{2}$



$|z_1 - z_2|_{\max} = AB = 6 + \frac{5}{2} = \frac{17}{2}$

11. Let the circle $x^2 + y^2 = 4$ intersect x-axis at the points $A(a, 0)$, $a > 0$ and $B(b, 0)$. Let $P(2\cos\alpha, 2\sin\alpha)$, $0 < \alpha < \frac{\pi}{2}$ and $Q(2\cos\beta, 2\sin\beta)$ be two points such

that $(\alpha - \beta) = \frac{\pi}{2}$. Then the point of intersection of

AQ and BP lies on

(1) $x^2 + y^2 - 4x - 4y - 4 = 0$

(2) $x^2 + y^2 - 4x - 4 = 0$

(3) $x^2 + y^2 - 4y - 4 = 0$

(4) $x^2 + y^2 - 4x - 4y = 0$

Answer (3)

Sol. $A(2, 0)$

$B(-2, 0)$

P and Q lies on the given circle

$P(2\cos\alpha, 2\sin\alpha)$, $Q(2\sin\alpha, -2\cos\alpha)$

Slope of BP : $\frac{2\sin\alpha}{2\cos\alpha + 2} = \frac{\sin\alpha}{\cos\alpha + 1} = \tan\frac{\alpha}{2}$

$\therefore BP: y = (x + 2)\tan\frac{\alpha}{2}$

Slope of AQ :

$\frac{2\cos\alpha}{2(1 - \sin\alpha)} = \frac{\cos\frac{\alpha}{2} + \sin\frac{\alpha}{2}}{\cos\frac{\alpha}{2} - \sin\frac{\alpha}{2}} = \tan\left(\frac{\pi}{4} + \frac{\alpha}{2}\right)$

$AQ: y = \tan\left(\frac{\pi}{4} + \frac{\alpha}{2}\right)(x - 2)$

$\frac{y}{x-2} = \frac{1 + \frac{y}{x+2}}{1 - \frac{y}{x+2}} \quad \left(\because \tan\frac{\alpha}{2} = \frac{y}{x+2}\right)$

$\Rightarrow \frac{y}{x-2} = \frac{x+2+y}{x+2-y}$

$\Rightarrow (x+y+2)(x-2) = (x-y+2)(y)$

$\Rightarrow x^2 + y^2 - 4y - 4 = 0$

12. The probability distribution of a random variable X is given below:

X	$4k$	$\frac{30}{7}k$	$\frac{32}{7}k$	$\frac{34}{7}k$	$\frac{36}{7}k$	$\frac{38}{7}k$	$\frac{40}{7}k$	$6k$
$P(X)$	$\frac{2}{15}$	$\frac{1}{15}$	$\frac{2}{15}$	$\frac{1}{5}$	$\frac{1}{15}$	$\frac{2}{15}$	$\frac{1}{5}$	$\frac{1}{15}$

If $E(X) = \frac{263}{15}$, then $P(X < 20)$ is equal to

(1) $\frac{11}{15}$

(2) $\frac{14}{15}$

(3) $\frac{3}{5}$

(4) $\frac{8}{15}$

Answer (1)

Sol. $E(x) = \frac{263}{15}$

$\Rightarrow \sum xP(x) = \frac{263}{15}$

$\Rightarrow \frac{526}{105}k = \frac{263}{15}$

$\Rightarrow k = \frac{7}{2}$

$P(x < 20) = 1 - \left(P(6k) + P\left(\frac{40}{7}k\right) \right)$

$= 1 - P(21) - P(20)$

$= 1 - \frac{1}{15} - \frac{1}{5}$

$= \frac{11}{15}$

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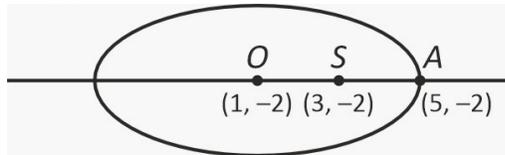


13. An ellipse has its centre at $(1, -2)$ one focus at $(3, -2)$ and one vertex at $(5, -2)$. Then the length of its latus rectum is:

- (1) $6\sqrt{3}$ (2) $\frac{16}{\sqrt{3}}$
(3) 6 (4) $4\sqrt{3}$

Answer (3)

Sol.



$\therefore ae = 2$ and $a = 4$

$\therefore e = \frac{1}{2}$

$b^2 = a^2(1 - e^2)$

$b^2 = 16\left(1 - \frac{1}{4}\right) = 12$

\therefore Length of lotus rectum $= \frac{2b^2}{a} = \frac{2 \times 12}{4}$

$= 6$

14. Let the ellipse $E: \frac{x^2}{144} + \frac{y^2}{169} = 1$ and the hyperbola

$H: \frac{x^2}{16} - \frac{y^2}{\lambda^2} = -1$ have the same foci. If e and L

respectively denote the eccentricity and the length of the latus rectum of H , then the value of $24(e + L)$ is:

- (1) 126 (2) 128
(3) 67 (4) 296

Answer (4)

Sol. $\frac{x^2}{144} + \frac{y^2}{169} = 1$

$e^2 = 1 - \frac{144}{169}$

$= \frac{25}{169} \Rightarrow e = \frac{5}{13}$

$F_{\text{ellipse}} = \left(0, \pm \frac{5}{13} \times 13\right)$

$= (0, \pm 5)$

$\frac{x^2}{16} - \frac{y^2}{\lambda^2} = -1$

$e_H^2 = 1 + \frac{16}{\lambda^2}$

$F = \left(0, \pm \lambda \sqrt{1 + \frac{16}{\lambda^2}}\right)$

$\Rightarrow \lambda \sqrt{1 + \frac{16}{\lambda^2}} = 5$

$\lambda^2 + 16 = 25$

$\lambda^2 = 9$

Now $e_H = \sqrt{1 + \frac{16}{9}} = \sqrt{\frac{25}{9}} = \frac{5}{3}$

$L(\text{LR}) = \frac{2a^2}{b} = \frac{2 \times 16}{3} = \frac{32}{3}$

$24(e + L) = 24\left(\frac{5}{3} + \frac{32}{3}\right) = 24\left(\frac{37}{3}\right)$

$= 8 \times 37 = 296$

15. Given below are two statements :

Statement I : The function $f : \mathbf{R} \rightarrow \mathbf{R}$ defined by

$f(x) = \frac{x}{1 + |x|}$ is one-one

Statement II : The function $f : \mathbf{R} \rightarrow \mathbf{R}$ defined by

$f(x) = \frac{x^2 + 4x - 30}{x^2 - 8x + 18}$ is many-one

In the light of the above statements, choose the **correct answer**

- (1) Statement I is false but statement II is true
(2) Both Statement I and statement II is false
(3) Statement I is true but statement II is false
(4) Both Statement I and statement II is true

Answer (4)

Sol. Statement 1: $F(x) = \frac{x}{1 + |x|}$

$$F(x) = \begin{cases} \frac{x}{1-x} & x < 0 \\ \frac{x}{1+x} & x \geq 0 \end{cases}$$

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$$F'(x) = \begin{cases} \frac{1}{(1-x)^2} & x < 0 \\ \frac{1}{(1+x)^2} & x \geq 0 \end{cases}$$

⇒ $F(x)$ is increasing in R and $f(x)$ is continuous $\forall x \in R$

⇒ $F(x)$ is one-one

Statement 2: $F(x) = \frac{x^2 + 4x - 30}{x^2 - 8x + 18}$

$$F'(x) = \frac{(x^2 - 8x + 18)(2x + 4) - (x^2 + 4x - 30)(2x - 8)}{(x^2 - 8x + 18)^2}$$

$$= \frac{(2x^3 - 16x^2 + 36x + 4x^2 - 32x + 72) - (2x^3 + 8x^2 - 60x - 8x^2 - 32x + 240)}{(x^2 - 8x + 18)^2}$$

$$= \frac{12x^2 + 96x - 72}{(x^2 - 8x + 18)^2}$$

$$= \frac{12(x^2 - 8x + 6)}{(x^2 - 8x + 18)^2}$$

$F'(x)$ will become 0 at 2 distinct points and also $F(x)$ is continuous.

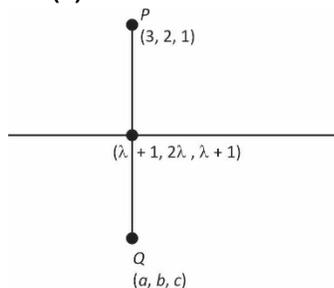
⇒ $F(x)$ is many-one function.

16. Let $Q(a, b, c)$ be the image of the point $P(3, 2, 1)$ in the line $\frac{x-1}{1} = \frac{y}{2} = \frac{z-1}{1}$. Then the distance of Q from the line $\frac{x-9}{3} = \frac{y-9}{2} = \frac{z-5}{-2}$ is

- (1) 7 (2) 6
(3) 8 (4) 5

Answer (1)

Sol.



$PQ \perp$ line

$$\Rightarrow (\lambda + 1 - 3)(1) + (2\lambda - 2)(2) + (\lambda + 1 - 1)(1) = 0$$

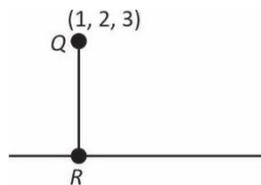
$$\Rightarrow (\lambda - 2) + 4(\lambda - 1) + \lambda = 0$$

$$6\lambda = 6 \Rightarrow \lambda = 1$$

⇒ Image point is $Q(1, 2, 3)$.

The Distance of Point Q from a Second Line

$$\frac{x-9}{3} = \frac{y-9}{2} = \frac{z-5}{-2}$$



$$(3k + 9 - 1)(3) + (2k + 9 - 2)(2) + (-2k + 5 - 3)(-2) = 0$$

$$\Rightarrow k = -2$$

$$R \equiv (3k + 9, 2k + 9, -2k + 5), \text{ for } k = -2$$

$$\Rightarrow R \equiv (3, 5, 9)$$

$$QR = \sqrt{2^2 + 3^2 + 6^2} = 7$$

17. Let $[\cdot]$ denote the greatest integer function. Then

$$\int_{-\pi/2}^{\pi/2} \left(\frac{12(3 + [x])}{3 + [\sin x] + [\cos x]} \right) dx \text{ is equal to}$$

- (1) $13\pi + 1$ (2) $12\pi + 5$
(3) $15\pi + 4$ (4) $11\pi + 2$

Answer (4)

Sol. $\int_{-\pi/2}^{-1} \frac{12(3-2)}{3-1+0} dx + \int_{-1}^0 \frac{12(3-1)}{3-1+0} dx +$

$$\int_0^1 \frac{12(3+0)}{3+0+0} dx + \int_1^{\pi/2} \frac{12(3+1)}{3+0+0} dx$$

$$= \int_{-\pi/2}^{-1} 6 dx + \int_{-1}^0 12 dx + \int_0^1 12 dx + \int_1^{\pi/2} 16 dx$$

$$= 6 \left(-1 + \frac{\pi}{2} \right) + 12(1) + 12(1) + 16 \left(\frac{\pi}{2} - 1 \right)$$

$$= -6 + 3\pi + 12 + 12 + 8\pi - 16$$

$$= 2 + 11\pi$$

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$$\Rightarrow y = x \ln|\sin x| + x$$

$$6y\left(\frac{\pi}{6}\right) - 8y\left(\frac{\pi}{4}\right)$$

$$= 6\left[\frac{\pi}{6}\ln\left(\frac{1}{2}\right) + \frac{\pi}{6}\right] - 8\left[\frac{\pi}{4}\ln\left(\frac{1}{\sqrt{2}}\right) + \frac{\pi}{4}\right]$$

$$\pi - 2\pi = -\pi$$

SECTION - B

Numerical Value Type Questions: This section contains 5 Numerical based questions. The answer to each question should be rounded-off to the nearest integer.

21. Let f be a differentiable function satisfying

$$f(x) = 1 - 2x + \int_0^x e^{(x-t)} f(t) dt, x \in \mathbb{R} \quad \text{and} \quad \text{let}$$

$$g(x) = \int_0^x (f(t) + 2)^{15} (t - 4)^6 (t + 12)^{17} dt, x \in \mathbb{R}. \quad \text{If } p$$

and q are respectively the points of local minima and local maxima of g , then the value of $|p + q|$ is equal to _____.

Answer (9)

Sol. $f(x) = 1 - 2x + e^x \int_0^x \frac{f(t)}{e^t} dt$

$$f'(x) = -2 + \left(\int_0^x \frac{f(t)}{e^t} dt\right) e^x + \frac{e^x f(x)}{e^x}$$

$$\Rightarrow f'(x) = -2 + (f(x) + 2x - 1) + f(x)$$

Let $y = f(x) = 2f(x) + 2x - 3$

$$\frac{dy}{dx} = 2y + 2x - 3, \text{ let } y + x = t$$

$$\left(\frac{dt}{dx} - 1\right) = (2t - 3)$$

$$\Rightarrow \frac{dt}{t-1} = \int 2dx$$

$$\Rightarrow \ln|t-1| = 2x + c$$

$$\ln|x+y-1| = 2x + c \Rightarrow x+y-1 = ke^{2x}$$

$$\lim_{x \rightarrow 0} y = 1 \Rightarrow k = 0 \Rightarrow y = 1 - x$$

$$g(x) = \int_0^x (3-t)^{15} (t-4)^6 (t+12)^{17} dt$$

$$g'(x) = (3-x)^{15} (x-4)^6 (x+12)^{17}$$



local minima at $p = -12$

local maxima at $q = 3$

$$\Rightarrow |p + q| = 9$$

22. If $\sum_{r=1}^{25} \left(\frac{r}{r^4 + r^2 + 1}\right) = \frac{p}{q}$, where p and q are positive integers such that $\gcd(p, q) = 1$, then $p + q$ is equal to _____.

Answer (976)

Sol. $\sum_{r=1}^{25} \frac{r}{(r^2 + 1)^2 - r^2} = \sum_{r=1}^{25} \frac{r}{(r^2 + 1 + r)(r^2 + 1 - r)}$

$$= \frac{1}{2} \sum_{r=1}^{25} \left(\frac{1}{r^2 + 1 - r} - \frac{1}{r^2 + 1 + r}\right)$$

$$= \frac{1}{2} \left[\left(\frac{1}{1} - \frac{1}{3}\right) + \left(\frac{1}{3} - \frac{1}{7}\right) + \dots + \left(\frac{1}{601} - \frac{1}{657}\right)\right]$$

$$= \frac{1}{2} \left[1 - \frac{1}{657}\right]$$

$$= \frac{1}{2} \left[\frac{650}{657}\right]$$

$$= \frac{325}{657}$$

$$\therefore p + q = 976$$

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23. Let $A = \begin{bmatrix} 3 & -4 \\ 1 & -1 \end{bmatrix}$ and B be two matrices such that $A^{100} = 100B + I$. Then the sum of all the elements of B^{100} is _____

Answer (0)

Sol. $A = \begin{bmatrix} 3 & -4 \\ 1 & -1 \end{bmatrix}$

$$A^2 = \begin{bmatrix} 3 & -4 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} 3 & -4 \\ 1 & -1 \end{bmatrix} = \begin{bmatrix} 3 \cdot 3 - 4 & -3 \cdot 4 + 1 \cdot 4 \\ 1 \cdot 3 - 1 & -4 + 1 \end{bmatrix} = \begin{bmatrix} 5 & -8 \\ 2 & -3 \end{bmatrix}$$

$$\begin{bmatrix} 2 \cdot 2 + 1 & -(4 \cdot 2) \\ 1 \cdot 2 & -(2 \cdot 2 - 1) \end{bmatrix}$$

$$A^2 = \begin{bmatrix} 7 & -12 \\ 3 & -5 \end{bmatrix}, A^3 = \begin{bmatrix} 11 & -10 \\ 5 & -9 \end{bmatrix}, \dots$$

$$\therefore A^n = \begin{bmatrix} 2n+1 & -4n \\ n & 1-2n \end{bmatrix}$$

$$\Rightarrow A^{100} = \begin{bmatrix} 201 & -400 \\ 100 & -199 \end{bmatrix} = 100B + \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 200 & -400 \\ 100 & -200 \end{bmatrix} = 100B$$

$$\Rightarrow B = \begin{bmatrix} 2 & -4 \\ 1 & -2 \end{bmatrix}$$

$$B^2 = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$$

$$\Rightarrow B^{100} = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$$

Sum of elements of $B = 0$

24. Three persons enter in a lift at the ground floor. The lift will go up to 10th floor. The number of ways, in which the three persons can exit the lift at three different floors, if the lift does not stop at first, second and third floors, is equal to _____.

Answer (210)

Sol. $G = \frac{x}{1} \frac{x}{2} \frac{x}{3} \frac{x}{4} \frac{x}{5} \frac{x}{6} \frac{x}{7} \frac{x}{8} \frac{x}{9} \frac{x}{10}$

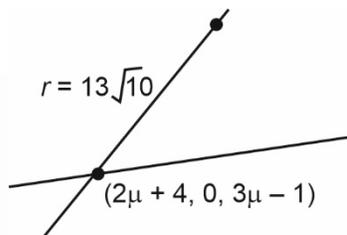
${}^7C_3 \cdot 3!$ for different floors with all arrangement with 3 people

$$\Rightarrow \boxed{210 \cdot 00}$$

25. the distance of the point $P(43, \alpha, \beta)$, $\beta < 0$, from the line $\vec{r} = 4\hat{i} - \hat{k} + \mu(2\hat{i} + 3\hat{k})$, $\mu \in R$ along a line with direction ratios 3, -1, 0 is $13\sqrt{10}$, then $\alpha^2 + \beta^2$ is equal to _____

Answer (170)

Sol.



$$\frac{x - (2\mu + 4)}{\frac{3}{\sqrt{10}}} = \frac{y - 0}{\frac{-1}{\sqrt{10}}} = \frac{z - (3\mu - 1)}{0} = \pm 13\sqrt{10}$$

$$\Rightarrow x - (2\mu + 4) = \pm 39$$

$$y = \pm 13$$

$$3 = (3\mu - 1)$$

Since $x = 43$

$$\Rightarrow 2\mu + 4 = 43 \pm (39) \quad 4 \text{ or } 41$$

$$\Rightarrow \mu = 0, \frac{37}{2}$$

$$\Rightarrow \mu = 0 \text{ as } \beta < 0$$

$$\Rightarrow P(43, -13, -1)$$

$$\Rightarrow \alpha^2 + \beta^2 = 169 + 1 = 170$$

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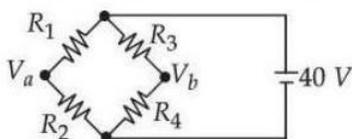


PHYSICS

SECTION - A

Multiple Choice Questions: This section contains 20 multiple choice questions. Each question has 4 choices (1), (2), (3) and (4), out of which **ONLY ONE** is correct.

26. Wheatstone bridge is initially at room temperature and all arms of the bridge have same value of resistances ($R_1 = R_2 = R_3 = R_4$). When R_3 resistance is heated to some temperature, its resistance value has gone up by 10%. The potential difference ($V_a - V_b$) (after R_3 is heated) is ____ V.



- (1) 0.95
- (2) 1.05
- (3) 2
- (4) 0

Answer (1)

Sol. Initially, $V_a - V_b = 0$, so $(V_a - V_b) = 0$

After R_1 is heated by 10%, $R_1 = 1.1R$ while $R_2 = R_3 = R_4 = R$.

$$V_a = V \frac{R_2}{R_1 + R_2} = 40 \frac{R}{1.1R + R} = \frac{40}{2.1} \text{ and}$$

$$V_b = \frac{R_4}{R_3 + R_4} = 40 \frac{R}{R + R} = 20$$

$$|V_a - V_b| = |19.05 - 20| \approx 0.95 \text{ V}$$

27. A particle starts moving from time $t = 0$ and its coordinate is given as $x(t) = 4t^3 - 3t$
- A. The particle returns to its original position (origin) 0.866 units later
 - B. The particle is 1 unit away from origin at its turning point
 - C. Acceleration of the particle is non-negative
 - D. The particle is 0.5 units away from origin at its turning point
 - E. Particle never turns back as acceleration is non-negative

Choose the correct answer from the options given below :

- (1) A, C, D only
- (2) C, E only
- (3) A, C only
- (4) A, B, C only

Answer (4)

Sol. $x(t) = 4t^3 - 3t$. For $x(t) = 0 \Rightarrow t(4t^2 - 3) = 0$

$$\Rightarrow t = \sqrt{3} / 2 \approx 0.866 \text{ s}$$

$$v(t) = 12t^2 - 3. \text{ Turning point at } v = 0 \Rightarrow t^2 = 1/4$$

$$\Rightarrow t = 0.5 \text{ s}$$

$$\text{At } t = 0.5, x(0.5) = 4(0.125) - 3(0.5) = 0.5 - 1.5 = -1.0$$

The distance is 1 unit.

$$a(t) = 24t, \text{ which is non-negative for } t \geq 0.$$

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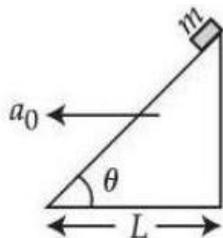
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28. A small block of mass m slides down from the top of a frictionless inclined surface, while the inclined plane is moving towards left with constant acceleration a_0 . The angle between the inclined plane and ground is θ and its base length is L . Assuming that initially the small block is at the top of the inclined plane, the time it takes to reach the lowest point of the inclined plane is _____.



(1) $\sqrt{\frac{2L}{g \sin 2\theta - a_0(1 + \cos 2\theta)}}$

(2) $\sqrt{\frac{2L}{g \sin \theta - a_0 \cos \theta}}$

(3) $\sqrt{\frac{4L}{g \cos^2 \theta - a_0 \sin \theta \cos \theta}}$

(4) $\sqrt{\frac{4L}{g \sin 2\theta - a_0(1 + \cos 2\theta)}}$

Answer (4)

Sol. $a_{\text{net}} = g \sin \theta - a_0 \cos \theta$

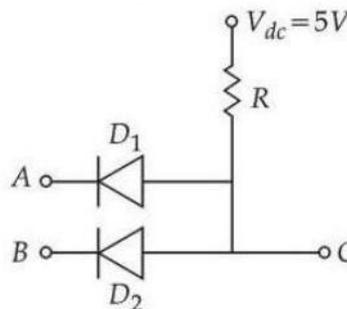
Distance $s = L / \cos \theta$.

$$t = \sqrt{\frac{2s}{a_{\text{net}}}} = \sqrt{\frac{2L}{\cos \theta (g \sin \theta - a_0 \cos \theta)}}$$

Using $2 \sin \theta \cos \theta = \sin 2\theta$ and $2 \cos^2 \theta = 1 + \cos 2\theta$,

We get option 4.

29. Two p-n junction diodes D_1 and D_2 are connected as shown in figure. A and B are input signals and C is the output. The given circuit will function as a ____.



- (1) NOR Gate
- (2) OR Gate
- (3) AND Gate
- (4) NAND Gate

Answer (3)

Sol. Truth table

A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

So AND Gate.

30. Which one of the following is not a measurable quantity?

- (1) Resistance
- (2) Voltage
- (3) Voltage difference
- (4) Displacement current

Answer (2)

Sol. Voltage is not a measurable quantity.

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34. Identify the correct statements :

- A. Electrostatic field lines form closed loops.
- B. The electric field lines point radially outward when charge is greater than zero.
- C. The Gauss - Law is valid only for inverse - square force.
- D. The workdone in moving a charged particle in a static electric field around a closed path is zero.
- E. The motion of a particle under Coulomb's force must take place in a plane.

Choose the correct answer from the options given below :

- (1) A, B, C, D Only
- (2) A, C, E Only
- (3) B, C, D, E Only
- (4) A, B, D, E Only

Answer (3)

Sol. Static electric field lines do NOT form closed loops (they start on positive and end on negative charges), making statement A false.

35. In an experiment, a set of readings are obtained as follows - 1.24 mm, 1.25 mm, 1.23 mm, 1.21 mm.

The expected least count of the instrument used in recording these readings is _____ mm.

- (1) 0.05
- (2) 0.1
- (3) 0.001
- (4) 0.01

Answer (4)

Sol. Readings : 1.24, 1.25, 1.23, 1.21 mm.

All readings have two decimal places.

The smallest difference between any two readings is 0.01 mm.

36. A plane electromagnetic wave is moving in free space with velocity $c = 3 \times 10^8$ m/s and its electric field is given as $\vec{E} = 54 \sin(kz - \omega t) \hat{j}$ V/m, where \hat{j} is the unit vector along y-axis. The magnetic field vector \vec{B} of the wave is

- (1) $-1.8 \times 10^{-7} \sin(kz - \omega t) \hat{i}$ T
- (2) $1.4 \times 10^{-7} \sin(kz - \omega t) \hat{k}$ T
- (3) $1.4 \times 10^{-7} \sin(kz - \omega t) \hat{i}$ T
- (4) $+1.8 \times 10^{-7} \sin(kz - \omega t) \hat{i}$ T

Answer (1)

Sol. For an electromagnetic wave, the magnetic field amplitude B_0 is $\frac{E_0}{c}$. The direction of the magnetic

field is given by the unit vector $\hat{B} = \hat{k} \times \hat{E}$, where \hat{k} is the direction of propagation.

Stepwise equations :

$$B_0 = \frac{E_0}{c} = \frac{54}{(3 \times 10^8)} = 1.8 \times 10^{-7} T$$

Propagation is along $+z(\hat{k})$ and E is along $+y(\hat{j})$

$$\text{Direction } \hat{B} = \hat{z} \times \hat{y} = -\hat{i}$$

37. The speed of a longitudinal wave in a metallic bar is 400 m/s. If the density and Young's modulus of the bar material are increased by 0.5% and 1%, respectively then the speed of the wave is changed approximately to _____ m/s.

- (1) 399
- (2) 401
- (3) 398
- (4) 402

Answer (2)

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Sol. The speed of a longitudinal wave in a bar is $v = \sqrt{\frac{Y}{\rho}}$

$$\frac{\Delta v}{v} = \frac{1}{2}(1\% - 0.5\%) = 0.25\%$$

$$\Delta v = 400 \times 0.0025 = 1 \text{ m/s}$$

$$\text{New speed} = 400 + 1 = 401 \text{ m/s}$$

38. When the position vector $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ changes sign as $-\vec{r}$, which one of the following vector will not flip under sign change?

- (1) Acceleration (2) Velocity
(3) Linear momentum (4) Angular momentum

Answer (4)

Sol. $r \rightarrow -r$

$$p \rightarrow -p.$$

$$L = (-r) \times (-p) = r \times p = L \text{ (No flip).}$$

39. Number of photons of equal energy emitted per second by a 6 mW laser source operating at 663 nm is _____.

$$\text{(Given : } h = 6.63 \times 10^{-34} \text{ J.s and } c = 3 \times 10^8 \text{ m/s)}$$

- (1) 10×10^{15} (2) 5×10^{15}
(3) 5×10^{16} (4) 2×10^{16}

Answer (4)

$$\text{Sol. } E = \frac{(6.63 \times 10^{-34} \times 3 \times 10^8)}{(663 \times 10^{-9})} = 3 \times 10^{-19} \text{ J.}$$

$$N = \frac{(6 \times 10^{-3})}{(3 \times 10^{-19})} = 2 \times 10^{16}.$$

40. A nucleus has mass number α and radius R_α . Another nucleus has mass number β and radius R_β . If $\beta = 8\alpha$ then R_α / R_β is:

- (1) 2 (2) 1
(3) 8 (4) 0.5

Answer (4)

$$\text{Sol. } R_\alpha = R_0(\alpha)^{1/3} \text{ and } R_\beta = R_0(8\alpha)^{1/3}$$

$$R_\alpha / R_\beta = \frac{1}{2}$$

41. A long cylindrical conductor with large cross section carries an electric current distributed uniformly over its cross-section. Magnetic field due to this current is :

- A. Maximum at either ends of the conductor and minimum at the midpoint.
B. Maximum at the axis of the conductor
C. Minimum at the surface of the conductor
D. Minimum at the axis of the conductor
E. Same at all points in the cross-section of the conductor

Choose the correct answer from the options given below :

- (1) A, D Only (2) D Only
(3) B, C Only (4) E Only

Answer (2)

Sol. Using Ampere's Circuital Law, the magnetic field inside a cylindrical conductor increases linearly with distance from the axis ($B \propto r$) and decreases outside ($B \propto 1/r$). Thus, the field is zero (minimum) at the axis.

42. The mean free path of a molecule of diameter 5×10^{-10} m at the temperature 41°C and pressure 1.38×10^5 Pa, is given as _____ m.

$$\text{(Given } k_B = 1.38 \times 10^{-23} \text{ J/K).}$$

- (1) 2×10^{-8} (2) $2\sqrt{2} \times 10^{-8}$
(3) $2\sqrt{2} \times 10^{-10}$ (4) $10\sqrt{2} \times 10^{-8}$

Answer (2)

Sol. The mean free path λ is given by $\lambda = \frac{k_B T}{\sqrt{2} \pi d^2 P}$. We

substitute the given temperature in Kelvin, the pressure and the molecular diameter to find the value.

$$T = 41 + 273 = 314 \text{ K.}$$

$$\lambda = \frac{1.38 \times 10^{-23} \times 314}{\sqrt{2} \times \pi \times (5 \times 10^{-10})^2 \times 1.38 \times 10^5}$$

Calculation yields approximately $2\sqrt{2} \times 10^{-8}$ m.

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43. The time period of a simple harmonic oscillator is $T = 2\pi\sqrt{\frac{k}{m}}$. Measured value of mass (m) of the object is 10 g with an accuracy of 10 mg and time for 50 oscillations of the spring is found to be 60 s using a watch of 2 s resolution. Percentage error in determination of spring constant (k) is _____ %.

- (1) 3.43 (2) 7.60
(3) 6.76 (4) 3.35

Answer (3)

Sol. From $T = 2\pi\sqrt{m/k}$, we get $k = 4\pi^2m/T^2$. The percentage error in k is $\Delta k/k = \Delta m/m + 2\Delta T/T$. Note that $\Delta T/T = \Delta t/t$, where t is the total time for N oscillations.

$$\Delta m/m = 10 \text{ mg}/10 \text{ g} = 0.01/10 = 0.1\%$$

$$2\Delta t/t = 2(2/60) = 4/60 \approx 6.67\%$$

$$\text{Total error} = 0.1\% + 6.67\% + \dots \approx 6.7\%$$

44. Identify the correct statements :

- A. Effective capacitance of a series combination of capacitors is always smaller than the smallest capacitance of the capacitor in the combination.
- B. When a dielectric medium is placed between the charged plates of a capacitor, displacement of charges cannot occur due to insulation property of dielectric.
- C. Increasing of area of capacitor plate or decreasing of thickness of dielectric is an alternate method to increase the capacitance.
- D. For a point charge, concentric spherical shells centered at the location of the charge are equipotential surfaces.

Choose the correct answer from the options given below :

- (1) B and D Only (2) A, C and D Only
(3) C and D Only (4) A, B and C Only

Answer (2)

Sol. Series capacitance C_{eq} is always less than any individual C (A is true). Capacitance $C = \epsilon_0 A/d$, so increasing A or decreasing d increases C (C is true). Equipotential surface for a point charge are indeed spheres (D is true). Statement B is false as polarization/displacement does occur in dielectrics.

45. For a transparent prism, if the angle of minimum deviation is equal to its refracting angle, the refractive index n of the prism satisfies.

- (1) $1 < n < 2$ (2) $n \geq 2$
(3) $\sqrt{2} < n < 2\sqrt{2}$ (4) $\sqrt{2} < n < 2$

Answer (4)

Sol. $2i - 2r = \delta$

$$\Rightarrow 2i = 2A$$

$$\text{so, } \sin i = n \sin r$$

$$2 \cos\left(\frac{A}{2}\right) = n$$

$$\text{so, } n < 2$$

$$\text{But } i < 90^\circ$$

$$\text{so, } \sqrt{2} < n < 2$$

SECTION - B

Numerical Value Type Questions: This section contains 5 Numerical based questions. The answer to each question should be rounded-off to the nearest integer.

46. A fly wheel having mass 3 kg and radius 5 m is free to rotate about a horizontal axis. A string having negligible mass is wound around the wheel and the loose end of the string is connected to 3 kg mass. The mass is kept at rest initially and released. Kinetic energy of the wheel when the mass descends by 3 m is _____ J. ($g = 10 \text{ m/s}^2$)

Answer (30)

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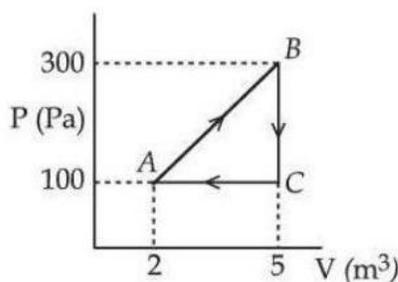
Sol. $(3 \times 10 \times 3) = \frac{1}{2}(m)v^2 + \frac{1}{2}m \frac{R^2}{2} \frac{v^2}{R^2}$

$\Rightarrow 90 = \frac{1}{2}mv^2 \left(\frac{3}{2}\right)$

$\Rightarrow \frac{1}{2}mv^2 = 60$

so, KE of wheel is $\frac{1}{2} \left(\frac{1}{2}mv^2\right) = 30$ Joule

47. A thermodynamic system is taken through the cyclic process ABC as shown in the figure. The total work done by the system during the cycle ABC is _____ J.



Answer (300)

Sol. $\Delta w = \frac{1}{2} \times 3 \times 200 = 300$ Joule

48. A beam of light consisting of wavelengths 650 nm and 550 nm illuminates the Young's double slits with separation of 2 mm such that the interference fringes are formed on a screen, placed at a distance of 1.2 m from the slits. The least distance of a point from the central maximum, where the bright fringes due to both the wavelengths coincide, is _____ $\times 10^{-5}$ m.

Answer (429)

Sol. $\Delta w_1 = \frac{(650) \times 1.2 \times 10^{-9}}{2 \times 10^{-3}}$

$\Delta w_2 = \frac{550 \times 1.2 \times 10^{-9}}{2 \times 10^{-3}}$

so, 11th order of 650 will coincide with 13th order of 550.

so, $\Delta w = \frac{11 \times 650 \times 1.2 \times 10^{-9}}{2 \times 10^{-3}} = 429 \times 10^{-5}$ m

49. An inductor stores 16 J of magnetic field energy and dissipates 32 W of thermal energy due to its resistance when an a.c. current of 2 A (rms) and frequency 50 Hz flows through it. The ratio of inductive reactance to its resistance is _____. ($\pi = 3.14$)

Answer (314)

Sol. $i^2 R = 32$

$\Rightarrow R = 8 \Omega$

$\frac{1}{2} Li^2 = 16$

$\Rightarrow L = 8 H$

so, $\frac{WL}{R} = W = 2\pi \times 50 = 314$

50. Two tuning forks A and B are sounded together giving rise to 8 beats in 2 s. When fork A is loaded with wax, the beat frequency is reduced to 4 beats in 2 s. If the original frequency of tuning fork B is 380 Hz, then original frequency of tuning fork A is _____ Hz.

Answer (384)

Sol. Clearly the frequency of A will decrease

So, initially A will have 384 Hz.

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CHEMISTRY

SECTION - A

Multiple Choice Questions: This section contains 20 multiple choice questions. Each question has 4 choices (1), (2), (3) and (4), out of which **ONLY ONE** is correct.

Choose the correct answer :

51. For the given reaction;

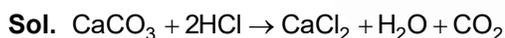


If 90 g CaCO_3 is added to 300 mL of HCl which contains 38.55% HCl by mass and has density 1.13 g mL^{-1} , then which of the following option is **correct** ?

Given molar mass of H, Cl, Ca and O are 1, 35.5, 40 and 16 g mol^{-1} respectively.

- (1) 97.30 g of HCl reacted
- (2) 60.32 g of HCl remains unreacted
- (3) 32.85 g of CaCO_3 remains unreacted
- (4) 64.97 g of HCl remains unreacted

Answer (4)



$$\text{Given : } n_{\text{CaCO}_3} = \frac{90}{100} = 0.9 \text{ mol}$$

Volume of HCl = 300 mL

Density = 1.13 g/mL

$$d = \frac{\text{mass}}{\text{volume}}$$

$$\begin{aligned} \text{Mass of HCl(g)} &= d \times v \\ &= 1.13 \times 300 \\ &= 339 \text{ g} \end{aligned}$$

$$\text{Mass of HCl taken} = 339 \times \frac{38.55}{100} = 130.68 \text{ g}$$

$$\text{Mole of HCl} = \frac{130.68}{36.5} \text{ mol} = 3.58 \text{ mol}$$

CaCO_3 is limiting reagent

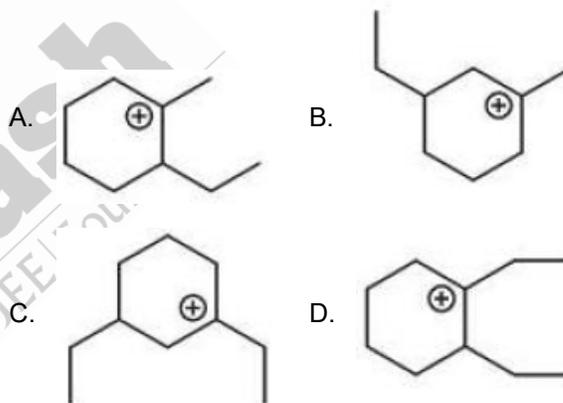
1 mol CaCO_3 reacted with 2 mol HCl

0.9 mol of CaCO_3 will react with 1.8 mol HCl

$$\begin{aligned} \text{Mole of HCl unreacted} &= (3.58 - 1.8) \text{ mol} \\ &= 1.78 \text{ mol} \end{aligned}$$

Mass of HCl unreacted = 64.98 g

52. The cyclic cations having the same number of hyperconjugation are :



Choose the **correct** answer from the options given below:

- (1) A and B Only
- (2) A, C and D only
- (3) B and C Only
- (4) A and C Only

Answer (4)

Sol. A & C have same number of α -H, so same number of hyperconjugation.

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53. Consider the following aqueous solutions.
- I. 2.2 g Glucose in 125 mL of solution.
 - II. 1.9 g Calcium chloride in 250 mL of solution.
 - III. 9.0 g Urea in 500 mL of solution.
 - IV. 20.5 g Aluminium sulphate in 750 mL of solution.

The **correct** increasing order of boiling point of these solutions will be :

[Given : Molar mass in g mol^{-1} : H=1, C=12, N=14, O=16, Cl=35.5, Ca=40, Al=27 and S=32]

- (1) II < III < IV < I (2) II < III < I < IV
(3) I < II < III < IV (4) III < I < II < IV

Answer (3)

Sol. I : $M = \frac{2.2}{180 \times 0.125} = 0.098 \text{ M}$

II : $M = \frac{1.9}{111 \times 0.250} = 0.068 \text{ M}$

III : $M = \frac{9}{60 \times 0.5} = 0.3 \text{ M}$

IV : $M = \frac{20.5}{342 \times 0.75} = 0.08 \text{ M}$

Assuming molarity = molality

Assuming 100% dissociation of electrolyte.

Effective concentration = $i \times m$

I = $1 \times 0.098 = 0.098$

II = $3 \times 0.068 = 0.204$

III = $1 \times 0.3 = 0.3$

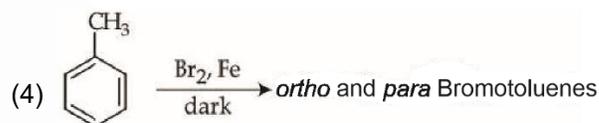
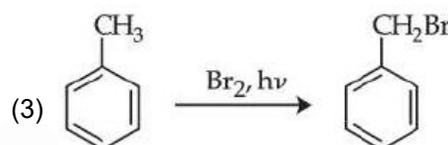
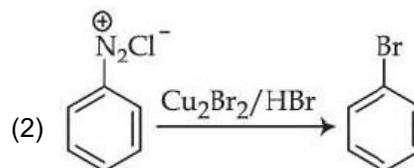
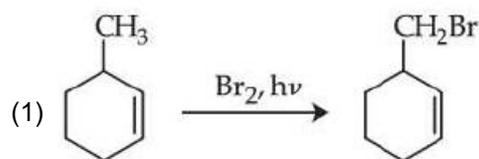
IV = $5 \times 0.08 = 0.4$

$\Delta T_b \propto$ effective concentration

Boiling point \propto effective concentration

IV > III > II > I

54. Which of the following reaction is NOT correctly represented?



Answer (1)



55. Given below are two statements :

Statement I : The increasing order of boiling point of hydrogen halides is $\text{HCl} < \text{HBr} < \text{HI} < \text{HF}$.

Statement II: The increasing order of melting point of hydrogen halides is $\text{HCl} < \text{HBr} < \text{HF} < \text{HI}$.

In the light of the above statements, choose the **correct** answer from the options given below :

- (1) Both Statement I and Statement II are false
- (2) Both Statement I and Statement II are true
- (3) Statement I is false but Statement II is true
- (4) Statement I is true but Statement II is false

Answer (2)

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Sol. **BP (K)** **MP (K)**

HF	293	190
HCl	189	159
HBr	206	185
HI	238	222

BP order \Rightarrow HCl < HBr < HI < HF

MP order \Rightarrow HCl < HBr < HF < HI

56. Total number of alkali insoluble solid sulphonamides obtained by reaction of given amines with Hinsberg's reagent is _____.

Aniline, N-Methylaniline, Methanamine,

N, N-Dimethylmethanamine, N-Methyl methanamine, Phenylmethanamine,

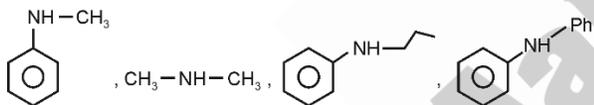
N-propylaniline, N-phenylaniline,

N, N-Dimethylaniline, Allyl amine, Isopropyl amine

- | | |
|-------|-------|
| (1) 8 | (2) 5 |
| (3) 4 | (4) 2 |

Answer (3)

Sol. 2° amines are alkali insoluble solid sulfonamides.



57. Identify the **correct** statements :

The presence of $-\text{NO}_2$ group in benzene ring

- activates the ring towards electrophilic substitutions.
- deactivates the ring towards electrophilic substitutions.
- activates the ring towards nucleophilic substitutions.
- deactivates the ring towards nucleophilic substitutions.

Choose the **correct** answer from the options given below :

- | | |
|------------------|------------------|
| (1) A and D Only | (2) B and C Only |
| (3) C and A Only | (4) B and D Only |

Answer (2)

Sol. $-\text{NO}_2$ is electron withdrawing group and deactivates the ring towards electrophilic substitutions.

activates the ring towards nucleophilic substitutions.

58. Consider the following reactions

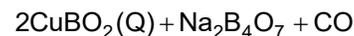


The oxidation states of Cu in Z and Q, respectively are :

- | | |
|---------------|---------------|
| (1) +1 and +1 | (2) +2 and +2 |
| (3) +2 and +1 | (4) +1 and +2 |

Answer (3)

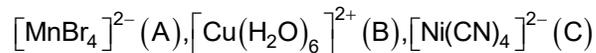
Sol. $\text{Na}_2\text{B}_4\text{O}_7 \xrightarrow{\Delta} 2\text{NaBO}_2(\text{X}) + \text{B}_2\text{O}_3(\text{Y})$



Oxidation state of Cu in Z = $\text{Cu}(\text{BO}_2)_2 = +2$

Oxidation state of Cu in Q = $\text{Cu}(\text{BO}_2) = +1$

59. The correct increasing order of spin-only magnetic moment values of the complex ions



and $[\text{Ni}(\text{H}_2\text{O})_6]^{2+} (\text{D})$ is :

- | | |
|---|---|
| (1) $\text{C} < \text{B} < \text{D} < \text{A}$ | (2) $\text{A} = \text{B} < \text{C} < \text{D}$ |
| (3) $\text{C} = \text{D} < \text{B} < \text{A}$ | (4) $\text{A} = \text{B} < \text{D} < \text{C}$ |

Answer (1)

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Sol. (A) $[\text{MnBr}_4]^{2-} \Rightarrow \text{Mn}^{2+} \Rightarrow 3d^5 \Rightarrow \text{Br}^-$ as WFL

$$\Rightarrow n = 5$$

(B) $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} \Rightarrow \text{Cu}^{2+} \Rightarrow 3d^9 \Rightarrow \text{H}_2\text{O}$ as WFL

$$\Rightarrow n = 1$$

(C) $[\text{Ni}(\text{CN})_4]^{2-} \Rightarrow \text{Ni}^{2+} \Rightarrow 3d^8 \Rightarrow \text{CN}^-$ as SFL

$$\Rightarrow n = 0$$

(D) $[\text{Ni}(\text{H}_2\text{O})_6]^{2+} \Rightarrow \text{Ni}^{2+} \Rightarrow 3d^8 \Rightarrow \text{H}_2\text{O}$ as WFL

$$\Rightarrow n = 2$$

More the number of unpaired electron more will be spin only magnetic moment

$$C < B < D < A$$

60. A student has been given 0.314 g of an organic compound and asked to estimate Sulphur. During the experiment, the student has obtained 0.4813 g of barium sulphate. The percentage of sulphur present in the compound is _____. (Given Molar mass in g mol^{-1} S : 32, BaSO_4 : 233)

- (1) 63.15%
- (2) 21.05%
- (3) 42.10%
- (4) 48.24%

Answer (2)

$$\text{Sol. \% of S} = \frac{0.4813}{0.314} \times \frac{32}{233} \times 100$$

$$= 21.05$$

61. Consider the following statements about manganate and permanganate ions. Identify the **correct** statements.

- A. The geometry of both manganate and permanganate ions is tetrahedral.
- B. The oxidation states of Mn in manganate and permanganate are +7 and +6, respectively.
- C. Oxidation of Mn(II) salt by peroxodisulphate gives manganate ion as the final product.
- D. Manganate ion is paramagnetic and permanganate ions is diamagnetic.
- E. Acidified permanganate ion reduces oxalate, nitrite and iodide ions.

Choose the correct answer from the options given below :

- (1) A, D and E Only
- (2) A, B and C Only
- (3) A and D Only
- (4) A, C and D Only

Answer (3)

Sol. (A) MnO_4^- and MnO_4^{2-} both are tetrahedral.

(B) $\text{MnO}_4^- \Rightarrow \text{Mn}^{+7}$

$\text{MnO}_4^{2-} \Rightarrow \text{Mn}^{+6}$

(C) $2\text{Mn}^{2+} + 5\text{S}_2\text{O}_8^{2-} + 8\text{H}_2\text{O} \rightarrow \text{MnO}_4^- + \text{HSO}_4^- + \text{H}^+$

(D) $\text{Mn}^{+6} = 3d^1, \text{Mn}^{+7} = 3d^0$

(E) MnO_4^- oxidises not reduces.

62. The plot of $\log_{10}K$ vs $\frac{1}{T}$ gives a straight line. The intercept and slope respectively are (where K is equilibrium constant).

(1) $\frac{\Delta S^\circ}{2.303R}, -\frac{\Delta H^\circ}{2.303R}$ (2) $-\frac{\Delta S^\circ R}{2.303}, \frac{\Delta H^\circ R}{2.303}$

(3) $-\frac{\Delta H^\circ}{2.303R}, \frac{\Delta S^\circ}{2.303R}$ (4) $\frac{2.303R}{\Delta H^\circ}, \frac{2.303R}{\Delta S^\circ}$

Answer (1)

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Sol. $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

$$-2.303RT \log K = \Delta H^\circ - T\Delta S^\circ$$

$$\log K = \frac{-\Delta H}{2.303R T} + \frac{\Delta S^\circ}{2.303R}$$

$$\text{Slop} = \frac{-\Delta H}{2.303R}$$

$$\text{Intercept} = \frac{\Delta S^\circ}{2.303R}$$

63. Match List-I with List-II according to shape.

	List-I		List-II
A.	XeO ₃	I.	BrF ₅
B.	XeF ₂	II.	NH ₃
C.	XeO ₂ F ₂	III.	[I ₃] ⁻
D.	XeOF ₄	IV.	SF ₄

Choose the **correct** answer from the options given below:

(1) A – II, B – III, C – IV, D – I

(2) A – III, B – II, C – IV, D – I

(3) A – II, B – III, C – I, D – IV

(4) A – II, B – I, C – III, D – IV

Answer (1)

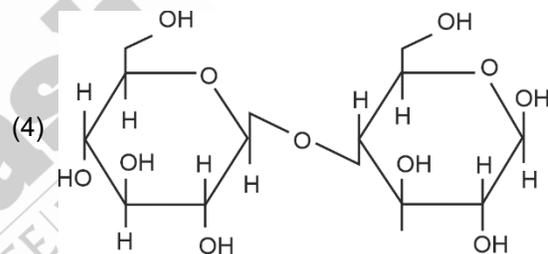
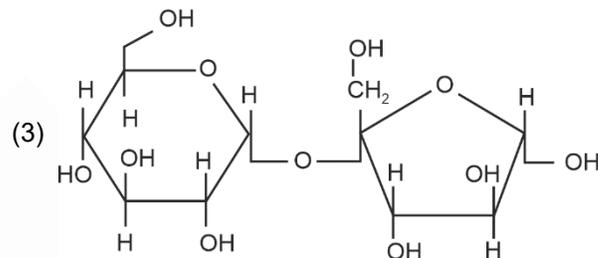
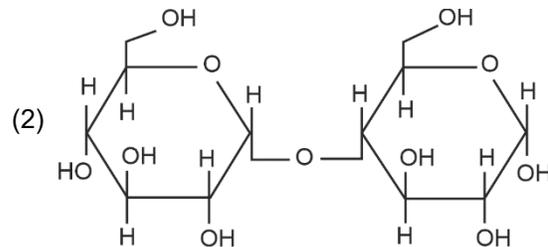
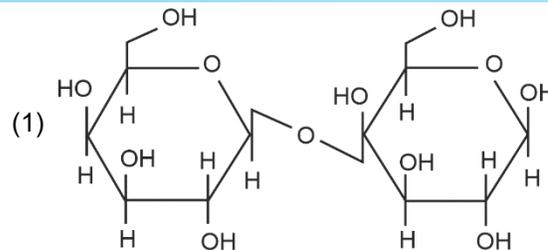
Sol. XeO₃ and NH₃ are trigonal pyramidal

XeF₂ and I₃⁻ are linear

XeO₂F₂ and SF₄ are see-saw

XeOF₄ and BrF₅ are square pyramidal

64. Structures of four disaccharides are given below. Among the given disaccharides, the non-reducing sugar is:



Answer (3)

Sol. Disaccharide with hemiacetal linkage will reduce Tollen's reagent and will be reducing sugar.

(3) does not have hemiacetal linkage.

65. The wavelength of photon 'A' is 400 nm. The frequency of photon 'B' is 10¹⁶ s⁻¹. The wave number of photon 'C' is 10⁴ cm⁻¹. The correct order of energy of these photons is :

(1) C > B > A

(2) A > B > C

(3) B > A > C

(4) A > C > B

Answer (3)

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Sol. $\lambda_A = 400 \times 10^{-9} \text{ m} = 4 \times 10^{-7} \text{ m}$

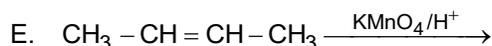
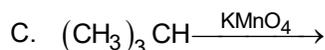
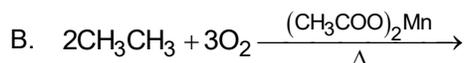
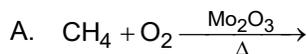
$$\lambda_B = 3 \times 10^{-8} \text{ m}$$

$$\lambda_C = 10^{-6} \text{ m}$$

$$\lambda_C > \lambda_A > \lambda_B$$

Energy order will be opposite.

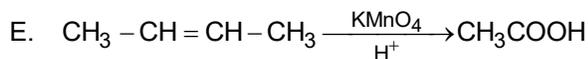
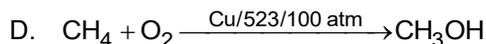
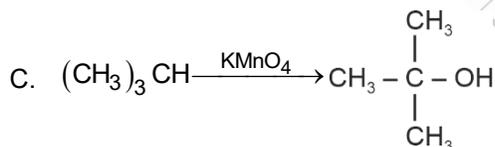
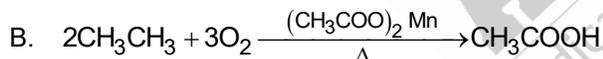
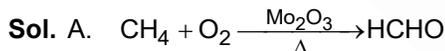
66. The reactions which produce alcohol as the product are:



Choose the **correct** answer from the options given below:

- (1) C and D only (2) A, C and E only
(3) A and D only (4) B, D and E only

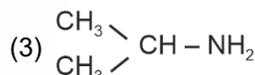
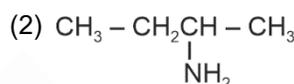
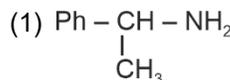
Answer (1)



67. A student performed analysis of aliphatic organic compound 'X' which on analysis gave C = 61.01%, H = 15.25%, N = 23.74%.

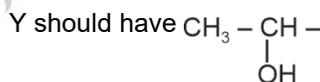
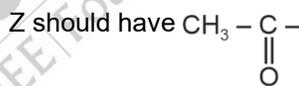
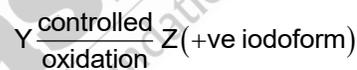
This compound, on treatment with $\text{HNO}_2/\text{H}_2\text{O}$ produced another compound 'Y' which did not contain any nitrogen atom. However, the compound 'Y' upon controlled oxidation produced another compound 'Z' that responded to iodoform test.

The structure of 'X' is:



Answer (3)

Sol. Y should be 1° amine



	100 g	molar ratio	simple ratio
C	61 g	$\frac{61}{12} = 5.083$	3
H	15.25 g	$\frac{15.25}{1} = 15.833$	9
N	23.74 g	$\frac{23.74}{14} = 1.7$	1

Empirical formula $\Rightarrow \text{C}_3\text{H}_9\text{N}$

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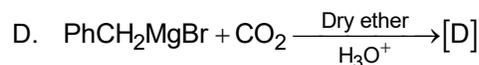
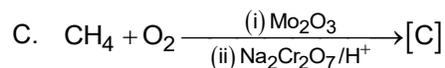
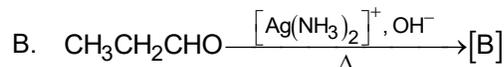
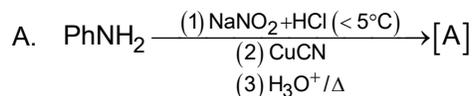
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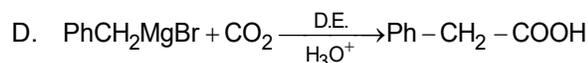
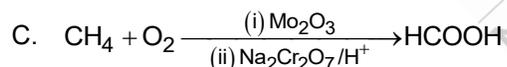
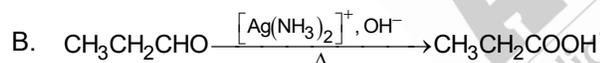
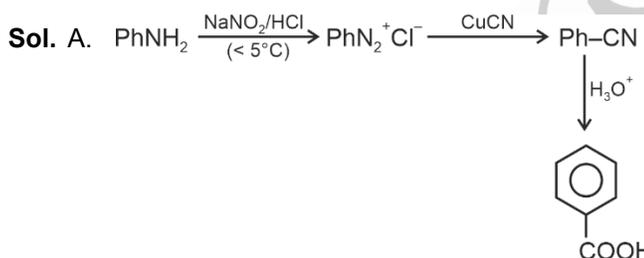
68. The correct order of acidic strength of the major products formed in the given reactions, is:



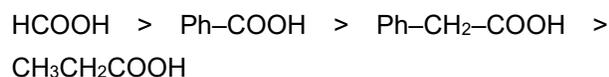
Choose the **correct** answer from the options given below:

- (1) $\text{C} > \text{B} > \text{A} > \text{D}$
- (2) $\text{A} > \text{D} > \text{B} > \text{C}$
- (3) $\text{A} > \text{D} > \text{C} > \text{B}$
- (4) $\text{C} > \text{A} > \text{D} > \text{B}$

Answer (4)



Order of acidic strength



69. Consider the elements N, P, O, S, Cl and F. The number of valence electrons present in the elements with most and least metallic character from the above list is respectively.

- (1) 7 and 5
- (2) 6 and 7
- (3) 5 and 6
- (4) 5 and 7

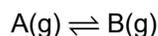
Answer (4)

Sol. Metallic character decreases down the group and left to right in periodic table

Least metallic – F

Most metallic – P

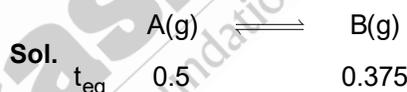
70. Observe the following equilibrium in a 1 L flask.



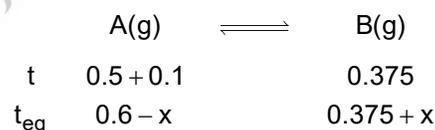
At T(K), the equilibrium concentrations of A and B are 0.5 M and 0.375 M respectively. 0.1 moles of A is added into the flask and heated to T(K) to establish the equilibrium again. The new equilibrium concentrations (in M) of A and B are respectively

- (1) 0.557, 0.418
- (2) 0.742, 0.557
- (3) 0.367, 0.275
- (4) 0.53, 0.4

Answer (1)



$$K_{\text{eq}} = \frac{[\text{B}]}{[\text{A}]} = \frac{0.375}{0.5} = 0.75 = \frac{3}{4}$$



$$K_{\text{eq}} = \frac{0.375 + x}{0.6 - x} = \frac{3}{4}$$

$$1.5 + 4x = 1.8 - 3x$$

$$7x = 0.3$$

$$0.042 = x$$

$$[\text{A}]_{\text{new}} = 0.6 - x = 0.557$$

$$[\text{B}]_{\text{new}} = 0.375 + 0.042 = 0.418$$

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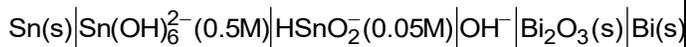
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SECTION - B

Numerical Value Type Questions: This section contains 5 Numerical based questions. The answer to each question should be rounded-off to the nearest integer.

71. A volume of x mL of 5M NaHCO₃ solution was mixed with 10 mL of 2M H₂CO₃ solution to make an electrolytic buffer. If the same buffer was used in the following electrochemical cell to record a cell potential of 235.3 mV, then the value of x = ___ mL (nearest integer).



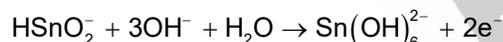
Consider upto one place of decimal for intermediate calculations

$$\left[\begin{array}{l} \text{Given: } E^\circ_{\text{HSnO}_2^- | \text{Sn(OH)}_6^{2-}} = -0.9 \text{ V} \\ E^\circ_{\text{Bi}_2\text{O}_3 | \text{Bi}} = -0.44 \text{ V} \\ \text{pK}_a(\text{H}_2\text{CO}_3) = 6.11 \\ \frac{2.303 RT}{F} = 0.059 \text{ V} \\ \text{Antilog}(1.29) = 19.5 \end{array} \right]$$

Answer (Bonus)

Sol. Data Incorrect Question to be challenged.

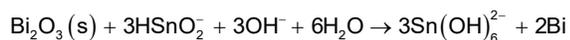
Reaction at anode



Reaction at cathode



Cell reaction



$$Q_{\text{cell}} = \frac{(0.5)^3 \times 1}{(0.05)^3 (\text{OH}^-)^3}$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{0.059}{6} \log \frac{10^3}{(\text{OH}^-)^3}$$

$$0.2353 = -0.44\text{V} - (+0.9) - \frac{0.059}{2} \log \frac{10}{\text{OH}^-}$$

$$\log \frac{10}{\text{OH}^-} = \left(\frac{1.34 - 0.2353}{0.059} \right) \times 2$$

$$\log \frac{10}{\text{OH}^-} = -53.4$$

$$1 - \log \text{OH}^- = -53.4$$

$$1 + \text{pOH} = -53.4$$

$$\text{pOH} = -54.4$$

It is an impossible value

72. The number of isoelectronic species among Sc³⁺, Cr²⁺, Mn³⁺, Co³⁺ and Fe³⁺ is 'n'. If 'n' moles of AgCl is formed during the reaction of complex with formula CoCl₃(en)₂NH₃ with excess of AgNO₃ solution, then the number of electrons present in the t_{2g} orbital of the complex is _____.

Answer (6)

Sol. Sc³⁺ ⇒ 3d⁰ number of e⁻ = 18

Cr²⁺ ⇒ 3d⁴ number of e⁻ = 22

Mn³⁺ ⇒ 3d⁴ number of e⁻ = 22

Co³⁺ ⇒ 3d⁶ number of e⁻ = 24

Fe³⁺ ⇒ 3d⁵ number of e⁻ = 23

Number of isoelectronic species = 2 = n

Mole of AgCl formed = 2

Formula for complex ⇒ [Co(en)₂NH₃Cl]

For Co³⁺, e⁻ configuration ⇒ t_{2g}⁶e_g⁰

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73. A → B (first reaction)
C → D (second reaction)

Consider the above two first-order reactions. The rate constant for first reaction at 500 K is double of the same at 300 K. At 500 K, 50% of the reaction becomes complete in 2 hour. The activation energy of the second reaction is half of that of first reaction. If the rate constant at 500 K of the second reaction becomes double of the rate constant of first reaction at the same temperature; then rate constant for the second reaction at 300 K is _____ × 10⁻¹ hour⁻¹ (nearest integer).

Answer (5)

- Sol.** A → B
C → D

For 1st reaction

$$k_{500} = 2k_{300}$$

$$\log \frac{k_{500}}{k_{300}} = \frac{E_a}{2.303 R} \left[\frac{1}{300} - \frac{1}{500} \right]$$

$$\log \frac{0.693}{2} = \frac{(E_a)_1 \times 200}{2.303 \times R \times 300 \times 500} \dots (i)$$

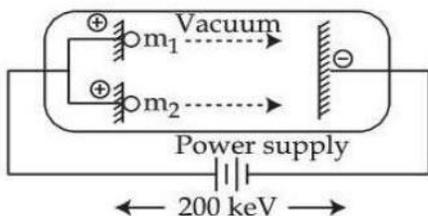
For 2nd reaction

$$\log \frac{k_{500}}{k_{300}} = \frac{(E_a)_2 \times 200}{2.303 \times R \times 300 \times 500}$$

$$\log \frac{0.693}{k_{300}} = \frac{E_{a_1} \times 200}{2 \times 2.303 \times R \times 300 \times 500} \dots (ii)$$

Solving $k_{300K} \cong 5 \times 10^{-1}$

74. Two positively charged particles m_1 and m_2 have been accelerated across the same potential difference of 200 keV as shown below.



[Given mass of $m_1 = 1$ amu and $m_2 = 4$ amu]

The deBroglie wavelength of m_1 will be x times of m_2 . The value of x is _____ (nearest integer)

Answer (2)

Sol. $\lambda = \frac{h}{\sqrt{2m(eV)}}$

$$\frac{\lambda_{m_1}}{\lambda_{m_2}} = \frac{1}{\frac{\sqrt{2 \times 1 (eV)}}{1}} = 2$$

$$\lambda_{m_1} = 2\lambda_{m_2}$$

$$x = 2$$

75. For strong electrolyte Λ_m increases slowly with dilution and can be represented by the equation

$$\Lambda_m = \Lambda_m^\circ - Ac^{1/2}$$

Molar conductivity values of the solutions of strong electrolyte AB at 18°C are given below :

c [mol L ⁻¹]	0.04	0.09	0.16	0.25
Λ_m [S cm ² mol ⁻¹]	96.1	95.7	95.3	94.9

The value of constant A based on the above data [in S cm² mol⁻¹/(mol/L)^{1/2}] unit is _____.

Answer (4)

Sol. $\Lambda_m = \Lambda_m^\circ - Ac^{1/2}$

$$96.1 = \Lambda_m^\circ - A(0.04)^{1/2} \dots (1)$$

$$95.7 = \Lambda_m^\circ - A(0.09)^{1/2} \dots (2)$$

$$0.4 = A \left[(0.09)^{1/2} - (0.04)^{1/2} \right]$$

$$0.4 = A[0.3 - 0.2]$$

$$0.4 = 0.1 A$$

$$A = 4$$

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