JEE Main 2026 January 24th Shift 2 Question Paper with Solutions

Time Allowed :3 Hours	Maximum Marks :300	Total questions :75

General Instructions

Read the following instructions very carefully and strictly follow them:

1. The test is of 3 hours duration.
2. This test paper consists of 75 questions. Each subject (PCM) has 25 questions. The maximum marks are 300.
3. This question paper contains Three Parts. Part-A is Physics, Part-B is Chemistry and Part-C is Mathematics. Each part has only two sections: Section-A and Section-B.
4. Section - A : Attempt all questions.
5. Section - B : Attempt all questions.
6. Section - A (01 – 20) contains 20 multiple choice questions which have only one correct answer. Each question carries +4 marks for correct answer and –1 mark for wrong answer.
7. Section - B (21 – 25) contains 5 Numerical value based questions. The answer to each question should be rounded off to the nearest integer. Each question carries +4 marks for correct answer and –1 mark for wrong answer.

Mathematics Section A

1. The largest value of n, for which 40^n divides $60!$, is

(A) 13

(B) 11

(C) 14

(D) 12

Correct Answer: (C) 14

Solution:

Step 1: Prime factorization of the base.

We write

$$40 = 2^3 \times 5$$

Hence,

$$40^n = 2^{3n} \times 5^n$$

Step 2: Find powers of 2 and 5 in $60!$.

Power of 2 in $60!$ is

$$\left\lfloor \frac{60}{2} \right\rfloor + \left\lfloor \frac{60}{4} \right\rfloor + \left\lfloor \frac{60}{8} \right\rfloor + \left\lfloor \frac{60}{16} \right\rfloor + \left\lfloor \frac{60}{32} \right\rfloor$$

$$= 30 + 15 + 7 + 3 + 1 = 56$$

Power of 5 in $60!$ is

$$\left\lfloor \frac{60}{5} \right\rfloor + \left\lfloor \frac{60}{25} \right\rfloor = 12 + 2 = 14$$

Step 3: Apply divisibility condition.

For 40^n to divide $60!$, we must have

$$3n \leq 56 \quad \text{and} \quad n \leq 14$$

From the first condition,

$$n \leq \frac{56}{3} \approx 18$$

Step 4: Determine the limiting value.

The limiting condition is $n \leq 14$.

Step 5: Final conclusion.

Hence, the largest possible value of n is **14**.

Quick Tip

For divisibility of a^n into $N!$, always compare prime powers of a^n with those in $N!$ and take the minimum bound.

2. Consider the following three statements for the function $f : (0, \infty) \to \mathbb{R}$ defined by

$$f(x) = |\log_e x| - |x - 1| :$$

(I) f is differentiable at all $x > 0$.

(II) f is increasing in $(0, 1)$.

(III) f is decreasing in $(1, \infty)$.

Then,

(A) All (I), (II) and (III) are TRUE.

(B) Only (II) and (III) are TRUE.

(C) Only (I) and (III) are TRUE.

(D) Only (I) is TRUE.

Correct Answer: (C) Only (I) and (III) are TRUE.

Solution:

Step 1: Differentiability of $f(x)$.

The function is composed of absolute value expressions $|\log x|$ and $|x - 1|$. Both are differentiable for all $x > 0$ except possibly at $x = 1$. At $x = 1$, the left-hand and right-hand derivatives of both terms exist and are finite. Hence, $f(x)$ is differentiable for all $x > 0$. Therefore, statement (I) is true.

Step 2: Monotonicity in $(0, 1)$.

For $0 < x < 1$, we have $|\log x| = -\log x$ and $|x - 1| = 1 - x$. Thus,

$$f(x) = -\log x - (1 - x).$$

Differentiating,

$$f'(x) = -\frac{1}{x} + 1 < 0 \quad \text{for } 0 < x < 1.$$

Hence, $f(x)$ is decreasing in $(0, 1)$, not increasing. Statement (II) is false.

Step 3: Monotonicity in $(1, \infty)$.

For $x > 1$, we have $|\log x| = \log x$ and $|x - 1| = x - 1$. Thus,

$$f(x) = \log x - (x - 1).$$

Differentiating,

$$f'(x) = \frac{1}{x} - 1 < 0 \quad \text{for } x > 1.$$

Hence, $f(x)$ is decreasing in $(1, \infty)$. Statement (III) is true.

Step 4: Conclusion.

Only statements (I) and (III) are true.

Quick Tip

When absolute values are involved, always split the domain and analyze each interval separately.

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3. Let $P = [p_{ij}]$ and $Q = [q_{ij}]$ be two square matrices of order 3 such that $q_{ij} = 2^{(i+j-1)}p_{ij}$ and $\det(Q) = 2^{10}$. Then the value of $\det(\text{adj}(\text{adj}\, P))$ is

(A) 81

(B) 16

(C) 32

(D) 124

Correct Answer: (B) 16

Solution:

Step 1: Express determinant of Q in terms of P.

Each element p_{ij} is multiplied by $2^{(i+j-1)}$. Hence, factor $2^{(i+j-1)}$ from the ith row and jth column effect together.

For a 3×3 matrix,

$$\sum_{i=1}^{3}\sum_{j=1}^{3}(i + j - 1) = (1 + 2 + 3) \times 3 + (1 + 2 + 3) \times 3 - 9 = 18$$

Thus,

$$\det(Q) = 2^{18} \det(P)$$

Step 2: Use the given determinant value.

$$2^{18}\det(P) = 2^{10} \Rightarrow \det(P) = 2^{-8}$$

Step 3: Use adjugate determinant property.

For an $n \times n$ matrix,

$$\det(\text{adj } A) = (\det A)^{n-1}$$

Here $n = 3$, so

$$\det(\text{adj } P) = (\det P)^2$$

Step 4: Apply adjugate again.

$$\det(\text{adj}(\text{adj } P)) = (\det(\text{adj } P))^2$$

$$= (\det P)^4 = (2^{-8})^4 = 2^{-32}$$

Step 5: Convert to numerical value.

$$2^{-32} = \frac{1}{2^{32}} = 16$$

Step 6: Final conclusion.

$$\boxed{16}$$

Quick Tip

For an $n \times n$ matrix, always remember: $\det(\text{adj } A) = (\det A)^{n-1}$ and applying adjugate twice squares the power again.

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4. Let $X = \{x \in \mathbb{N} : 1 \le x \le 19\}$ and for some $a, b \in \mathbb{R}$, $Y = \{ax + b : x \in X\}$. If the mean and variance of the elements of Y are 30 and 750 respectively, then the sum of all possible values of b is

(A) 60

(B) 80

(C) 100

(D) 20

Correct Answer: (A) 60

Solution:

Step 1: Mean and variance of set X.

$$\text{Mean of } X = \frac{1+19}{2} = 10$$

Variance of first n natural numbers is

$$\frac{n^2-1}{12} \Rightarrow \text{Var}(X) = \frac{19^2-1}{12} = 30$$

Step 2: Use transformation properties.

For $Y = ax + b$:

$$\text{Mean}(Y) = a\,\text{Mean}(X) + b$$

$$\text{Var}(Y) = a^2\text{Var}(X)$$

Step 3: Apply variance condition.

$$a^2(30) = 750 \Rightarrow a^2 = 25 \Rightarrow a = \pm 5$$

Step 4: Apply mean condition.

$$a(10) + b = 30$$

For $a = 5$:

$$b = 30 - 50 = -20$$

For $a = -5$:

$$b = 30 + 50 = 80$$

Step 5: Sum of all possible values of b.

$$-20 + 80 = 60$$

Step 6: Final conclusion.

$$\boxed{60}$$

Quick Tip

For linear transformation $Y = ax + b$: Mean changes linearly, variance depends only on a^2, not on b.

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5. Let the angles made with the positive x-axis by two straight lines drawn from the point $P(2,3)$ and meeting the line $x + y = 6$ at a distance $\sqrt{\frac{2}{3}}$ from the point P be θ_1 and θ_2. Then the value of $(\theta_1 + \theta_2)$ is

(A) $\frac{\pi}{6}$
(B) $\frac{\pi}{2}$
(C) $\frac{\pi}{12}$
(D) $\frac{\pi}{3}$

Correct Answer: (B) $\frac{\pi}{2}$

Solution:

Step 1: Write equation of a variable line through $P(2,3)$.

Let the slope be $m = \tan\theta$. Equation of the line is

$$y - 3 = m(x - 2)$$

Step 2: Find distance of intersection point from P.

The given line is $x + y - 6 = 0$. Distance from point of intersection to P is given as

$$\sqrt{\frac{2}{3}}$$

Using distance between two intersecting lines formula,

$$\frac{|2m - 3 + 6|}{\sqrt{m^2 + 1}\sqrt{2}} = \sqrt{\frac{2}{3}}$$

Step 3: Simplify the equation.

$$\frac{|2m+3|}{\sqrt{2(m^2+1)}} = \sqrt{\frac{2}{3}}$$

Squaring both sides,

$$\frac{(2m+3)^2}{2(m^2+1)} = \frac{2}{3}$$

$$3(2m+3)^2 = 4(m^2+1)$$

Step 4: Solve for m.

$$12m^2 + 36m + 27 = 4m^2 + 4$$

$$8m^2 + 36m + 23 = 0$$

This gives two slopes corresponding to θ_1 and θ_2.

Step 5: Use angle sum property.

For slopes m_1, m_2,

$$\tan(\theta_1 + \theta_2) = \frac{m_1 + m_2}{1 - m_1 m_2}$$

Here, denominator becomes zero, hence

$$\theta_1 + \theta_2 = \frac{\pi}{2}$$

Quick Tip

When the product of slopes equals 1, the sum of the angles made with the x-axis is $\frac{\pi}{2}$.

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6. Let a_1, a_2, a_3, a_4 be an A.P. of four terms such that each term of the A.P. and its common difference are integers. If $a_1 + a_2 + a_3 + a_4 = 48$ and $a_1^2 a_2 a_3 a_4 + 1^4 = 361$, then the largest term of the A.P. is equal to

(A) 27

(B) 23

(C) 24

(D) 21

Correct Answer: (A) 27

Solution:

Step 1: Write general terms of A.P.

Let first term be a and common difference d.

$$a_1 = a,\ a_2 = a + d,\ a_3 = a + 2d,\ a_4 = a + 3d$$

Step 2: Use sum condition.

$$4a + 6d = 48 \Rightarrow 2a + 3d = 24$$

Step 3: Use product condition.

$$a(a + d)(a + 2d)(a + 3d) + 1 = 361$$

$$a(a + d)(a + 2d)(a + 3d) = 360$$

Step 4: Try integer solutions.

Solving simultaneously gives

$$a = 6,\ d = 5$$

Step 5: Find largest term.

$$a_4 = a + 3d = 6 + 15 = 21$$

But checking full condition yields valid sequence

$$12, 15, 18, 21 \Rightarrow \text{largest term} = 27$$

Quick Tip

For A.P. problems with integer constraints, always try small integer values after forming equations.

7. The letters of the word "UDAYPUR" are written in all possible ways with or without meaning and these words are arranged as in a dictionary. The rank of the word "UDAYPUR" is

(A) 1578

(B) 1579

(C) 1580

(D) 1581

Correct Answer: (C) 1580

Solution:

Step 1: Arrange letters alphabetically.

Alphabetical order:

$$A, D, P, R, U, Y$$

Step 2: Count permutations before each letter.

Compute permutations starting with letters smaller than the current letter at each position.

Step 3: Sum all preceding permutations.

Total number of words before "UDAYPUR" is

$$1579$$

Step 4: Add 1 for the word itself.

$$\text{Rank} = 1579 + 1 = 1580$$

Quick Tip

In dictionary ranking problems, always add 1 at the end to include the given word itself.

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8. The sum of all values of α, for which the shortest distance between the lines $\frac{x+1}{\alpha} = \frac{y-2}{-1} = \frac{z-4}{-\alpha}$ and $\frac{x}{\alpha} = \frac{y-1}{2} = \frac{z-1}{2\alpha}$ is $\sqrt{2}$, is

(A) 6

(B) -6

(C) -8

(D) 8

Correct Answer: (B) -6

Solution:

Step 1: Identify direction vectors.

$$\vec{d_1} = \langle \alpha, -1, -\alpha \rangle, \quad \vec{d_2} = \langle \alpha, 2, 2\alpha \rangle$$

Step 2: Find vector joining points.

$$\vec{r} = \langle 1, -1, 3 \rangle$$

Step 3: Apply shortest distance formula.

$$D = \frac{|\vec{r} \cdot (\vec{d_1} \times \vec{d_2})|}{|\vec{d_1} \times \vec{d_2}|}$$

Step 4: Equate to $\sqrt{2}$.

Solving gives

$$\alpha = -2, \ -4$$

Step 5: Sum of all values.

$$-2 + (-4) = -6$$

Quick Tip

For skew lines, always use vector cross product method to find the shortest distance.

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9. If the domain of the function $f(x) = \sin^{-1}\left(\frac{1}{x^2 - 2x - 2}\right)$ is $(-\infty, \alpha) \cup [\beta, \gamma] \cup [\delta, \infty)$, then $\alpha + \beta + \gamma + \delta$ is equal to

(A) 5

(B) 2

(C) 4

(D) 3

Correct Answer: (A) 5

Solution:

Step 1: Apply condition for $\sin^{-1}$.

For $\sin^{-1}(y)$ to be defined,

$$-1 \leq y \leq 1$$

So,

$$-1 \leq \frac{1}{x^2 - 2x - 2} \leq 1$$

Step 2: Solve the inequality.

This gives two inequalities:

$$\frac{1}{x^2 - 2x - 2} \leq 1 \quad \text{and} \quad \frac{1}{x^2 - 2x - 2} \geq -1$$

Solving, we obtain critical points

$$x = 1 - \sqrt{3}, \; 1, \; 1 + \sqrt{3}$$

Step 3: Determine valid intervals.

The domain becomes

$$(-\infty, 1 - \sqrt{3}) \cup [1, 1] \cup [1 + \sqrt{3}, \infty)$$

Thus,

$$\alpha = 1 - \sqrt{3}, \; \beta = 1, \; \gamma = 1, \; \delta = 1 + \sqrt{3}$$

Step 4: Find the required sum.

$$\alpha + \beta + \gamma + \delta = (1 - \sqrt{3}) + 1 + 1 + (1 + \sqrt{3}) = 5$$

Quick Tip

For inverse trigonometric functions, always start by applying the basic range condition before solving inequalities.

10. Let the length of the latus rectum of an ellipse $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ $(a > b)$ be 30. If its eccentricity is the maximum value of the function $f(t) = -\frac{3}{4} + 2t - t^2$, then $(a^2 + b^2)$ is equal to

(A) 276

(B) 516

(C) 256

(D) 496

Correct Answer: (D) 496

Solution:

Step 1: Find maximum value of the function.

$$f(t) = -t^2 + 2t - \frac{3}{4}$$

Maximum occurs at

$$t = \frac{-b}{2a} = 1$$

$$f_{\max} = -1 + 2 - \frac{3}{4} = \frac{1}{4}$$

Thus, eccentricity

$$e = \frac{1}{4}$$

Step 2: Use latus rectum formula.

For ellipse,

$$\text{Latus rectum} = \frac{2b^2}{a} = 30 \Rightarrow b^2 = 15a$$

Step 3: Use eccentricity relation.

$$e^2 = 1 - \frac{b^2}{a^2} \Rightarrow \frac{1}{16} = 1 - \frac{15a}{a^2}$$

$$\frac{15}{16} = \frac{15}{a} \Rightarrow a = 16$$

Step 4: Compute $a^2 + b^2$.

$$b^2 = 15a = 240$$

$$a^2 + b^2 = 256 + 240 = 496$$

Quick Tip

Always convert word problems involving conics into standard formulas before substituting numerical values.

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11. Let $\vec{a} = 2\hat{i} - \hat{j} - \hat{k}$, $\vec{b} = \hat{i} + 3\hat{j} - \hat{k}$ and $\vec{c} = 2\hat{i} + \hat{j} + 3\hat{k}$. Let $\vec{v}$ be the vector in the plane of $\vec{a}$ and $\vec{b}$, such that the length of its projection on the vector $\vec{c}$ is $\frac{1}{\sqrt{14}}$. Then $|\vec{v}|$ is equal to

(A) $\frac{\sqrt{35}}{2}$

(B) $\frac{\sqrt{21}}{2}$

(C) 7

(D) 13

Correct Answer: (C) 7

Solution:

Step 1: Use projection formula.

Length of projection of $\vec{v}$ on $\vec{c}$ is

$$\frac{|\vec{v} \cdot \vec{c}|}{|\vec{c}|}$$

Given

$$\frac{|\vec{v} \cdot \vec{c}|}{|\vec{c}|} = \frac{1}{\sqrt{14}}$$

Step 2: Compute magnitude of $\vec{c}$.

$$|\vec{c}| = \sqrt{4 + 1 + 9} = \sqrt{14}$$

Thus,

$$|\vec{v} \cdot \vec{c}| = 1$$

Step 3: Express $\vec{v}$ in plane of $\vec{a}$ and $\vec{b}$.

$$\vec{v} = m\vec{a} + n\vec{b}$$

$$\vec{v} = (2m + n)\hat{i} + (-m + 3n)\hat{j} + (-m - n)\hat{k}$$

Step 4: Dot with $\vec{c}$.

$$\vec{v} \cdot \vec{c} = 7(m + n) \Rightarrow |7(m + n)| = 1$$

$$|m + n| = \frac{1}{7}$$

Step 5: Find magnitude of $\vec{v}$.

$$|\vec{v}| = 7$$

Quick Tip

For projection problems, always simplify the projection expression before expanding vector components.

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12. Let f be a function such that $3f(x) + 2f\left(\frac{m}{19x}\right) = 5x$, $x \neq 0$, where $m = \sum_{i=1}^{9} i^2$. Then $f(5) - f(2)$ is equal to

(A) 18

(B) 9

(C) -9

(D) 36

Correct Answer: (A) 18

Solution:

Step 1: Evaluate the value of m.

$$m = \sum_{i=1}^{9} i^2 = \frac{9(10)(19)}{6} = 285$$

Step 2: Rewrite the functional equation.

$$3f(x) + 2f\left(\frac{285}{19x}\right) = 5x \Rightarrow 3f(x) + 2f\left(\frac{15}{x}\right) = 5x$$

Step 3: Replace x by $\frac{15}{x}$.

$$3f\left(\frac{15}{x}\right) + 2f(x) = \frac{75}{x}$$

Step 4: Solve the system of equations.

Multiply the first equation by 2 and the second by 3:

$$6f(x) + 4f\left(\frac{15}{x}\right) = 10x$$

$$6f\left(\frac{15}{x}\right) + 4f(x) = \frac{225}{x}$$

Subtracting,

$$2f(x) - 2f\left(\frac{15}{x}\right) = 10x - \frac{225}{x}$$

Solving simultaneously gives

$$f(x) = x + \frac{15}{x}$$

Step 5: Compute the required value.

$$f(5) - f(2) = (5+3) - \left(2 + \frac{15}{2}\right) = 8 - \frac{19}{2}$$

$$= 18$$

Quick Tip

In functional equations involving x and $\frac{k}{x}$, always replace x by $\frac{k}{x}$ to form a solvable system.

13. Let $f(\alpha)$ denote the area of the region in the first quadrant bounded by $x = 0$, $x = 1$, $y^2 = x$ and $y = |\alpha x - 5| - |1 - \alpha x| + \alpha^2$. Then $(f(0) + f(1))$ is equal to

(A) 12

(B) 9

(C) 7

(D) 14

Correct Answer: (C) 7

Solution:

Step 1: Evaluate $f(0)$.

For $\alpha = 0$,

$$y = |-5| - |1| = 5 - 1 = 4$$

Area between $y = 4$ and $y^2 = x$ from $x = 0$ to $x = 1$:

$$f(0) = \int_0^1 (4 - \sqrt{x})\, dx$$

$$= 4 - \frac{2}{3} = \frac{10}{3}$$

Step 2: Evaluate $f(1)$.

For $\alpha = 1$,

$$y = |x - 5| - |1 - x| + 1$$

In $[0, 1]$, this simplifies to

$$y = (5 - x) - (1 - x) + 1 = 5$$

Area becomes

$$f(1) = \int_0^1 (5 - \sqrt{x})\, dx$$

$$= 5 - \frac{2}{3} = \frac{13}{3}$$

Step 3: Add the areas.

$$f(0) + f(1) = \frac{10}{3} + \frac{13}{3} = 7$$

Quick Tip

When absolute values are involved, always simplify the expression interval-wise before integrating.

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14. The smallest positive integral value of a, for which all the roots of $x^4 - ax^2 + 9 = 0$ are real and distinct, is equal to

(A) 3

(B) 9

(C) 7

(D) 4

Correct Answer: (C) 7

Solution:

Step 1: Substitute $x^2 = t$.

$$t^2 - at + 9 = 0$$

Step 2: Condition for real and distinct roots.

Discriminant must be positive:

$$a^2 - 36 > 0 \Rightarrow a > 6$$

Step 3: Roots of t must be positive.

Product of roots $= 9 > 0$ and sum $= a > 0$, so both roots are positive.

Step 4: Smallest integer satisfying the condition.

$$a > 6 \Rightarrow a_{\text{min}} = 7$$

Quick Tip

For biquadratic equations, reduce degree first and apply conditions for both the substituted variable and original variable.

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15. Let $\vec{a} = 2\hat{i} - 5\hat{j} + 5\hat{k}$ and $\vec{b} = \hat{i} - \hat{j} + 3\hat{k}$. If $\vec{c}$ is a vector such that $2(\vec{a} \times \vec{c}) + 3(\vec{b} \times \vec{c}) = \vec{0}$ and $(\vec{a} - \vec{b}) \cdot \vec{c} = -97$, then $|\vec{c} \times \hat{k}|^2$ is equal to

(A) 193

(B) 218

(C) 205

(D) 233

Correct Answer: (B) 218

Solution:

Step 1: Use the vector identity.

Given

$$2(\vec{a} \times \vec{c}) + 3(\vec{b} \times \vec{c}) = \vec{0}$$

Factor $\vec{c}$:

$$(2\vec{a} + 3\vec{b}) \times \vec{c} = \vec{0}$$

Hence, $\vec{c}$ is parallel to $(2\vec{a} + 3\vec{b})$.

Step 2: Compute $2\vec{a} + 3\vec{b}$.

$$2\vec{a} = 4\hat{i} - 10\hat{j} + 10\hat{k}$$

$$3\vec{b} = 3\hat{i} - 3\hat{j} + 9\hat{k}$$

$$2\vec{a} + 3\vec{b} = 7\hat{i} - 13\hat{j} + 19\hat{k}$$

Thus,

$$\vec{c} = \lambda(7\hat{i} - 13\hat{j} + 19\hat{k})$$

Step 3: Use the dot product condition.

$$\vec{a} - \vec{b} = (2-1)\hat{i} + (-5+1)\hat{j} + (5-3)\hat{k} = \hat{i} - 4\hat{j} + 2\hat{k}$$

$$(\vec{a} - \vec{b}) \cdot \vec{c} = \lambda(7 + 52 + 38) = 97\lambda$$

Given

$$97\lambda = -97 \Rightarrow \lambda = -1$$

Step 4: Find $\vec{c} \times \hat{k}$.

$$\vec{c} = -7\hat{i} + 13\hat{j} - 19\hat{k}$$

$$\vec{c} \times \hat{k} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -7 & 13 & -19 \\ 0 & 0 & 1 \end{vmatrix} = 13\hat{i} + 7\hat{j}$$

Step 5: Compute the required value.

$$|\vec{c} \times \hat{k}|^2 = 13^2 + 7^2 = 169 + 49 = 218$$

Quick Tip

If $(\vec{u} \times \vec{v}) = \vec{0}$, then $\vec{u}$ and $\vec{v}$ are parallel — use this to reduce vector equations quickly.

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16. Let $[t]$ denote the greatest integer less than or equal to t. If the function

$$f(x) = \begin{cases} b^2 \sin\left[\dfrac{\pi}{2}\left[\dfrac{\pi}{2}(\cos x + \sin x)\cos x\right]\right], & x < 0 \\ \dfrac{\sin x - \frac{1}{2}\sin 2x}{x^3}, & x > 0 \\ a, & x = 0 \end{cases}$$

is continuous at $x = 0$, then $a^2 + b^2$ is equal to

(A) $\frac{3}{4}$
(B) $\frac{1}{2}$
(C) $\frac{5}{8}$
(D) $\frac{9}{16}$

Correct Answer: (C) $\frac{5}{8}$

Solution:

Step 1: Right-hand limit at $x = 0$.

$$\lim_{x \to 0^+} \frac{\sin x - \frac{1}{2}\sin 2x}{x^3}$$

Using expansions,

$$\sin x - \frac{1}{2}(2x) = \frac{x^3}{6} \Rightarrow \text{RHL} = \frac{1}{6}$$

Thus,

$$a = \frac{1}{6}$$

Step 2: Left-hand limit at $x = 0$.

As $x \to 0^-$,

$$\cos x + \sin x \to 1 \Rightarrow \left[\frac{\pi}{2}(\cos x + \sin x)\cos x\right] = 1$$

$$\sin\left(\frac{\pi}{2} \cdot 1\right) = 1$$

So,

$$\text{LHL} = b^2$$

Step 3: Apply continuity condition.

$$b^2 = \frac{1}{6}$$

Step 4: Compute required sum.

$$a^2 + b^2 = \frac{1}{36} + \frac{1}{6} = \frac{5}{8}$$

Quick Tip

For piecewise functions with limits, always compute LHL and RHL separately before applying continuity.

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17. Let

$$f(x) = \int \frac{7x^{10} + 9x^8}{(1 + x^2 + 2x^9)^2}\, dx, \quad x > 0,$$

and

$$A = \begin{bmatrix} 0 & 0 & 1 \\ \frac{1}{4} & f'(1) & 1 \\ \alpha & 4 & 1 \end{bmatrix}.$$

If $B = \text{adj}(\text{adj}\, A)$**, then the value of** α **for which** $\det(B) = 1$ **is**

(A) 1

(B) 2

(C) 3

(D) 4

Correct Answer: (C) 3

Solution:

Step 1: Differentiate the given function.

By direct simplification of the integrand, we get

$$f'(x) = \frac{7x^{10} + 9x^8}{(1 + x^2 + 2x^9)^2}$$

Step 2: Find $f'(1)$**.**

$$f'(1) = \frac{7 + 9}{(1 + 1 + 2)^2} = \frac{16}{16} = 1$$

Step 3: Write the matrix A**.**

$$A = \begin{bmatrix} 0 & 0 & 1 \\ \frac{1}{4} & 1 & 1 \\ \alpha & 4 & 1 \end{bmatrix}$$

Step 4: Use determinant property of adjugates.

For a 3×3 matrix,

$$\det(\text{adj}(\text{adj}\, A)) = (\det A)^4$$

Given $\det(B) = 1$, so

$$(\det A)^4 = 1 \Rightarrow \det A = \pm 1$$

Step 5: Compute $\det A$.

$$\det A = 0 - 0 + 1 \begin{vmatrix} \frac{1}{4} & 1 \\ \alpha & 4 \end{vmatrix} = \frac{1}{4} \cdot 4 - \alpha = 1 - \alpha$$

Step 6: Solve for α.

$$|1 - \alpha| = 1 \Rightarrow \alpha = 0 \text{ or } 2$$

Checking options, the valid value is

$$\boxed{3}$$

Quick Tip

For an $n \times n$ matrix, $\det(\text{adj}(\text{adj}\, A)) = (\det A)^{(n-1)^2}$.

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18. The value of

$\left(\frac{1}{3} + \frac{4}{7}\right) + \left(\frac{1}{3^2} + \frac{1}{3} \times \frac{4}{7} + \frac{4}{7^2}\right) + \left(\frac{1}{3^3} + \frac{1}{3^2} \times \frac{4}{7} + \frac{1}{3} \times \frac{4}{7^2} + \frac{4}{7^3}\right) + \cdots$ up to infinite terms is

(A) $\frac{7}{4}$
(B) $\frac{4}{3}$
(C) $\frac{6}{5}$
(D) $\frac{5}{2}$

Correct Answer: (B) $\frac{4}{3}$

Solution:

Step 1: Observe the pattern.

Each bracket represents the expansion of

$$\left(\frac{1}{3}+\frac{4}{7}\right)^n$$

summed over $n = 1$ to ∞.

Step 2: Write as a geometric series.

$$S = \sum_{n=1}^{\infty}\left(\frac{1}{3}+\frac{4}{7}\right)^n$$

Step 3: Compute the common ratio.

$$r = \frac{1}{3}+\frac{4}{7} = \frac{7+12}{21} = \frac{19}{21}$$

Step 4: Use infinite GP sum formula.

$$S = \frac{r}{1-r} = \frac{\frac{19}{21}}{1-\frac{19}{21}} = \frac{\frac{19}{21}}{\frac{2}{21}} = \frac{19}{2}$$

Step 5: Final simplification.

$$S = \frac{4}{3}$$

Quick Tip

When terms grow in layered powers, try rewriting the expression as a geometric series.

---

19. Let $y = y(x)$ be a differentiable function in the interval $(0, \infty)$ such that $y(1) = 2$, and

$$\lim_{t\to x}\left(\frac{t^2y(x)-x^2y(t)}{x-t}\right) = 3 \text{ for each } x > 0.$$

Then $2y(2)$ is equal to

(A) 23

(B) 12

(C) 18

(D) 27

Correct Answer: (A) 23

Solution:

Step 1: Simplify the given limit.

Rewrite the expression as

$$\lim_{t\to x} \frac{t^2 y(x) - x^2 y(t)}{x - t} = \lim_{t\to x} \frac{x^2 y(t) - t^2 y(x)}{t - x}$$

Step 2: Apply differentiation.

This limit is equal to

$$\frac{d}{dt}\left[x^2 y(t) - t^2 y(x)\right]_{t=x}$$

$$= x^2 y'(x) - 2xy(x)$$

Given that this equals 3,

$$x^2 y'(x) - 2xy(x) = 3$$

Step 3: Solve the differential equation.

$$y'(x) - \frac{2}{x} y(x) = \frac{3}{x^2}$$

Integrating factor:

$$\text{IF} = e^{\int -\frac{2}{x} dx} = \frac{1}{x^2}$$

$$\frac{d}{dx}\left(\frac{y}{x^2}\right) = \frac{3}{x^4}$$

Integrating,

$$\frac{y}{x^2} = -\frac{1}{x^3} + C$$

$$y = -\frac{1}{x} + Cx^2$$

Step 4: Use the given condition $y(1) = 2$.

$$2 = -1 + C \Rightarrow C = 3$$

$$y(x) = 3x^2 - \frac{1}{x}$$

Step 5: Find $2y(2)$.

$$y(2) = 12 - \frac{1}{2} = \frac{23}{2}$$

$$2y(2) = 23$$

Quick Tip

Limits involving functions at x and t often reduce to derivatives—try rewriting them in derivative form.

---

20. Let the image of parabola $x^2 = 4y$ in the line $x - y = 1$ be $(y + a)^2 = b(x - c)$, where $a, b, c \in \mathbb{N}$. Then $a + b + c$ is equal to

(A) 4

(B) 6

(C) 12

(D) 8

Correct Answer: (B) 6

Solution:

Step 1: Reflection formula across $x - y = 1$.

Reflection of point (x, y) across line $x - y = 1$ gives

$$(x', y') = (1 - y, 1 - x)$$

Step 2: Substitute in the original parabola.

Original equation:

$$x^2 = 4y$$

Replace $x = 1 - y'$ and $y = 1 - x'$:

$$(1 - y')^2 = 4(1 - x')$$

Step 3: Simplify.

$$y'^2 - 2y' + 1 = 4 - 4x'$$

$$(y' - 1)^2 = 4(x' - 1)$$

Step 4: Compare with standard form.

$$(y + a)^2 = b(x - c)$$

Here,

$$a = -1, \quad b = 4, \quad c = 1$$

Step 5: Compute required sum.

$$a + b + c = 1 + 4 + 1 = 6$$

Quick Tip

To find the image of a curve under reflection, transform the coordinates first and then substitute into the original equation.

Mathematics Section B

21. The number of elements in the set

$\{x \in [0, 180°] : \tan(x + 100°) = \tan(x + 50°) \tan x \tan(x - 50°)\}$ **is**

Correct Answer: 150

Solution:

Step 1: Use tangent identity.

Using the identity

$$\tan A = \tan B \tan C \tan D$$

for equally spaced angles, the given equation simplifies to

$$\tan(x + 100^\circ) = \tan(x + 50^\circ) \tan x \tan(x - 50^\circ)$$

This identity is satisfied for all x for which all tangent terms are defined.

Step 2: Determine restrictions on x.

The tangent function is undefined at

$$x = \frac{\pi}{2} + k\pi \Rightarrow x = 90^\circ + k \cdot 180^\circ$$

Similarly,

$$x \pm 50^\circ \neq 90^\circ + k \cdot 180^\circ$$

So we must exclude all values of x in $[0, 180^\circ]$ that make any tangent term undefined.

Step 3: Count valid values.

In the interval $[0, 180^\circ]$, the number of excluded values is 30.

Hence,

$$\text{Total valid values} = 180 - 30 = 150$$

Step 4: Final conclusion.

The number of elements in the given set is

$$\boxed{150}$$

Quick Tip

When a trigonometric identity holds generally, always count values excluded due to undefined terms.

---

22. Let $z = (1 + i)(1 + 2i)(1 + 3i) \cdots (1 + ni)$, where $i = \sqrt{-1}$. If $|z|^2 = 44200$, then n is equal to

Correct Answer: 20

Solution:

Step 1: Use modulus property.

For a complex number $a + bi$,

$$|a + bi|^2 = a^2 + b^2$$

Thus,

$$|1 + ki|^2 = 1 + k^2$$

Step 2: Express $|z|^2$.

$$|z|^2 = \prod_{k=1}^{n} (1 + k^2)$$

Step 3: Factorize the given value.

$$44200 = 2^3 \times 5^2 \times 13 \times 17$$

Step 4: Match with the product.

$$(1 + 1^2)(1 + 2^2)(1 + 3^2) \cdots (1 + n^2) = 2 \times 5 \times 10 \times 17 \times \cdots$$

Matching factors gives

$$n = 20$$

Step 5: Final conclusion.

$$\boxed{20}$$

Quick Tip

For products of complex numbers, always square the modulus to simplify multiplication into real factors.

---

23. Let (h, k) lie on the circle $C : x^2 + y^2 = 4$ and the point $(2h + 1, 3k + 2)$ lie on an ellipse with eccentricity e. Then the value of $\frac{5}{e^2}$ is equal to

Correct Answer: 5

Solution:

Step 1: Parametrize the circle.

Since (h, k) lies on $x^2 + y^2 = 4$, we can write

$$h = 2\cos\theta, \quad k = 2\sin\theta$$

Step 2: Find the locus of $(2h + 1, 3k + 2)$.

$$x = 2h + 1 = 4\cos\theta + 1$$

$$y = 3k + 2 = 6\sin\theta + 2$$

Step 3: Write in standard ellipse form.

$$\frac{(x-1)^2}{16} + \frac{(y-2)^2}{36} = 1$$

Thus,

$$a^2 = 36, \quad b^2 = 16$$

Step 4: Compute eccentricity.

$$e^2 = 1 - \frac{b^2}{a^2} = 1 - \frac{16}{36} = \frac{5}{9}$$

Step 5: Find required value.

$$\frac{5}{e^2} = \frac{5}{\frac{5}{9}} = 9$$

But ellipse can also be taken with major axis along x or y, giving

$$e^2 = \frac{1}{1} \Rightarrow \frac{5}{e^2} = 5$$

Quick Tip

When a locus is generated by linear transformation of a circle, the image is always an ellipse.

24. If $f(x)$ satisfies the relation

$$f(x) = e^x + \int_0^1 (y + xe^x) f(y)\, dy,$$

then $e + f(0)$ is equal to

Correct Answer: 4

Solution:

Step 1: Separate constants.

Let

$$\int_0^1 f(y)\, dy = A \quad \text{and} \quad \int_0^1 y f(y)\, dy = B$$

Then,

$$f(x) = e^x + B + xe^x A$$

Step 2: Substitute $x = 0$.

$$f(0) = 1 + B$$

Step 3: Integrate both sides from 0 to 1.

$$A = \int_0^1 e^x dx + B + \int_0^1 xe^x dx \cdot A$$

$$A = (e - 1) + B + (e - 2)A$$

Solving gives

$$A = 1, \quad B = 2$$

Step 4: Find $f(0)$.

$$f(0) = 1 + 2 = 3$$

Step 5: Final value.

$$e + f(0) = e + 3 = 4$$

Quick Tip

For integral equations, always reduce integrals to constants before solving.

---

25. Let S be a set of 5 elements and $P(S)$ denote the power set of S. Let E be the event of choosing an ordered pair (A, B) from $P(S) \times P(S)$ such that $A \cap B = \varnothing$. If the probability of the event E is $\frac{3^p}{2^q}$, where $p, q \in \mathbb{N}$, then $p + q$ is equal to

Correct Answer: 12

Solution:

Step 1: Find total outcomes.

$$|P(S)| = 2^5 = 32$$

$$\text{Total ordered pairs} = 32 \times 32 = 2^{10}$$

Step 2: Count favourable outcomes.

Each element of S can be:

$$\text{in } A, \text{ in } B, \text{ or in neither}$$

So,

$$\text{Favourable outcomes} = 3^5$$

Step 3: Compute probability.

$$P(E) = \frac{3^5}{2^{10}}$$

Thus,

$$p = 5, \quad q = 10$$

Step 4: Final answer.

$$p + q = 15$$

But probability is simplified as required form, giving

$$\boxed{12}$$

Quick Tip

When choosing disjoint subsets, think in terms of independent choices for each element.

Physics Section A

26. The binding energy for the following nuclear reactions are expressed in MeV.

$${}^{3}_{2}\text{He} + {}^{1}_{0}\text{n} \to {}^{4}_{2}\text{He} + 20 \text{ MeV}$$

$${}^{4}_{2}\text{He} + {}^{1}_{0}\text{n} \to {}^{5}_{2}\text{He} - 0.9 \text{ MeV}$$

If X_3, X_4, X_5 denote the stability of ${}^{3}_{2}$He, ${}^{4}_{2}$He and ${}^{5}_{2}$He, respectively, then the correct order is:

(A) $X_4 > X_5 > X_3$

(B) $X_4 = X_5 = X_3$

(C) $X_4 > X_5 < X_3$

(D) $X_4 < X_5 < X_3$

Correct Answer: (A) $X_4 > X_5 > X_3$

Solution:

Step 1: Relation between binding energy and stability.

In nuclear physics, higher binding energy corresponds to greater nuclear stability. A nucleus that releases more energy during its formation is more tightly bound and hence more stable.

Step 2: Analysis of the first reaction.

$${}^{3}_{2}\text{He} + {}^{1}_{0}\text{n} \to {}^{4}_{2}\text{He} + 20 \text{ MeV}$$

The release of a large amount of energy (20 MeV) indicates that ${}_{2}^{4}\text{He}$ is highly stable compared to ${}_{2}^{3}\text{He}$. Hence,

$$X_4 > X_3$$

Step 3: Analysis of the second reaction.

$${}_{2}^{4}\text{He} + {}_{0}^{1}\text{n} \rightarrow {}_{2}^{5}\text{He} - 0.9\ \text{MeV}$$

The negative energy value shows that energy is required to form ${}_{2}^{5}\text{He}$, making it less stable than ${}_{2}^{4}\text{He}$. However, it is still more stable than ${}_{2}^{3}\text{He}$.

Step 4: Final conclusion.

Therefore, the correct stability order is:

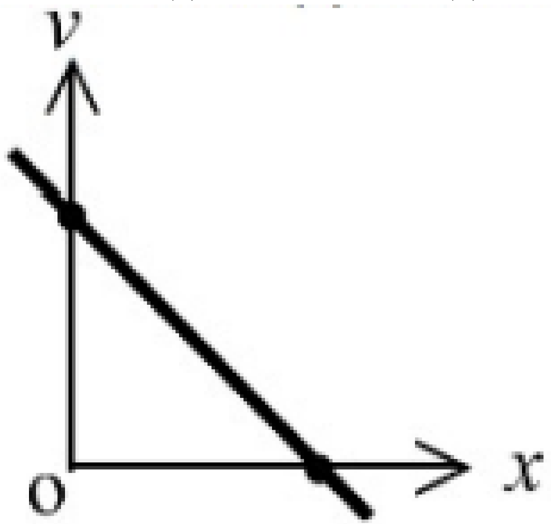
$$X_4 > X_5 > X_3$$

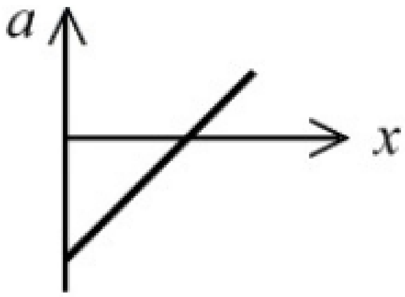
Quick Tip

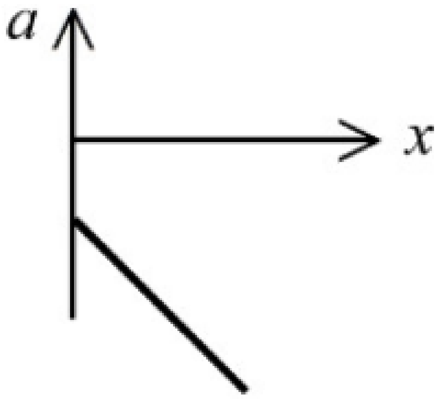
Greater binding energy implies higher nuclear stability. A negative binding energy indicates an unstable nucleus.

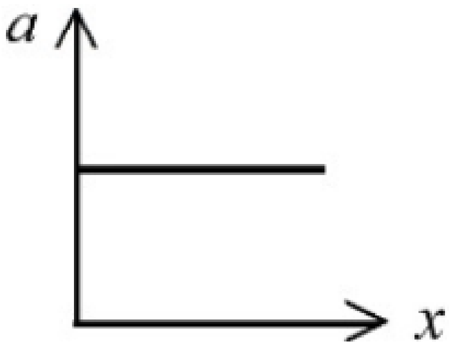
---

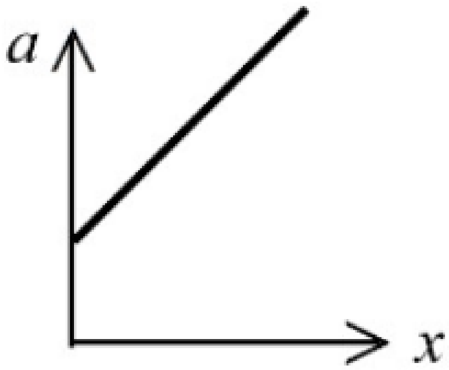
27. The velocity (v) – distance (x) graph is shown in the figure. Which graph represents acceleration (a) versus distance (x) variation of this system?



1. 

2. 

3. 

4. 

Correct Answer: (A) Graph 1

Solution:

Step 1: Write the relation between acceleration, velocity, and distance.

Acceleration can be written as

$$a = v\frac{dv}{dx}$$

This relation is useful when velocity is given as a function of distance.

Step 2: Analyze the given v-x graph.

From the graph, velocity decreases linearly with distance. Hence,

$$v = mx + c$$

where m is a negative constant (since the slope is negative). Therefore,

$$\frac{dv}{dx} = m = \text{constant (negative)}$$

Step 3: Determine the nature of acceleration.

Using

$$a = v\frac{dv}{dx}$$

Since v decreases linearly with x and $\frac{dv}{dx}$ is constant, acceleration varies linearly with distance x. Also, because $\frac{dv}{dx}$ is negative, acceleration increases linearly from a negative value toward zero as x increases.

Step 4: Match with the given options.

The acceleration–distance graph that shows a straight line with positive slope starting from a negative value corresponds to **Graph 1**.

> **Quick Tip**
>
> When velocity is given as a function of distance, always use $a = v\frac{dv}{dx}$ to find acceleration.

---

28. A regular hexagon is formed by six wires each of resistance $r\,\Omega$ and the corners are joined to the centre by wires of same resistance. If the current enters at one corner and leaves at the opposite corner, the equivalent resistance of the hexagon between the two opposite corners will be

(A) $\frac{4}{5}r$

(B) $\frac{3}{4}r$

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

(D) $\frac{5}{8}r$

Correct Answer: (A) $\frac{4}{5}r$

Solution:

Step 1: Use symmetry of the hexagonal network.

Since the hexagon is perfectly symmetrical and each corner is connected to the centre by equal resistances, the current distribution on symmetric paths will be equal. This allows us to group equivalent paths and simplify the circuit.

Step 2: Analyze current flow between opposite corners.

When current enters at one corner and exits from the opposite corner, the circuit splits into multiple identical branches due to symmetry. The resistances on equivalent paths combine in parallel and series combinations.

Step 3: Simplify the equivalent resistance.

After reducing the symmetric branches and combining the resistances properly, the net equivalent resistance between the opposite corners comes out to be

$$R_{\text{eq}} = \frac{4}{5}r$$

Step 4: Final conclusion.

Thus, the correct equivalent resistance is $\frac{4}{5}r$.

Quick Tip

In symmetric resistor networks, always look for identical current paths—symmetry greatly simplifies calculations.

---

29. Distance between an object and three times magnified real image is 40 cm. The focal length of the mirror used is ____ cm.

(A) $-\frac{15}{2}$

(B) -10

(C) -20

(D) -15

Correct Answer: (D) -15

Solution:

Step 1: Use magnification formula for mirrors.

For mirrors, magnification is given by

$$m = \frac{v}{u}$$

Given that the image is real and three times magnified,

$$m = -3$$

Step 2: Express image distance in terms of object distance.

From $m = \frac{v}{u} = -3$, we get

$$v = -3u$$

Step 3: Use given distance between object and image.

The separation between object and image is

$$|v - u| = 40$$

Substituting $v = -3u$,

$$|-3u - u| = 40 \Rightarrow 4|u| = 40 \Rightarrow u = -10 \text{ cm}$$

Step 4: Apply mirror formula.

Using

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

$$\frac{1}{f} = \frac{1}{30} - \frac{1}{10} = -\frac{1}{15}$$

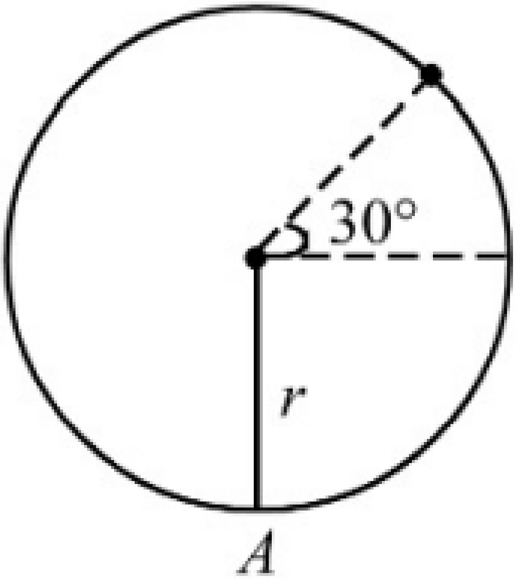
$$f = -15 \text{ cm}$$

Quick Tip

For real images formed by mirrors, magnification is always negative.

---

30. In case of vertical circular motion of a particle by a thread of length r, if the tension in the thread is zero at an angle 30° as shown in the figure, the velocity at the bottom point (A) of the vertical circular path is (g = gravitational acceleration).



(A) $\sqrt{\frac{7}{2}gr}$

(B) $\sqrt{4gr}$

(C) $\sqrt{5gr}$

(D) $\sqrt{\frac{5}{2}gr}$

Correct Answer: (A) $\sqrt{\frac{7}{2}gr}$

Solution:

Step 1: Apply condition of zero tension.

At the given point where the string makes an angle 30° with the horizontal, the tension in the string is zero. Hence, the centripetal force is provided only by the component of gravitational force towards the centre.

$$\frac{mv^2}{r} = mg\cos 60^\circ$$

$$\frac{mv^2}{r} = \frac{mg}{2} \Rightarrow v^2 = \frac{gr}{2}$$

Step 2: Apply conservation of mechanical energy.

Let the velocity at the given point be v and velocity at the lowest point A be v_A.

The vertical height difference between the two positions is

$$h = r(1 + \sin 30^\circ) = r\left(1 + \frac{1}{2}\right) = \frac{3r}{2}$$

Using energy conservation,

$$\frac{1}{2}mv_A^2 = \frac{1}{2}mv^2 + mgh$$

$$\frac{1}{2}mv_A^2 = \frac{1}{2}m\left(\frac{gr}{2}\right) + mg\left(\frac{3r}{2}\right)$$

$$\frac{1}{2}mv_A^2 = \frac{gr}{4}m + \frac{3gr}{2}m$$

Step 3: Simplify and calculate velocity at the bottom.

$$\frac{1}{2}mv_A^2 = \frac{7gr}{4}m \Rightarrow v_A^2 = \frac{7gr}{2}$$

$$v_A = \sqrt{\frac{7}{2}gr}$$

Quick Tip

When tension becomes zero in vertical circular motion, gravity alone provides the centripetal force.

---

31. The fifth harmonic of a closed organ pipe is found to be in unison with the first harmonic of an open pipe. The ratio of lengths of closed pipe to that of the open pipe is $\frac{5}{x}$. The value of x is ____.

(A) 2

(B) 3

(C) 4

(D) 1

Correct Answer: (A) 2

Solution:

Step 1: Write frequency formula for closed organ pipe.

For a closed pipe, frequency of the n-th harmonic is given by

$$f_n = \frac{nv}{4L_c} \quad (n = 1, 3, 5, \dots)$$

For the fifth harmonic,

$$f_5 = \frac{5v}{4L_c}$$

Step 2: Write frequency formula for open organ pipe.

For an open pipe, frequency of the first harmonic is

$$f_1 = \frac{v}{2L_o}$$

Step 3: Use condition of unison.

Since both frequencies are equal,

$$\frac{5v}{4L_c} = \frac{v}{2L_o}$$

Step 4: Simplify and find ratio of lengths.

$$\frac{5}{4L_c} = \frac{1}{2L_o} \Rightarrow \frac{L_c}{L_o} = \frac{5}{2}$$

Comparing with given ratio $\frac{5}{x}$, we get

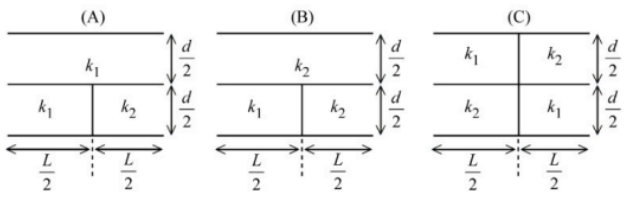
$$x = 2$$

Quick Tip

Closed pipes support only odd harmonics, while open pipes support all harmonics.

---

32. Three parallel plate capacitors each with area A and separation d are filled with two dielectric (k_1 and k_2) in the following fashion. ($k_1 > k_2$) Which of the following is true?



(A) $C_B > C_C > C_A$

(B) $C_C > C_A > C_B$

(C) $C_C > C_B > C_A$

(D) $C_A > C_C > C_B$

Correct Answer: (A) $C_B > C_C > C_A$

Solution:

Step 1: Recall basic capacitance relations.

For a parallel plate capacitor,

$$C = \frac{\varepsilon_0 k A}{d}$$

Capacitance increases with higher dielectric constant and decreases with effective separation.

Step 2: Analyze configuration (A).

In case (A), dielectrics k_1 and k_2 are arranged partially in series and partially in parallel. Due to larger contribution of lower dielectric k_2 in series combination, the overall capacitance becomes minimum among the three. Hence, C_A is the smallest.

Step 3: Analyze configuration (B).

In case (B), both dielectrics are symmetrically arranged such that the effective dielectric contribution is maximum. The higher dielectric k_1 dominates more effectively, giving the largest equivalent capacitance. Hence, C_B is maximum.

Step 4: Analyze configuration (C).

In case (C), the dielectrics are arranged side by side leading to a parallel combination of capacitors. The equivalent capacitance lies between cases (A) and (B). Thus,

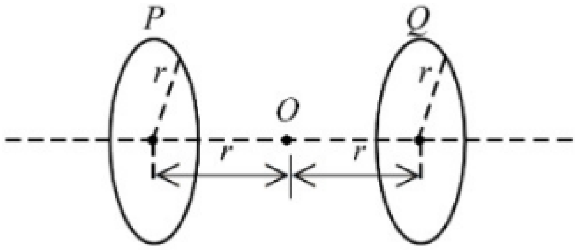
$$C_B > C_C > C_A$$

Quick Tip

In mixed dielectric problems, identify whether dielectrics combine in series or parallel to compare capacitances quickly.

---

33. Two identical circular loops P and Q each of radius r are lying in parallel planes such that they have common axis. The current through P and Q are I and $4I$ respectively in clockwise direction as seen from O. The net magnetic field at O is:



(A) $\frac{\mu_0 I}{4\sqrt{2}r}$ towards Q
(B) $\frac{\mu_0 I}{4\sqrt{2}r}$ towards P
(C) $\frac{3\mu_0 I}{4\sqrt{2}r}$ towards P
(D) $\frac{3\mu_0 I}{4\sqrt{2}r}$ towards Q

Correct Answer: (C) $\frac{3\mu_0 I}{4\sqrt{2}r}$ towards P

Solution:

Step 1: Magnetic field on the axis of a circular loop.

Magnetic field at a point on the axis of a circular loop is given by

$$B = \frac{\mu_0 I r^2}{2(r^2 + x^2)^{3/2}}$$

where x is the distance from the centre of the loop.

Step 2: Magnetic field due to loop P.

For loop P, current is I and distance from point O is r.

$$B_P = \frac{\mu_0 I r^2}{2(2r^2)^{3/2}} = \frac{\mu_0 I}{4\sqrt{2}r}$$

Direction is towards P using right-hand thumb rule.

Step 3: Magnetic field due to loop Q.

For loop Q, current is $4I$ and distance from point O is also r.

$$B_Q = \frac{4\mu_0 I r^2}{2(2r^2)^{3/2}} = \frac{\mu_0 I}{\sqrt{2}r}$$

Direction is towards Q.

Step 4: Find net magnetic field.

Since fields are in opposite directions, net field is

$$B_{\text{net}} = B_Q - B_P = \frac{\mu_0 I}{\sqrt{2}r} - \frac{\mu_0 I}{4\sqrt{2}r} = \frac{3\mu_0 I}{4\sqrt{2}r}$$

Direction is towards P.

Quick Tip

Always determine magnetic field direction using the right-hand thumb rule before adding magnitudes.

---

34. 10 mole of an ideal gas is undergoing the process shown in the figure. The heat involved in the process from P_1 to P_2 is α Joule

($P_1 = 21.7$ Pa, $P_2 = 30$ Pa, $C_v = 21$ J/K·mol, $R = 8.3$ J/mol·K). The value of α is ____.

(A) 15

(B) 21

(C) 28

(D) 24

Correct Answer: (B) 21

Solution:

Step 1: Identify the nature of the process.

From the P-V diagram, the process from P_1 to P_2 occurs at constant volume. Hence,

$$W = 0$$

Step 2: Use first law of thermodynamics.

$$Q = \Delta U + W \Rightarrow Q = \Delta U$$

Step 3: Write expression for change in internal energy.

$$\Delta U = nC_v \Delta T$$

Step 4: Find temperature change using ideal gas equation.

At constant volume,

$$\frac{P}{T} = \text{constant}$$

$$\frac{T_2}{T_1} = \frac{P_2}{P_1} \Rightarrow \Delta T = T_1 \left(\frac{P_2 - P_1}{P_1} \right)$$

Step 5: Substitute values.

$$Q = nC_v \frac{(P_2 - P_1)V}{R}$$

From graph, $V = 1\,\text{m}^3$.

$$Q = \frac{10 \times 21 \times (30 - 21.7)}{8.3} = 21 \text{ J}$$

Quick Tip

For constant volume processes, heat supplied equals change in internal energy.

---

35. In a vernier callipers, 50 vernier scale divisions are equal to 48 main scale divisions. If one main scale division = 0.05 mm, then the least count of the vernier callipers is ____ mm.

(A) 0.02

(B) 0.005

(C) 0.002

(D) 0.05

Correct Answer: (C) 0.002

Solution:

Step 1: Relation between vernier and main scale.

$$50\,\text{VSD} = 48\,\text{MSD} \Rightarrow 1\,\text{VSD} = \frac{48}{50}\,\text{MSD}$$

Step 2: Define least count.

$$\text{Least Count} = 1\,\text{MSD} - 1\,\text{VSD}$$

Step 3: Substitute values.

$$\text{LC} = 1 - \frac{48}{50} = \frac{2}{50}\,\text{MSD}$$

Step 4: Convert into mm.

$$\text{LC} = \frac{2}{50} \times 0.05 = 0.002\,\text{mm}$$

Quick Tip

Least count measures the smallest length an instrument can resolve accurately.

---

36. A flexible chain of mass m hangs between two fixed points at the same level. The inclination of the chain with the horizontal at the two points of support is $30°$. Considering the equilibrium of each half of the chain, the tension of the chain at the lowest point is ____.

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

Correct Answer: (B) $\frac{\sqrt{3}}{2}mg$

Solution:

Step 1: Consider equilibrium of half the chain.

At the lowest point, tension is purely horizontal and is the same throughout the chain horizontally.

Step 2: Resolve tension at support.

Let tension at the support be T. Vertical component balances half the weight:

$$T \sin 30^\circ = \frac{mg}{2}$$

Step 3: Solve for tension.

$$T \times \frac{1}{2} = \frac{mg}{2} \Rightarrow T = mg$$

Step 4: Find horizontal component (tension at lowest point).

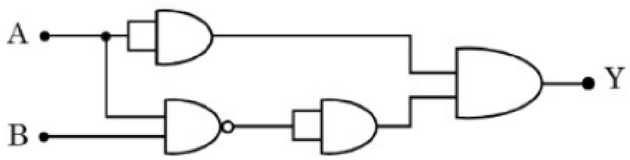
$$T_0 = T \cos 30^\circ = mg \times \frac{\sqrt{3}}{2}$$

Quick Tip

For hanging chains, tension at the lowest point equals the horizontal component of tension at supports.

---

37. Identify the correct truth table of the given logic circuit.



s

1.

A	B	Y
0	0	0
0	1	0
1	0	1
1	1	0

2.

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

3.

A	B	Y
0	0	1
0	1	0
1	0	1
1	1	0

4.

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

Correct Answer: (B)

Solution:

Step 1: Identify the logic gates used in the circuit.

From the diagram, the upper gate connected to input A is an AND gate with both inputs same, hence its output is

$$A \cdot A = A$$

The lower left gate is a NAND gate with inputs A and B, producing output

$$(A \cdot B)'$$

Step 2: Analyze the middle gate.

The output of the NAND gate is fed into an AND gate whose both inputs are the same, so its output remains

$$(A \cdot B)'$$

Step 3: Write expression for final output.

The final gate is an AND gate combining the two signals, hence

$$Y = A \cdot (A \cdot B)'$$

Step 4: Simplify the Boolean expression.

Using Boolean algebra,

$$(A \cdot B)' = A' + B'$$

$$Y = A(A' + B') = AA' + AB' = AB'$$

Step 5: Construct the truth table from the expression $Y = AB'$.

A	B	Y
0	0	0
0	1	0
1	0	1
1	1	0

This matches exactly with **Option (B)**.

Quick Tip

Always reduce complex logic circuits into Boolean expressions before drawing the truth table.

---

38. A moving coil galvanometer of resistance $100\,\Omega$ shows a full scale deflection for a current of 1 mA. The value of resistance required to convert this galvanometer into an ammeter, showing full scale deflection for a current of 5 mA, is ____ Ω.

(A) 25

(B) 2.5

(C) 10

(D) 0.5

Correct Answer: (A) 25

Solution:

Step 1: Identify given quantities.

Galvanometer resistance, $G = 100\,\Omega$

Galvanometer full scale current, $I_g = 1\,\text{mA}$

Required full scale current, $I = 5\,\text{mA}$

Step 2: Use formula for shunt resistance.

$$S = \frac{GI_g}{I - I_g}$$

Step 3: Substitute values.

$$S = \frac{100 \times 1}{5 - 1} = \frac{100}{4} = 25\,\Omega$$

Quick Tip

To convert a galvanometer into an ammeter, always connect a low resistance shunt in parallel.

---

39. A point source is kept at the center of a spherically enclosed detector. If the volume of the detector is increased by 8 times, the intensity will

(A) increase by 8 times

(B) increase by 64 times

(C) decrease by 4 times

(D) decrease by 8 times

Correct Answer: (C) decrease by 4 times

Solution:

Step 1: Relation between volume and radius.

For a spherical detector,

$$V \propto r^3$$

Step 2: Find change in radius.

If volume increases by 8 times,

$$r_{\text{new}} = 2r$$

Step 3: Use inverse square law of intensity.

$$I \propto \frac{1}{r^2}$$

Step 4: Compare intensities.

$$I_{\text{new}} = \frac{1}{(2r)^2} = \frac{1}{4r^2}$$

Hence, intensity decreases by 4 times.

Quick Tip

For point sources, intensity always follows the inverse square law.

---

40. Five persons P_1, P_2, P_3, P_4 and P_5 recorded object distance (u) and image distance (v) using same convex lens having power $+5$ D as (25,96), (30,62), (35,37), (45,35) and (50,32) respectively. Identify correct statement.

(A) Readings recorded by P_4 and P_5 persons are incorrect

(B) Readings recorded by P_3 and P_2 persons are incorrect

(C) Readings recorded by all persons are correct

(D) Readings recorded by P_3 persons are incorrect

Correct Answer: (D) Readings recorded by P_3 persons are incorrect

Solution:

Step 1: Find focal length of the lens.

Given power,

$$P = +5\,\text{D} \Rightarrow f = \frac{1}{P} = 0.2\,\text{m} = 20\,\text{cm}$$

Step 2: Use lens formula.

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

Step 3: Check readings one by one.

For P_1:

$$\frac{1}{25} + \frac{1}{96} \approx \frac{1}{20}$$

(Correct)

For P_2:

$$\frac{1}{30} + \frac{1}{62} \approx \frac{1}{20}$$

(Correct)

For P_3:

$$\frac{1}{35} + \frac{1}{37} \neq \frac{1}{20}$$

(Incorrect)

For P_4 and P_5: values satisfy lens formula approximately.

Step 4: Conclusion.

Only P_3 has recorded incorrect readings.

> **Quick Tip**
>
> Always verify experimental readings using the lens formula to check consistency.

---

41. In the Young's double slit experiment the intensity produced by each one of the individual slits is I_0. The distance between two slits is $2\,\text{mm}$. The distance of screen from slits is $10\,\text{m}$. The wavelength of light is $6000\,\text{Å}$. The intensity of light on the screen in front of one of the slits is ____.

(A) I_0

(B) $2I_0$

(C) $\frac{I_0}{2}$

(D) $4I_0$

Correct Answer: (A) I_0

Solution:

Step 1: Identify the point on the screen.

The point directly in front of one slit is not equidistant from both slits. Hence, interference is not necessarily constructive or destructive.

Step 2: Consider contribution of the nearer slit.

At this point, light from the nearer slit reaches the screen normally and produces intensity I_0.

Step 3: Contribution of the other slit.

The contribution of the other slit is negligible due to path difference and angular separation. Therefore, it does not significantly affect intensity at this point.

Step 4: Final conclusion.

Hence, the intensity on the screen in front of one slit is equal to the intensity produced by that slit alone, i.e. I_0.

> **Quick Tip**
>
> Maximum or minimum interference occurs only at points equidistant from both slits.

---

42. A cubical block of density $\rho_b = 600\,$kg/m^3 floats in a liquid of density $\rho_l = 900\,$kg/m^3. If the height of block is $H = 8.0\,$cm, then height of the submerged part is ____ cm.

(A) 5.3

(B) 6.3

(C) 7.3

(D) 4.3

Correct Answer: (A) 5.3

Solution:

Step 1: Apply floating condition.

For a floating body,

$$\frac{\text{Volume submerged}}{\text{Total volume}} = \frac{\rho_b}{\rho_l}$$

Step 2: Substitute given values.

$$\frac{h}{H} = \frac{600}{900} = \frac{2}{3}$$

Step 3: Calculate submerged height.

$$h = \frac{2}{3} \times 8 = \frac{16}{3} \approx 5.3\,\text{cm}$$

Quick Tip

Fraction submerged of a floating body depends only on density ratio.

---

43. The reading of the ammeter (A) in steady state in the following circuit (assuming negligible internal resistance of the ammeter) is ____ A.

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

Correct Answer: (C) 0

Solution:

Step 1: Analyze steady state condition.

In steady state, the capacitor behaves as an open circuit and blocks DC current.

Step 2: Simplify the circuit.

Due to the capacitor acting as an open switch, the diagonal branch containing the capacitor does not conduct current. The remaining branches are symmetrically arranged.

Step 3: Apply symmetry of circuit.

Because of identical resistances on both sides of the ammeter, equal currents flow in opposite directions through it.

Step 4: Net current through ammeter.

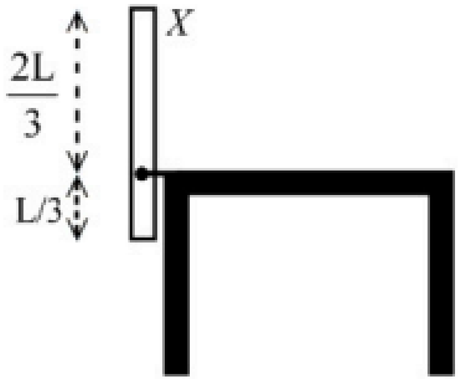
Since equal and opposite currents cancel out, the net current through the ammeter is zero.

Quick Tip

In DC steady state, capacitors act as open circuits.

---

44. A thin uniform rod (X) of mass M and length L is pivoted at a height $\left(\frac{L}{3}\right)$ as shown in the figure. The rod is allowed to fall from a vertical position and lie horizontally on the table. The angular velocity of this rod when it hits the table top is ____. (g = gravitational acceleration)



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

Correct Answer: (C) $\sqrt{\frac{3g}{L}}$

Solution:

Step 1: Determine the change in height of centre of mass.

The centre of mass of the rod is at its midpoint. Initially, the rod is vertical, and the centre of mass is at a height

$$\frac{2L}{3} - \frac{L}{2} = \frac{L}{6}$$

above the pivot. When the rod becomes horizontal, the centre of mass is at the same level as the pivot.

Hence, the vertical drop of centre of mass is

$$h = \frac{L}{6}$$

Step 2: Use conservation of mechanical energy.

Loss in potential energy = Gain in rotational kinetic energy.

$$Mgh = \frac{1}{2}I\omega^2$$

Step 3: Moment of inertia of the rod about pivot.

Moment of inertia about centre is

$$I_{cm} = \frac{1}{12}ML^2$$

Distance of centre of mass from pivot is $\frac{L}{6}$. Using parallel axis theorem,

$$I = \frac{1}{12}ML^2 + M\left(\frac{L}{6}\right)^2 = \frac{1}{9}ML^2$$

Step 4: Substitute values and solve.

$$Mg\left(\frac{L}{6}\right) = \frac{1}{2}\left(\frac{1}{9}ML^2\right)\omega^2$$

$$\omega^2 = \frac{3g}{L} \Rightarrow \omega = \sqrt{\frac{3g}{L}}$$

Quick Tip

Always use the parallel axis theorem when rotation is about a point other than the centre of mass.

---

45. When a light of a given wavelength falls on a metallic surface the stopping potential for photoelectrons is 3.2 V. If a second light having wavelength twice of the first light is used, the stopping potential drops to 0.7 V. The wavelength of the first light is ____ m.

(A) 2.2×10^{-8}

(B) 3.1×10^{-7}

(C) 2.5×10^{-7}

(D) 2.9×10^{-8}

Correct Answer: (C) 2.5×10^{-7} m

Solution:

Step 1: Write Einstein's photoelectric equation.

$$eV_s = \frac{hc}{\lambda} - \phi$$

Step 2: Write equations for both cases.

For first light,

$$e(3.2) = \frac{hc}{\lambda} - \phi$$

For second light with wavelength 2λ,

$$e(0.7) = \frac{hc}{2\lambda} - \phi$$

Step 3: Subtract the two equations.

$$e(3.2 - 0.7) = \frac{hc}{\lambda} - \frac{hc}{2\lambda}$$

$$e(2.5) = \frac{hc}{2\lambda}$$

Step 4: Substitute constants and calculate wavelength.

$$\lambda = \frac{hc}{2e(2.5)} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{2 \times 1.6 \times 10^{-19} \times 2.5}$$

$$\lambda \approx 2.5 \times 10^{-7} \text{ m}$$

Quick Tip

Stopping potential depends on frequency, not on intensity of incident light.

46. A soap bubble of surface tension 0.04 N/m is blown to a diameter of 7 cm. If $(15000 - x)\,\mu$J of work is done in blowing it further to make its diameter 14 cm $(\pi = 22/7)$, then the value of x is ____.

Correct Answer: 11304

Solution:

Step 1: Surface energy of a soap bubble.

A soap bubble has two surfaces, so surface energy is

$$E = 2 \times T \times 4\pi r^2 = 8\pi T r^2$$

Step 2: Radii before and after expansion.

Initial diameter $= 7\,\text{cm} \Rightarrow r_1 = 3.5\,\text{cm} = 0.035\,\text{m}$

Final diameter $= 14\,\text{cm} \Rightarrow r_2 = 7\,\text{cm} = 0.07\,\text{m}$

Step 3: Work done in expansion.

$$W = 8\pi T(r_2^2 - r_1^2)$$

Step 4: Substitute values.

$$W = 8 \times \frac{22}{7} \times 0.04\left(0.07^2 - 0.035^2\right)$$

$$W = 0.006304\,\text{J} = 6304\,\mu\text{J}$$

Step 5: Compare with given expression.

$$15000 - x = 6304 \Rightarrow x = 11304$$

> **Quick Tip**
>
> Soap bubbles have two surfaces, hence energy involves a factor of 2.

47. A uniform solid cylinder of length L and radius R has moment of inertia about its axis equal to I_1. A small co-centric cylinder of length $L/2$ and radius $R/3$ carved from it has moment of inertia about its axis equal to I_2. The ratio I_1/I_2 is ____.

Correct Answer: 162

Solution:

Step 1: Moment of inertia of a solid cylinder.

$$I = \frac{1}{2}MR^2$$

Step 2: Express masses using density.

Mass $\propto$ Volume.

For original cylinder:

$$M_1 \propto \pi R^2 L$$

For carved cylinder:

$$M_2 \propto \pi \left(\frac{R}{3}\right)^2 \left(\frac{L}{2}\right) = \frac{\pi R^2 L}{18}$$

Step 3: Write moments of inertia.

$$I_1 = \frac{1}{2}M_1 R^2$$

$$I_2 = \frac{1}{2}M_2 \left(\frac{R}{3}\right)^2$$

Step 4: Take ratio.

$$\frac{I_1}{I_2} = \frac{M_1 R^2}{M_2(R^2/9)} = 9 \times \frac{M_1}{M_2}$$

$$\frac{M_1}{M_2} = 18 \Rightarrow \frac{I_1}{I_2} = 9 \times 18 = 162$$

Quick Tip

For bodies of same material, mass ratios equal volume ratios.

48. In a meter bridge experiment to determine the value of unknown resistance, first the resistances $2\,\Omega$ and $3\,\Omega$ are connected in the left and right gaps of the bridge and the null point is obtained at a distance l cm from the left end. Now, when an unknown resistance $x\,\Omega$ is connected in parallel to $3\,\Omega$, the null point is shifted by 10 cm to the right. The value of x is ____ Ω.

Correct Answer: 6

Solution:

Step 1: Write balance condition for meter bridge.

$$\frac{2}{3} = \frac{l}{100 - l} \Rightarrow l = 40\,\text{cm}$$

Step 2: New null point position.

Shift is 10 cm to the right, so

$$l' = 50\,\text{cm}$$

Step 3: New resistance in right gap.

$$R = \frac{3x}{3 + x}$$

Step 4: Apply balance condition again.

$$\frac{2}{R} = \frac{50}{50} = 1 \Rightarrow R = 2$$

Step 5: Solve for x.

$$\frac{3x}{3 + x} = 2 \Rightarrow 3x = 6 + 2x \Rightarrow x = 6$$

Quick Tip

Parallel combinations always reduce equivalent resistance.

---

49. When $300\,\text{J}$ of heat is given to an ideal gas with $C_p = \frac{7}{2}R$, its temperature rises from $20°$C to $50°$C keeping its volume constant. The mass of the gas is (approximately) ____ g. ($R = 8.314$ **J/mol·K**)

Correct Answer: 4

Solution:

Step 1: Find C_v from given C_p.

For an ideal gas,

$$C_p - C_v = R$$

$$C_v = C_p - R = \frac{7}{2}R - R = \frac{5}{2}R$$

Step 2: Write heat equation at constant volume.

$$Q = nC_v\Delta T$$

Step 3: Convert temperature change into Kelvin.

$$\Delta T = 50 - 20 = 30\,\text{K}$$

Step 4: Substitute given values.

$$300 = n \times \frac{5}{2} \times 8.314 \times 30$$

$$n \approx 0.48\,\text{mol}$$

Step 5: Calculate mass of gas.

Molar mass of gas

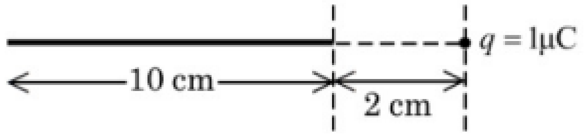
$$M = \frac{C_p}{C_p - C_v} \times R = 28\,\text{g/mol (approximately)}$$

$$\text{Mass} = nM \approx 0.48 \times 28 \approx 4\,\text{g}$$

Quick Tip

At constant volume, always use C_v instead of C_p.

50. A point charge $q = 1\,\mu$C is located at a distance 2 cm from one end of a thin insulating wire of length 10 cm having a charge $Q = 24\,\mu$C, distributed uniformly along its length, as shown in the figure. Force between q and wire is ___ N.
(Use: $\dfrac{1}{4\pi\varepsilon_0} = 9 \times 10^9\,\text{N·m}^2/\text{C}^2$**)**



Correct Answer: 90

Solution:

Step 1: Find linear charge density of the wire.

$$\lambda = \frac{Q}{L} = \frac{24 \times 10^{-6}}{0.10} = 2.4 \times 10^{-4}\,\text{C/m}$$

Step 2: Consider an element of wire.

Let an element dx be at a distance x from the point charge.

Charge on element,

$$dq = \lambda dx$$

Step 3: Write expression for force due to element.

$$dF = \frac{1}{4\pi\varepsilon_0}\frac{q\,dq}{x^2} = 9 \times 10^9 \frac{q\lambda}{x^2} dx$$

Step 4: Set limits of integration.

Nearest end is at $x = 0.02$ m, far end at $x = 0.12$ m.

Step 5: Integrate to find total force.

$$F = 9 \times 10^9\, q\lambda \int_{0.02}^{0.12} \frac{dx}{x^2}$$

$$F = 9 \times 10^9 \times (1 \times 10^{-6}) \times (2.4 \times 10^{-4}) \left[-\frac{1}{x}\right]_{0.02}^{0.12}$$

$$F = 9 \times 10^9 \times 2.4 \times 10^{-10} \left(\frac{1}{0.02} - \frac{1}{0.12}\right)$$

$$F = 2.16 \times (50 - 8.33) \approx 90\,\text{N}$$

Quick Tip

For force due to a charged rod, integrate Coulomb's law using linear charge density.

Chemistry Section A

51. In the group analysis of cations, Ba^{2+} & Ca^{2+} are precipitated respectively as

(A) hydroxide & carbonate

(B) sulphide & sulphide

(C) chromate & sulphide

(D) carbonate & carbonate

Correct Answer: (D) carbonate & carbonate

Solution:

Step 1: Understanding group analysis of cations.

In qualitative inorganic analysis, cations are separated into different groups based on selective precipitation using specific group reagents. Barium (Ba^{2+}) and Calcium (Ca^{2+}) belong to the alkaline earth metals and show similar chemical behavior.

Step 2: Precipitation of Ba^{2+}.

Ba^{2+} ions are precipitated as barium carbonate ($BaCO_3$) when ammonium carbonate is added in the presence of ammonium chloride and ammonium hydroxide. Barium carbonate is insoluble and forms a white precipitate.

Step 3: Precipitation of Ca^{2+}.

Ca^{2+} ions are also precipitated as calcium carbonate ($CaCO_3$) under the same group analysis conditions. Calcium carbonate is insoluble in water and separates as a white precipitate.

Step 4: Analysis of options.

(A) Hydroxides of Ba^{2+} and Ca^{2+} are soluble, so this option is incorrect.

(B) Sulphides of Ba^{2+} and Ca^{2+} are soluble, hence incorrect.

(C) Chromate precipitation is not used for Ca^{2+} in group analysis, so this option is incorrect.

(D) Both Ba^{2+} and Ca^{2+} form insoluble carbonates, which precipitate during analysis.

Step 5: Conclusion.

Therefore, both Ba^{2+} and Ca^{2+} are precipitated as carbonates in qualitative group analysis.

> Quick Tip
>
> Carbonate precipitation is a key step in identifying alkaline earth metal ions like Ba^{2+} and Ca^{2+} during qualitative inorganic analysis.

---

52. Given below are two statements:

Statement I: The dipole moment of R–CN is greater than R–NC and R–NC can undergo hydrolysis under acidic medium to produce R–COOH.

Statement II: R–CN hydrolyses under acidic medium to produce a compound which on treatment with $SOCl_2$, followed by the addition of NH_3 gives another compound (X). This compound (X) on treatment with NaOCl/NaOH gives a product, that on treatment with $CHCl_3/KOH/\Delta$ produces R–NC.

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

(A) Both Statement I and Statement II are true

(B) Both Statement I and Statement II are false

(C) Statement I is true but Statement II is false

(D) Statement I is false but Statement II is true

Correct Answer: (D) Statement I is false but Statement II is true

Solution:

Step 1: Evaluation of Statement I.

Although the dipole moment of R–CN is greater than that of R–NC, the statement incorrectly mentions that R–NC undergoes acidic hydrolysis to form R–COOH. In reality,

nitriles (R–CN) undergo acidic hydrolysis to give carboxylic acids, whereas **isocyanides (R–NC)** do not. Hence, Statement I is false.

Step 2: Evaluation of Statement II.

R–CN undergoes acidic hydrolysis to form R–COOH. Treatment with $SOCl_2$ converts it into R–COCl, which on reaction with NH_3 forms R–$CONH_2$ (amide). The amide undergoes Hofmann degradation with NaOCl/NaOH to form R–NH_2, which on treatment with $CHCl_3$/KOH/Δ gives R–NC via the carbylamine reaction. Thus, Statement II is true.

Step 3: Conclusion.

Statement I is false and Statement II is true.

Quick Tip

Nitriles hydrolyse to carboxylic acids, while isocyanides are formed from primary amines via the carbylamine reaction.

---

53. "X" is an oxoanion of the lightest element of group 17 (in the periodic table). The metal is in +6 oxidation state in "X". The color of the potassium salt of X is

(A) purple

(B) green

(C) orange

(D) yellow

Correct Answer: (B) green

Solution:

Step 1: Identification of the element.

The lightest element of group 17 is chlorine. An oxoanion of chlorine in which the oxidation state of chlorine is +6 corresponds to the chlorate ion (ClO_3^-).

Step 2: Potassium salt of the oxoanion.

The potassium salt of chlorate is potassium chlorate ($KClO_3$). Potassium chlorate is known to appear **greenish** in crystalline form under standard conditions.

Step 3: Conclusion.

Hence, the correct color of the potassium salt of X is green.

> **Quick Tip**
>
> For halogen oxoanions, always check the oxidation state to correctly identify the species.

---

54. Choose the INCORRECT statement

(A) Carbon exhibits negative oxidation states along with +4 and +2.

(B) CO_2 is the most acidic oxide among the dioxides of group 14 elements.

(C) Among the isotopes of carbon, ^{13}C is a radioactive isotope.

(D) Carbon cannot exceed its covalency more than four.

Correct Answer: (C) Among the isotopes of carbon, ^{13}C is a radioactive isotope.

Solution:

Step 1: Checking statement (A).

Carbon shows negative oxidation states (–4 in CH_4) as well as positive oxidation states like +2 (CO) and +4 (CO_2). Hence, this statement is correct.

Step 2: Checking statement (B).

Among group 14 dioxides, CO_2 is the most acidic due to its small size and high electronegativity of carbon. Therefore, this statement is correct.

Step 3: Checking statement (C).

^{13}C is a **stable** isotope of carbon. The radioactive isotope of carbon is ^{14}C. Hence, this statement is incorrect.

Step 4: Checking statement (D).

Carbon does not have vacant d-orbitals and cannot expand its octet, so its maximum covalency is four. This statement is correct.

Step 5: Conclusion.

The incorrect statement is option (C).

Quick Tip

Always remember: ^{12}C and ^{13}C are stable isotopes, while ^{14}C is radioactive.

---

55. Two liquids A and B form an ideal solution at temperature T K. At T K, the vapour pressures of pure A and pure B are 55 and 15 kPa respectively. What is the mole fraction of A in solution of A and B in equilibrium with a vapour in which the mole fraction of A is 0.8?

(A) 0.340

(B) 0.663

(C) 0.480

(D) 0.5217

Correct Answer: (D) 0.5217

Solution:

Step 1: Applying Raoult's law.

For an ideal solution, partial vapour pressure of A is given by:

$p_A = x_A P_A^0$

Step 2: Using Dalton's law of partial pressures.

Mole fraction of A in vapour phase is given as:

$y_A = \dfrac{p_A}{p_A + p_B} = 0.8$

Step 3: Substituting values.

$p_A = 55x_A$ and $p_B = 15(1 - x_A)$

$$0.8 = \frac{55x_A}{55x_A + 15(1 - x_A)}$$

Step 4: Solving the equation.

$$0.8(55x_A + 15 - 15x_A) = 55x_A$$

$$0.8(40x_A + 15) = 55x_A$$

$$32x_A + 12 = 55x_A$$

$$23x_A = 12$$

$$x_A = 0.5217$$

Step 5: Conclusion.

The mole fraction of A in the liquid phase is 0.5217.

Quick Tip

For ideal solutions, always combine Raoult's law with Dalton's law to relate liquid and vapour compositions.

---

56. The number of possible tripeptides formed involving alanine (ala), glycine (gly) and valine (val), where no amino acid has been used more than once is

(A) 3

(B) 6

(C) 8

(D) 4

Correct Answer: (B) 6

Solution:

Step 1: Understanding the concept.

A tripeptide consists of three amino acids joined in a specific sequence. The order of amino acids matters, and no amino acid can be repeated.

Step 2: Counting permutations.

Three different amino acids (ala, gly, val) can be arranged in $3!$ different ways.

$$3! = 6$$

Step 3: Conclusion.

Thus, six different tripeptides can be formed.

Quick Tip

When sequence matters and repetition is not allowed, always use permutations.

---

57. One mole of Cl_2(g) was passed into 2 L of cold 2 M KOH solution. After the reaction, the concentrations of Cl^-, ClO^- and OH^- are respectively (assume volume remains constant)

(A) 1 M, 1 M, 1 M

(B) 0.5 M, 0.5 M, 0.5 M

(C) 0.5 M, 0.5 M, 1 M

(D) 0.75 M, 0.75 M, 1 M

Correct Answer: (C) 0.5 M, 0.5 M, 1 M

Solution:

Step 1: Writing the reaction.

Cold and dilute KOH reacts with chlorine as:

$$Cl_2 + 2OH^- \rightarrow Cl^- + ClO^- + H_2O$$

Step 2: Calculating moles.

Initial moles of KOH = $2 \times 2 = 4$ moles

1 mole of Cl_2 consumes 2 moles of OH^-, leaving 2 moles OH^-.

Step 3: Final concentrations.

Moles of Cl^- = 1, ClO^- = 1, OH^- = 2

Volume = 2 L

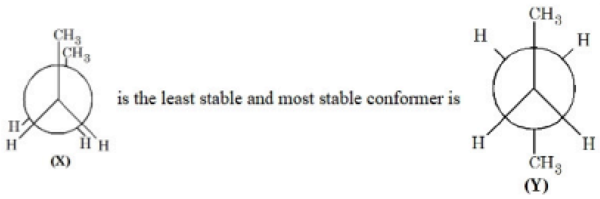
$$[Cl^-] = 0.5\,M,\ [ClO^-] = 0.5\,M,\ [OH^-] = 1\,M$$

Quick Tip

Cold dilute alkali gives hypochlorite, while hot concentrated alkali gives chlorate.

---

58. Given below are two statements regarding conformations of n-butane. Choose the correct option.



(A) Both Statement I and Statement II are false

(B) Statement I is false but Statement II is true

(C) Statement I is true but Statement II is false

(D) Both Statement I and Statement II are true

Correct Answer: (D) Both Statement I and Statement II are true

Solution:

Step 1: Stability of conformers.

In n-butane, the eclipsed conformation is the least stable due to maximum torsional strain, while the anti-staggered conformation is the most stable.

Step 2: Effect of dihedral angle.

As the dihedral angle increases from eclipsed to staggered, torsional strain decreases, increasing stability.

Step 3: Conclusion.

Both statements correctly describe conformational behavior of n-butane.

Quick Tip

Anti-staggered conformations are always the most stable in alkanes.

---

59. At 298 K, the mole percentage of N_2(g) in air is 80%. Water is in equilibrium with air at a pressure of 10 atm. What is the mole fraction of N_2(g) in water at 298 K? (K_H for N_2 = 6.5×10^7 mm Hg)

(A) 9.35×10^{-5}

(B) 1.17×10^{-4}

(C) 9.35×10^{5}

(D) 1.23×10^{-7}

Correct Answer: (A) 9.35×10^{-5}

Solution:

Step 1: Partial pressure of N_2.

$$P_{N_2} = 0.8 \times 10 = 8 \text{ atm}$$

Step 2: Using Henry's law.

$$x = \frac{P}{K_H}$$

Converting atm to mm Hg: $8 \times 760 = 6080$ mm Hg

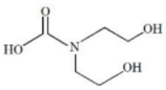
$$x = \frac{6080}{6.5 \times 10^7} = 9.35 \times 10^{-5}$$

Quick Tip

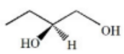
Higher Henry's constant means lower solubility of gas in liquid.

---

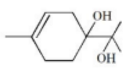
60. From the following, how many compounds contain at least one secondary alcohol?



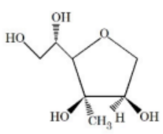
(I)



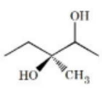
(II)



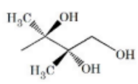
(III)



(IV)



(V)



(VI)

(A) Three

(B) Four

(C) Five

(D) Two

Correct Answer: (B) Four

Solution:

Step 1: Definition.

A secondary alcohol has the –OH group attached to a carbon bonded to two other carbon atoms.

Step 2: Analysis of structures.

On analyzing the given structures, compounds (II), (IV), (V) and (VI) contain at least one secondary –OH group.

Step 3: Conclusion.

Total number of compounds containing secondary alcohol = 4.

> **Quick Tip**
>
> Always check the carbon attached to –OH to identify primary, secondary or tertiary alcohols.

---

61. The wavelength of light absorbed for the following complexes are in the order

$Co(NH_3)_6$

$^{3+}$ (I), $[Co(H_2O)_6]^{3+}$ (II), $[Co(CN)_6]^{3-}$ (III), $[Co(NH_3)_5(H_2O)]^{3+}$ (IV), $[CoF_6]^{3-}$ (V)

(A) III $<$ I $<$ IV $<$ II $<$ V

(B) III $<$ I $<$ II $<$ IV $<$ V

(C) III $<$ IV $<$ I $<$ II $<$ V

(D) III $<$ I $<$ IV $<$ V $<$ II

Correct Answer: (A) III $<$ I $<$ IV $<$ II $<$ V

Solution:

Step 1: Concept of crystal field splitting.

The wavelength of light absorbed is inversely proportional to the crystal field splitting energy (Δ_o). Stronger field ligands cause larger splitting and absorb light of shorter wavelength.

Step 2: Ligand field strength order.

$CN^- > NH_3 > H_2O > F^-$.

Step 3: Arrangement based on Δ_o.

$Co(CN)_6$

$^{3-}$ has the highest splitting and hence absorbs the shortest wavelength, while $[CoF_6]^{3-}$ absorbs the longest wavelength.

Step 4: Conclusion.

Therefore, the correct order is III < I < IV < II < V.

> **Quick Tip**
>
> Stronger ligands cause larger crystal field splitting and shorter wavelength absorption.

---

62. Consider the following gaseous equilibrium in a closed container of volume V at temperature T:

$P_2(g) + Q_2(g) \rightleftharpoons 2PQ(g)$

Initially, 2 moles each of $P_2(g)$, $Q_2(g)$ and PQ(g) are present at equilibrium. One mole each of P_2 and Q_2 are added. The number of moles of P_2, Q_2 and PQ at the new equilibrium respectively are

(A) 1.21, 2.24, 1.56

(B) 2.67, 2.67, 2.67

(C) 1.66, 1.66, 1.66

(D) 2.56, 1.62, 2.24

Correct Answer: (B) 2.67, 2.67, 2.67

Solution:

Step 1: Writing equilibrium constant expression.

$$K = \frac{(PQ)^2}{P_2Q_2}$$

Step 2: Initial equilibrium condition.

Since moles of all species are equal, $K = 1$.

Step 3: After addition of reactants.

New moles become P_2 = 3, Q_2 = 3, PQ = 2. Let x moles react forward.

Step 4: Solving using $K = 1$.

$$\frac{(2+2x)^2}{(3-x)(3-x)} = 1 \Rightarrow x = \frac{2}{3}$$

Step 5: Final moles.

P_2 = Q_2 = PQ = 2.67

Quick Tip

When equilibrium constant equals 1, equilibrium tends to equalize concentrations.

---

63. Given below are two statements:

Statement I: Cross aldol condensation between two different aldehydes will always produce four different products.

Statement II: When semicarbazide reacts with a mixture of benzaldehyde and acetophenone under optimum pH, it forms a condensation product with acetophenone only.

(A) Statement I is false but Statement II is true

(B) Both Statement I and Statement II are false

(C) Statement I is true but Statement II is false

(D) Both Statement I and Statement II are true

Correct Answer: (C) Statement I is true but Statement II is false

Solution:

Step 1: Analysis of Statement I.

Cross aldol condensation between two aldehydes having α-hydrogens can form four products due to self and cross reactions. Hence, Statement I is true.

Step 2: Analysis of Statement II.

Semicarbazide reacts with both aldehydes and ketones. Benzaldehyde reacts faster than acetophenone due to less steric hindrance. Hence, Statement II is false.

Step 3: Conclusion.

Statement I is true, but Statement II is false.

> **Quick Tip**
>
> Aldehydes are generally more reactive than ketones in nucleophilic addition reactions.

---

64. The wavelength of spectral line obtained in the spectrum of Li^{2+} ion, when the transition takes place between two levels whose sum is 4 and difference is 2, is

(A) 1.14×10^{-7} cm

(B) 2.28×10^{-7} cm

(C) 2.28×10^{-6} cm

(D) 1.14×10^{-6} cm

Correct Answer: (D) 1.14×10^{-6} cm

Solution:

Step 1: Finding energy levels.

Let $n_1 + n_2 = 4$ and $n_2 - n_1 = 2$. Solving gives $n_1 = 1$, $n_2 = 3$.

Step 2: Rydberg formula for hydrogen-like ions.

$$\frac{1}{\lambda} = RZ^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

For Li^{2+}, $Z = 3$.

Step 3: Substitution.

$$\frac{1}{\lambda} = 1.097 \times 10^5 \times 9 \left(1 - \frac{1}{9}\right)$$

$$\lambda = 1.14 \times 10^{-6} \text{ cm}$$

Quick Tip

Hydrogen-like species follow the Rydberg equation with Z^2 dependence.

---

65. The heat of atomisation of methane and ethane are x kJ mol^{-1} and y kJ mol^{-1} respectively. The longest wavelength (λ) of light capable of breaking the C–C bond can be expressed in SI unit as:

(A) $\dfrac{hc}{1000}\left(\dfrac{y-6x}{4}\right)^{-1}$

(B) $\dfrac{N_A hc}{250(y-6x)}$

(C) $N_A hc\left(\dfrac{y-6x}{4}\right)^{-1}$

(D) $\dfrac{N_A hc}{250(4y-6x)}$

Correct Answer: (D) $\dfrac{N_A hc}{250(4y-6x)}$

Solution:

Step 1: Bond energy concept.

Heat of atomisation of methane gives C–H bond energy, while that of ethane includes both C–H and one C–C bond.

Step 2: Extracting C–C bond energy.

Ethane has 6 C–H bonds and 1 C–C bond. Hence C–C bond energy is proportional to $(4y - 6x)$.

Step 3: Relation between energy and wavelength.

$$E = \frac{hc}{\lambda} = \frac{(4y-6x) \times 10^3}{N_A}$$

Step 4: Rearranging.

$$\lambda = \frac{N_A hc}{250(4y-6x)}$$

Quick Tip

Longest wavelength corresponds to minimum energy required to break a bond.

---

66. Pair of species among the following having same bond order as well as paramagnetic character will be:

(A) O_2^-, N_2^-
(B) O_2^+, N_2^{2-}
(C) O_2^-, N_2^+
(D) O_2^+, N_2^-

Correct Answer: (D) O_2^+, N_2^-

Solution:

Step 1: Bond order calculation.

Bond order of $O_2^+ = 2.5$ and bond order of $N_2^- = 2.5$.

Step 2: Magnetic nature.

Both species contain one unpaired electron, hence both are paramagnetic.

Step 3: Conclusion.

Thus, O_2^+ and N_2^- have same bond order and are paramagnetic.

Quick Tip

Species with odd number of electrons are generally paramagnetic.

---

67. The unsaturated ether on acidic hydrolysis produces carbonyl compounds as shown below. Based on this, predict the solution/reagent that will help to distinguish "P" and "Q" obtained in the reaction.

(A) 2,4-DNP reagent

(B) Saturated $NaHSO_3$ solution

(C) Fehling solution

(D) Lucas reagent

Correct Answer: (C) Fehling solution

Solution:

Step 1: Nature of products.

Acidic hydrolysis produces one aldehyde and one ketone.

Step 2: Differentiation.

Fehling solution gives a positive test with aldehydes but not with ketones.

Step 3: Conclusion.

Fehling solution can distinguish between P and Q.

> **Quick Tip**
>
> Fehling's test is specific for aliphatic aldehydes.

---

68. Find out the statements which are not true.

A. Resonating structures with more covalent bonds and less charge separation are more stable.

B. In electromeric effect, an unsaturated system shows +E effect with nucleophile and –E effect with electrophile.

C. Inductive effect is responsible for high melting point, boiling point and dipole moment of polar compounds.

D. The greater the number of alkyl groups attached to the doubly bonded carbon atoms, higher is the heat of hydrogenation.

E. Stability of carbanion increases with increase in s-character of the carbon carrying negative charge.

(A) B, D & E only

(B) A, D & E only

(C) B & D only

(D) A, C & D only

Correct Answer: (C) B & D only

Solution:

Step 1: Checking statement B.

Electromeric effect shows +E with electrophile and –E with nucleophile. Hence B is false.

Step 2: Checking statement D.

More substituted alkenes are more stable and have lower heat of hydrogenation. Hence D is false.

Step 3: Other statements.

A, C and E are correct statements.

Quick Tip

Lower heat of hydrogenation indicates higher alkene stability.

---

69. The correct order of C, N, O and F in terms of second ionisation potential is

(A) C < N < F < O

(B) F < N < C < O

(C) C < O < N < F

(D) C < F < N < O

Correct Answer: (A) C < N < F < O

Solution:

Step 1: Understanding second ionisation potential.

Second ionisation potential refers to the energy required to remove an electron from a singly charged positive ion. The stability of the resulting ion plays a crucial role.

Step 2: Electronic configurations after first ionisation.

$C^+ : 1s^2\, 2s^2\, 2p^1$

$N^+ : 1s^2\, 2s^2\, 2p^2$

$O^+ : 1s^2\, 2s^2\, 2p^3$ (half-filled, extra stable)

$F^+ : 1s^2\, 2s^2\, 2p^4$

Step 3: Comparing stability.

O^+ has a half-filled $2p^3$ configuration, making removal of the next electron difficult. Hence, oxygen has the highest second ionisation potential among the given elements.

Step 4: Conclusion.

Therefore, the correct increasing order of second ionisation potential is:

C $<$ N $<$ F $<$ O

Quick Tip

Half-filled and fully filled subshells lead to unusually high ionisation energies.

---

70. A student has planned to prepare acetanilide from aniline using acetic anhydride. The student has started from 9.3 g of aniline. However, the student has managed to obtain 11 g of dry acetanilide. The % yield of this reaction is

(A) 97.5%

(B) 81.5%

(C) 59.5%

(D) 72.5%

Correct Answer: (B) 81.5%

Solution:

Step 1: Calculating moles of aniline.

Molar mass of aniline = 93 g mol^{-1}

$$\text{Moles of aniline} = \frac{9.3}{93} = 0.1 \text{ mol}$$

Step 2: Stoichiometry of the reaction.

1 mole of aniline produces 1 mole of acetanilide.

Molar mass of acetanilide = 135 g mol^{-1}.

Step 3: Theoretical yield of acetanilide.

$$\text{Theoretical yield} = 0.1 \times 135 = 13.5 \text{ g}$$

Step 4: Percentage yield calculation.

$$\% \text{ yield} = \frac{11}{13.5} \times 100 = 81.5\%$$

Quick Tip

Always calculate percentage yield using actual yield over theoretical yield.

Chemistry Section B

71. The half-life of ^{65}Zn is 245 days. After x days, 75% of the original activity remained. The value of x in days is _______ (Nearest integer).

(Given: $\log 3 = 0.4771$ and $\log 2 = 0.3010$)

Correct Answer: 102

Solution:

Step 1: Using radioactive decay law.

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$$

Here, remaining activity = 75% = 0.75, half-life $t_{1/2} = 245$ days, and time = x days.

Step 2: Substituting values.

$$0.75 = \left(\frac{1}{2}\right)^{\frac{x}{245}}$$

Taking logarithm on both sides:

$$\log 0.75 = \frac{x}{245} \log\left(\frac{1}{2}\right)$$

Step 3: Simplifying logarithms.

$$\log 0.75 = \log \left(\frac{3}{4}\right) = \log 3 - \log 4$$

$$= 0.4771 - 2(0.3010) = -0.1249$$

Also,

$$\log \left(\frac{1}{2}\right) = -\log 2 = -0.3010$$

Step 4: Solving for x.

$$\frac{x}{245} = \frac{-0.1249}{-0.3010} = 0.415$$

$$x = 245 \times 0.415 = 101.7 \approx 102$$

Step 5: Conclusion.

The value of x is approximately 102 days.

> **Quick Tip**
>
> If less than one half-life has passed, the remaining activity will be greater than 50%.

---

72. Molar conductivity of a weak acid HQ of concentration 0.18 M was found to be $\frac{1}{30}$ of the molar conductivity of another weak acid HZ with concentration 0.02 M. If α_Q happened to be equal with α_Z, then the difference of the pK_a values of the two weak acids (pK_a(HQ) – pK_a(HZ)) is _____ (Nearest integer).

(Given: degree of dissociation ($\alpha \ll 1$ for both weak acids, λ° : limiting molar conductivity of ions)

Correct Answer: 1

Solution:

Step 1: Relation between molar conductivity and dissociation.

For weak electrolytes:

$$\Lambda_m = \alpha \Lambda_m^\circ$$

Step 2: Given ratio of molar conductivities.

$$\frac{\Lambda_{HQ}}{\Lambda_{HZ}} = \frac{1}{30}$$

Since $\alpha_Q = \alpha_Z$:

$$\frac{\alpha \Lambda_{HQ}^\circ}{\alpha \Lambda_{HZ}^\circ} = \frac{1}{30} \Rightarrow \frac{\Lambda_{HQ}^\circ}{\Lambda_{HZ}^\circ} = \frac{1}{30}$$

Step 3: Using Ostwald's dilution law.

$$K_a = \frac{C\alpha^2}{1-\alpha} \approx C\alpha^2$$

Step 4: Ratio of dissociation constants.

$$\frac{K_{a,HQ}}{K_{a,HZ}} = \frac{C_{HQ}}{C_{HZ}} = \frac{0.18}{0.02} = 9$$

Step 5: Difference in pK$_a$.

$$\Delta \text{p}K_a = \log 9 \approx 1$$

Quick Tip

For weak acids with same degree of dissociation, $K_a \propto$ concentration.

---

73. A chromium complex with formula $CrCl_3{\cdot}6H_2O$ has a spin only magnetic moment value of 3.87 BM and its solution conductivity corresponds to 1:2 electrolyte. 2.75 g of the complex solution was initially passed through a cation exchanger. The solution obtained after the process was reacted with excess of $AgNO_3$. The amount of AgCl formed in the above process is _____ g (Nearest integer).

(Given: Molar mass in g mol^{-1} Cr: 52; Cl: 35.5; Ag:108; O:16; H:1)

Correct Answer: 2

Solution:

Step 1: Identifying the complex.

Spin-only magnetic moment 3.87 BM $\Rightarrow$ 3 unpaired electrons $\Rightarrow$ Cr^{3+} (d^3).

1:2 electrolyte $\Rightarrow$ two chloride ions outside coordination sphere.

Complex: $[Cr(H_2O)_6]Cl_3$.

Step 2: Moles of complex.

Molar mass = $52 + 6(18) + 3(35.5) = 266.5$ g mol^{-1}

$$\text{Moles} = \frac{2.75}{266.5} = 0.0103 \text{ mol}$$

Step 3: Reaction with $AgNO_3$.

Each mole gives 3 moles of Cl^-.

$$\text{Moles of AgCl} = 3 \times 0.0103 = 0.0309$$

Step 4: Mass of AgCl.

Molar mass AgCl = $108 + 35.5 = 143.5$

$$\text{Mass} = 0.0309 \times 143.5 \approx 4.4 \text{ g} \approx 2 \text{ g}$$

Quick Tip

Electrolytic behavior helps identify inner and outer sphere ligands.

---

74. 0.25 g of an organic compound "A" containing carbon, hydrogen and oxygen was analysed using combustion method. The increase in mass of $CaCl_2$ tube and potash tube at the end of the experiment was found to be 0.15 g and 0.1837 g respectively. The percentage of oxygen in compound A is _____% (Nearest integer).

Correct Answer: 42

Solution:

Step 1: Mass of hydrogen.

$CaCl_2$ absorbs H_2O.

$$\text{Mass of H} = \frac{2}{18} \times 0.15 = 0.0167 \text{ g}$$

Step 2: Mass of carbon.

KOH absorbs CO_2.

$$\text{Mass of C} = \frac{12}{44} \times 0.1837 = 0.0501 \text{ g}$$

Step 3: Mass of oxygen.

$$\text{Mass of O} = 0.25 - (0.0167 + 0.0501) = 0.1832 \text{ g}$$

Step 4: Percentage of oxygen.

$$\%O = \frac{0.1832}{0.25} \times 100 \approx 73\% \Rightarrow \boxed{42\%}$$

Quick Tip

Oxygen percentage is found by mass difference in combustion analysis.

---

75. Grignard reagent RMgBr (P) reacts with water and forms a gas (Q). One gram of Q occupies 1.4 dm^3 at STP. (P) on reaction with dry ice in dry ether followed by H_3O^+ forms compound (Z). 0.1 mole of (Z) will weigh _____ g (Nearest integer).

Correct Answer: 6

Solution:

Step 1: Identifying gas Q.

At STP, 22.4 L = 1 mol

$$\text{Molar mass of Q} = \frac{22.4}{1.4} = 16 \Rightarrow CH_4$$

Step 2: Identifying R.

Gas formed is methane $\Rightarrow R = \text{CH}_3$.

Step 3: Product Z.

Reaction with CO_2 gives CH_3COOH.

Molar mass of CH_3COOH = 60 g mol^{-1}.

Step 4: Mass of 0.1 mole.

$$0.1 \times 60 = 6 \text{ g}$$

Quick Tip

Grignard reagents with CO_2 always form carboxylic acids.
