AP EAPCET 2026 May 18 Shift 1

Question Paper (Memory-Based) with Solutions

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General Instructions

(i) The test is of 3 hours duration.

(ii) This test paper consists of 160 questions. The maximum marks are 160.

(iii) Physics and Chemistry contains 40 questions each and Mathematics contains 80 questions.

(iv) Each question carries +1 marks for correct answer and there is no negative marking for wrong answer.

1. If $A=\begin{bmatrix} x & y & y \\ y & x & y \\ y & y & x \end{bmatrix}$ **is a matrix such that** $5A^{-1}=\begin{bmatrix} -3 & 2 & 2 \\ 2 & -3 & 2 \\ 2 & 2 & -3 \end{bmatrix}$**, then** $A^2-4A=$

(A) $5A^{-1}$

(B) $5I$

(C) 0

(D) I

Correct Answer: (B) 5I

Solution:

Concept: The inverse of an invertible square matrix A satisfies the fundamental property:

$$A\cdot A^{-1}=A^{-1}\cdot A=I$$

where I is the identity matrix of the same order.

When given an explicit matrix expression for a scalar multiple of A^{-1}, we can eliminate the inverse term from our target expression by multiplying through by A. This allows us to work directly with matrix addition and scalar multiplication identities.

Step 1: Expressing the matrix $5A^{-1}$ as a combination of a standard pattern matrix.

Let the given matrix for $5A^{-1}$ be denoted as:

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

Notice that we can rewrite this matrix by separating the diagonal elements from the off-diagonal elements:

$$5A^{-1} = \begin{bmatrix} 2-5 & 2 & 2 \\ 2 & 2-5 & 2 \\ 2 & 2 & 2-5 \end{bmatrix} = \begin{bmatrix} 2 & 2 & 2 \\ 2 & 2 & 2 \\ 2 & 2 & 2 \end{bmatrix} - \begin{bmatrix} 5 & 0 & 0 \\ 0 & 5 & 0 \\ 0 & 0 & 5 \end{bmatrix}$$

Thus, we can represent it neatly as:

$$5A^{-1} = \begin{bmatrix} 2 & 2 & 2 \\ 2 & 2 & 2 \\ 2 & 2 & 2 \end{bmatrix} - 5I \quad \cdots(1)$$

Step 2: Multiplying both sides of equation (1) by matrix A.

Post-multiplying both sides of the equation by A, we get:

$$5A^{-1} \cdot A = \begin{bmatrix} 2 & 2 & 2 \\ 2 & 2 & 2 \\ 2 & 2 & 2 \end{bmatrix} A - 5I \cdot A$$

Using the property $A^{-1}A = I$ and $IA = A$:

$$5I = \begin{bmatrix} 2 & 2 & 2 \\ 2 & 2 & 2 \\ 2 & 2 & 2 \end{bmatrix} \begin{bmatrix} x & y & y \\ y & x & y \\ y & y & x \end{bmatrix} - 5A \quad \cdots(2)$$

Step 3: Evaluating the matrix product and establishing the characteristic relation.

Alternatively, a more direct approach is to multiply the original matrices directly using $A \cdot$

$(5A^{-1}) = 5I$:

$$\begin{bmatrix} x & y & y \\ y & x & y \\ y & y & x \end{bmatrix} \begin{bmatrix} -3 & 2 & 2 \\ 2 & -3 & 2 \\ 2 & 2 & -3 \end{bmatrix} = \begin{bmatrix} 5 & 0 & 0 \\ 0 & 5 & 0 \\ 0 & 0 & 5 \end{bmatrix}$$

Let's compute the elements of the resulting product matrix:

- Element (1,1): $-3x + 2y + 2y = -3x + 4y = 5 \quad \cdots(3)$
- Element (1,2): $2x - 3y + 2y = 2x - y = 0 \implies y = 2x \quad \cdots(4)$

Substituting equation (4) into equation (3):

$$-3x + 4(2x) = 5 \implies -3x + 8x = 5 \implies 5x = 5 \implies x = 1$$

Since $y = 2x$, we have $y = 2(1) = 2$. Thus, the matrix A is:

$$A = \begin{bmatrix} 1 & 2 & 2 \\ 2 & 1 & 2 \\ 2 & 2 & 1 \end{bmatrix}$$

Step 4: Computing $A^2 - 4A$ using the determined matrix A.

First, let's calculate A^2:

$$A^2 = \begin{bmatrix} 1 & 2 & 2 \\ 2 & 1 & 2 \\ 2 & 2 & 1 \end{bmatrix} \begin{bmatrix} 1 & 2 & 2 \\ 2 & 1 & 2 \\ 2 & 2 & 1 \end{bmatrix}$$

$$A^2 = \begin{bmatrix} 1(1)+2(2)+2(2) & 1(2)+2(1)+2(2) & 1(2)+2(2)+2(1) \\ 2(1)+1(2)+2(2) & 2(2)+1(1)+2(2) & 2(2)+1(2)+2(1) \\ 2(1)+2(2)+1(2) & 2(2)+2(1)+1(2) & 2(2)+2(2)+1(1) \end{bmatrix} = \begin{bmatrix} 9 & 8 & 8 \\ 8 & 9 & 8 \\ 8 & 8 & 9 \end{bmatrix}$$

Now, compute $A^2 - 4A$:

$$A^2 - 4A = \begin{bmatrix} 9 & 8 & 8 \\ 8 & 9 & 8 \\ 8 & 8 & 9 \end{bmatrix} - \begin{bmatrix} 4 & 8 & 8 \\ 8 & 4 & 8 \\ 8 & 8 & 4 \end{bmatrix} = \begin{bmatrix} 5 & 0 & 0 \\ 0 & 5 & 0 \\ 0 & 0 & 5 \end{bmatrix} = 5I$$

Quick Tip: For symmetric cyclic matrices of the form $\begin{bmatrix} x & y & y \\ y & x & y \\ y & y & x \end{bmatrix}$, the off-diagonal elements of the product with another similar matrix quickly yield linear systems. Solving for x and y directly is often much faster and less error-prone than attempting algebraic matrix manipulations!

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2. A value of θ lying between 0 and $\pi/2$ and satisfying

$$\begin{vmatrix} 1+\sin^2\theta & \cos^2\theta & 4\sin 4\theta \\ \sin^2\theta & 1+\cos^2\theta & 4\sin 4\theta \\ \sin^2\theta & \cos^2\theta & 1+4\sin 4\theta \end{vmatrix} = 0$$

is:

(A) $\frac{5\pi}{24}$

(B) $\frac{7\pi}{24}$

(C) $\frac{\pi}{8}$

(D) $\frac{3\pi}{8}$

Correct Answer: (B) $\frac{7\pi}{24}$

Solution:

Concept: Determinants can be simplified significantly before expansion by applying elementary row operations ($R_i \to R_i + kR_j$) or column operations ($C_i \to C_i + kC_j$). These operations preserve the value of the determinant.

Key trigonometric identity utilized:

$$\sin^2\theta + \cos^2\theta = 1$$

Step 1: Applying a column transformation to combine the trigonometric terms.

Let the given determinant be Δ. Apply the column operation $C_1 \to C_1 + C_2$:

$$\Delta = \begin{vmatrix} (1+\sin^2\theta+\cos^2\theta) & \cos^2\theta & 4\sin 4\theta \\ (\sin^2\theta+1+\cos^2\theta) & 1+\cos^2\theta & 4\sin 4\theta \\ (\sin^2\theta+\cos^2\theta) & \cos^2\theta & 1+4\sin 4\theta \end{vmatrix} = 0$$

Using $\sin^2\theta + \cos^2\theta = 1$, the first column simplifies to:

$$\begin{vmatrix} 2 & \cos^2\theta & 4\sin 4\theta \\ 2 & 1+\cos^2\theta & 4\sin 4\theta \\ 1 & \cos^2\theta & 1+4\sin 4\theta \end{vmatrix} = 0$$

Step 2: Applying row transformations to create maximum zeros in the determinant.

Perform the row operations $R_1 \to R_1 - 2R_3$ and $R_2 \to R_2 - 2R_3$:

$$\begin{vmatrix} 2-2(1) & \cos^2\theta - 2\cos^2\theta & 4\sin 4\theta - 2(1+4\sin 4\theta) \\ 2-2(1) & 1+\cos^2\theta - 2\cos^2\theta & 4\sin 4\theta - 2(1+4\sin 4\theta) \\ 1 & \cos^2\theta & 1+4\sin 4\theta \end{vmatrix} = 0$$

Simplifying the terms:

$$\begin{vmatrix} 0 & -\cos^2\theta & -2-4\sin 4\theta \\ 0 & 1-\cos^2\theta & -2-4\sin 4\theta \\ 1 & \cos^2\theta & 1+4\sin 4\theta \end{vmatrix} = 0$$

Step 3: Expanding the determinant along the first column.

Expanding along C_1:

$$1 \cdot \begin{vmatrix} -\cos^2\theta & -2-4\sin 4\theta \\ 1-\cos^2\theta & -2-4\sin 4\theta \end{vmatrix} = 0$$

Taking out the common factor $-(2+4\sin 4\theta)$ from the second column:

$$-(2+4\sin 4\theta)\begin{vmatrix} -\cos^2\theta & 1 \\ 1-\cos^2\theta & 1 \end{vmatrix} = 0$$

Evaluating the 2×2 determinant:

$$-\cos^2\theta(1) - (1-\cos^2\theta)(1) = -\cos^2\theta - 1 + \cos^2\theta = -1$$

Substituting this back gives:

$$-(2+4\sin 4\theta)(-1) = 0 \quad \Rightarrow \quad 2+4\sin 4\theta = 0$$

$$4\sin 4\theta = -2 \quad \Rightarrow \quad \sin 4\theta = -\frac{1}{2}$$

Step 4: Solving for θ in the given interval $0 < \theta < \pi/2$.

Given $0 < \theta < \frac{\pi}{2}$, multiplying by 4 gives the range for 4θ:

$$0 < 4\theta < 2\pi$$

In the interval $(0, 2\pi)$, $\sin 4\theta = -\frac{1}{2}$ occurs in the 3rd and 4th quadrants:

$$4\theta = \pi + \frac{\pi}{6} = \frac{7\pi}{6} \quad \Rightarrow \quad \theta = \frac{7\pi}{24}$$

$$4\theta = 2\pi - \frac{\pi}{6} = \frac{11\pi}{6} \quad \Rightarrow \quad \theta = \frac{11\pi}{24}$$

Comparing with the given options, $\theta = \frac{7\pi}{24}$ is option (B).

Quick Tip: When a determinant contains cyclic or repeating trigonometric functions across rows or columns, look for column operations like $C_1 + C_2$ to exploit the standard identity $\sin^2\theta + \cos^2\theta = 1$. This instantly reduces variables to constants!

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3. If $\begin{vmatrix} 1 & 2 & 3-\lambda \\ 0 & -1-\lambda & 2 \\ 1-\lambda & 1 & 3 \end{vmatrix} = A\lambda^3 + B\lambda^2 + C\lambda + D$, **then** $D + A =$

(A) 1

(B) -4

(C) -5

(D) 3

Correct Answer: (D) 3

Solution:

Concept: Since the given equation is an identity in λ, it holds true for all values of λ.

- The constant term D can be found by substituting $\lambda = 0$.
- The coefficient A of the term λ^3 can be determined by analyzing the terms that contribute to the highest power of λ when expanding the determinant.

Step 1: Finding the value of D by substituting $\lambda = 0$.

Substituting $\lambda = 0$ on both sides of the identity:

$$\begin{vmatrix} 1 & 2 & 3-0 \\ 0 & -1-0 & 2 \\ 1-0 & 1 & 3 \end{vmatrix} = A(0)^3 + B(0)^2 + C(0) + D$$

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

Expanding the determinant along the first column (C_1):

$$D = 1 \cdot \begin{vmatrix} -1 & 2 \\ 1 & 3 \end{vmatrix} - 0 + 1 \cdot \begin{vmatrix} 2 & 3 \\ -1 & 2 \end{vmatrix}$$

$$D = 1 \cdot [(-1)(3) - (2)(1)] + 1 \cdot [(2)(2) - (3)(-1)]$$

$$D = 1 \cdot (-3-2) + 1 \cdot (4+3) = -5 + 7 = 2$$

Step 2: Finding the coefficient of λ^3 (A).

Let $\Delta(\lambda)$ be the given determinant:

$$\Delta(\lambda) = \begin{vmatrix} 1 & 2 & 3-\lambda \\ 0 & -1-\lambda & 2 \\ 1-\lambda & 1 & 3 \end{vmatrix}$$

Expanding along the first column (C_1):

$$\Delta(\lambda) = 1 \cdot \begin{vmatrix} -1-\lambda & 2 \\ 1 & 3 \end{vmatrix} + (1-\lambda) \cdot \begin{vmatrix} 2 & 3-\lambda \\ -1-\lambda & 2 \end{vmatrix}$$

Evaluating the two parts:

- **First part:**

  $$1 \cdot [(-1-\lambda)(3) - 2] = -3\lambda - 5$$

  This term contains no λ^3 term.

- **Second part:**

  $$(1-\lambda) \cdot [4 - (3-\lambda)(-1-\lambda)]$$

Simplifying the expression within the brackets:

$$4-(\lambda^2-2\lambda-3)=-\lambda^2+2\lambda+7$$

Multiplying by $(1-\lambda)$:

$$(1-\lambda)(-\lambda^2+2\lambda+7)=\lambda^3-3\lambda^2-5\lambda+7$$

Combining both parts to obtain the complete polynomial:

$$\Delta(\lambda)=(-3\lambda-5)+(\lambda^3-3\lambda^2-5\lambda+7)=\lambda^3-3\lambda^2-8\lambda+2$$

Comparing this with $A\lambda^3+B\lambda^2+C\lambda+D$, we find:

$$A=1 \quad \text{and} \quad D=2$$

Step 3: Evaluating the required value $D+A$.

Using the values of A and D:

$$D+A=2+1=3$$

Quick Tip: For equations involving polynomial identities with determinants, substituting $\lambda=0$ is an efficient way to obtain the constant term D. To find the leading coefficient A, focus on the product pathways that yield the highest power of the variable rather than performing a full expansion.

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4. If $A=\begin{bmatrix} x & 2 & 1 \\ -2 & y & 0 \\ 2 & 0 & -1 \end{bmatrix}$, **$x$ and y are non-zero numbers, trace of $A=0$ and determinant of $A=-6$, then the minor of the element 1 of A is:**

(A) -4

(B) 4

(C) 2

(D) -2

Correct Answer: (A) -4

Solution:

Concept:

- **Trace of a Matrix:** The trace of a square matrix A, denoted as $\text{tr}(A)$, is the sum of the elements lying on its principal diagonal.
- **Minor of an Element:** The minor M_{ij} of an element a_{ij} in a matrix is the determinant of the submatrix left after deleting the i-th row and j-th column.

Step 1: Using the trace condition to establish a relationship between x and y.

Given that the trace of matrix A is 0:

$$\text{tr}(A) = x + y + (-1) = 0 \quad \Rightarrow \quad x + y = 1 \quad \Rightarrow \quad y = 1 - x \quad \cdots(1)$$

Step 2: Using the determinant condition to find the specific values of x and y.

The determinant of matrix A is given as -6:

$$|A| = \begin{vmatrix} x & 2 & 1 \\ -2 & y & 0 \\ 2 & 0 & -1 \end{vmatrix} = -6$$

Expanding along the third column (C_3) because it contains a zero element:

$$1 \cdot \begin{vmatrix} -2 & y \\ 2 & 0 \end{vmatrix} - 0 + (-1) \cdot \begin{vmatrix} x & 2 \\ -2 & y \end{vmatrix} = -6$$

$$1 \cdot [(-2)(0) - (y)(2)] - 1 \cdot [(x)(y) - (2)(-2)] = -6$$

$$-2y - (xy + 4) = -6 \quad \Rightarrow \quad -2y - xy - 4 = -6 \quad \Rightarrow \quad xy + 2y = 2 \quad \cdots(2)$$

Substitute equation (1) into equation (2):

$$x(1 - x) + 2(1 - x) = 2$$

$$x - x^2 + 2 - 2x = 2 \quad \Rightarrow \quad -x^2 - x + 2 = 2 \quad \Rightarrow \quad -x^2 - x = 0$$

$$-x(x + 1) = 0 \quad \Rightarrow \quad x = 0 \quad \text{or} \quad x = -1$$

Since the problem states that x and y are non-zero numbers, we discard $x = 0$. Therefore:

$$x = -1$$

Substituting $x = -1$ back into equation (1):

$$y = 1 - (-1) = 2$$

Step 3: Finding the minor of the element 1.

The element 1 is located at the first row and third column position (a_{13}). To find its minor M_{13}, delete the 1st row and 3rd column of matrix A:

$$M_{13} = \begin{vmatrix} -2 & y \\ 2 & 0 \end{vmatrix} = (-2)(0) - (y)(2) = -2y$$

Substituting the determined value of $y = 2$:

$$M_{13} = -2(2) = -4$$

Quick Tip: Always read the constraints carefully! Paying close attention to conditions like "non-zero numbers" allows you to instantly eliminate extraneous roots during quadratic factorization, keeping your calculations fast and precise.

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5. The determinant

$$\det \begin{bmatrix} \frac{a^2+b^2}{c} & c & c \\ a & \frac{b^2+c^2}{a} & a \\ b & b & \frac{c^2+a^2}{b} \end{bmatrix}$$

is equal to:

(A) $(a-b)(b-c)(c-a)$

(B) $(a+b)(b+c)(c+a)$

(C) $2abc$

(D) $4abc$

Correct Answer: (D) 4abc

Solution:

Concept: The value of a determinant can be simplified by applying elementary operations or factored out by clearing denominators. When a determinant expression is homogeneous and symmetric with respect to its variables (a, b, c), choosing strategic numeric values is a powerful method to quickly evaluate the algebraic expression without full expansion.

Step 1: Clearing denominators by taking out common scalar factors from the rows.

Let the given determinant be Δ. Take out $\frac{1}{c}$ from the 1st row (R_1), $\frac{1}{a}$ from the 2nd row (R_2), and $\frac{1}{b}$ from the 3rd row (R_3):

$$\Delta = \frac{1}{abc}\begin{vmatrix} a^2+b^2 & c^2 & c^2 \\ a^2 & b^2+c^2 & a^2 \\ b^2 & b^2 & c^2+a^2 \end{vmatrix}$$

Step 2: Applying row operations to reduce the cyclic expressions.

Apply the row operations $R_1 \to R_1 - R_2 - R_3$:

$$\Delta = \frac{1}{abc}\begin{vmatrix} (a^2+b^2)-a^2-b^2 & c^2-(b^2+c^2)-b^2 & c^2-a^2-(c^2+a^2) \\ a^2 & b^2+c^2 & a^2 \\ b^2 & b^2 & c^2+a^2 \end{vmatrix}$$

$$\Delta = \frac{1}{abc}\begin{vmatrix} 0 & -2b^2 & -2a^2 \\ a^2 & b^2+c^2 & a^2 \\ b^2 & b^2 & c^2+a^2 \end{vmatrix}$$

Taking out the common factor -2 from the first row:

$$\Delta = \frac{-2}{abc}\begin{vmatrix} 0 & b^2 & a^2 \\ a^2 & b^2+c^2 & a^2 \\ b^2 & b^2 & c^2+a^2 \end{vmatrix}$$

Step 3: Creating more zeros using row differences and expanding.

Apply the operations $R_2 \to R_2 - R_1$ and $R_3 \to R_3 - R_1$:

$$\Delta = \frac{-2}{abc}\begin{vmatrix} 0 & b^2 & a^2 \\ a^2 & c^2 & 0 \\ b^2 & 0 & c^2 \end{vmatrix}$$

Now, expand the simplified determinant along the first row (R_1):

$$\Delta = \frac{-2}{abc}\left[0 - b^2(a^2c^2 - 0) + a^2(0 - b^2c^2)\right]$$

$$\Delta = \frac{-2}{abc}\left[-a^2b^2c^2 - a^2b^2c^2\right] = \frac{-2}{abc}\left[-2a^2b^2c^2\right]$$

$$\Delta = \frac{4a^2b^2c^2}{abc} = 4abc$$

Quick Tip: For symmetric polynomial or rational matrix determinants, substitution saves immense time!

Let $a = 1, b = 1, c = 1$. The determinant becomes $\begin{vmatrix} 2 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 2 \end{vmatrix} = 2(4-1) - 1(2-1) + 1(1-2) = 6 - 1 - 1 = 4$.

Comparing with options: (a) 0, (b) 8, (c) 2, (d) 4. Option (D) matches instantly!

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6. A mass of 1 kg is attached to a spring of force constant 100 N/m. Time period is:

(A) 0.2π s

(B) 0.1π s

(C) 0.5π s

(D) 2π s

Correct Answer: (A) 0.2π s

Solution:

Concept: For a simple harmonic oscillator consisting of a mass m attached to an ideal elastic spring with force constant (or spring constant) k, the time period of oscillation T is governed by the inertia of the mass and the stiffness of the spring.

The standard formula connecting these physical quantities is:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where:

- T is the time period in seconds (s)
- m is the mass in kilograms (kg)

- k is the spring constant in Newtons per meter (N/m)

Step 1: Identifying the given parameters from the problem statement.

From the question, we are given:

- Mass attached, $m = 1$ kg
- Force constant of the spring, $k = 100$ N/m

Step 2: Substituting the values into the time period formula.

Using the formula for the time period:

$$T = 2\pi\sqrt{\frac{1}{100}}$$

Simplifying the square root of the fraction:

$$\sqrt{\frac{1}{100}} = \frac{1}{10} = 0.1$$

Now, computing the final value of T:

$$T = 2\pi \cdot (0.1) = 0.2\pi \text{ s}$$

This directly matches option (A).

Quick Tip: When evaluating time periods for spring-mass systems, remember that the time period is independent of the amplitude of oscillation or gravitational acceleration g. It depends solely on the ratio of mass to spring stiffness (m/k)!

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7. A particle in SHM has amplitude 2 m and total energy 8 J. Its potential energy at displacement 1 m is:

(A) 1 J

(B) 2 J

(C) 4 J

(D) 8 J

Correct Answer: (B) 2 J

Solution:

Concept: In Simple Harmonic Motion (SHM), the restoring force acting on the particle is directly proportional to its displacement from the mean position. The mechanical energy of the system oscillates between kinetic and potential forms.

The key equations governing the energy configurations are:

- Total Mechanical Energy (E): The total energy remains constant throughout the motion and depends on the amplitude A:

$$E = \frac{1}{2}m\omega^2 A^2$$

- Potential Energy (U): The potential energy at any displacement x from the mean equilibrium position is given by:

$$U = \frac{1}{2}m\omega^2 x^2$$

By taking the ratio of these two quantities, we can eliminate the system constants (m and ω).

Step 1: Identifying the parameters given in the question.

We are given:

- Amplitude of oscillation, $A = 2$ m
- Total mechanical energy, $E = 8$ J
- Instantaneous displacement, $x = 1$ m

Step 2: Establishing the ratio between potential energy and total energy.

Dividing the potential energy expression by the total energy expression:

$$\frac{U}{E} = \frac{\frac{1}{2}m\omega^2 x^2}{\frac{1}{2}m\omega^2 A^2} = \frac{x^2}{A^2}$$

Rearranging the formula to solve for the instantaneous potential energy U:

$$U = E \cdot \left(\frac{x}{A}\right)^2$$

Step 3: Substituting the numerical values into the ratio relationship.

Substitute $E = 8$, $x = 1$, and $A = 2$ into our equation:

$$U = 8 \cdot \left(\frac{1}{2}\right)^2$$

$$U = 8 \cdot \frac{1}{4} = 2 \text{ J}$$

This perfectly matches option (B).

Quick Tip: For energy problems in SHM, remember that Potential Energy scales quadratically with displacement ($U \propto x^2$). If the displacement becomes half of the maximum amplitude ($x = A/2$), the potential energy will always drop to exactly one-fourth (1/4) of the total energy!

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8. Two SHMs are given by:

$$x_1 = A \sin \omega t,$$

$$x_2 = A \cos \omega t.$$

Phase difference is:

(A) 0

(B) $\pi/4$

(C) $\pi/2$

(D) π

Correct Answer: (C) $\pi/2$

Solution:

Concept: The phase of an oscillating system characterizes its instantaneous state of motion at any given time t. To compare or compute the phase difference ($\Delta\phi$) between two Simple Harmonic Motions accurately, both displacement equations must be expressed using the same trigonometric function (either both as sine functions or both as cosine functions) with identical positive signs for their amplitudes.

A useful trigonometric reduction formula to convert a cosine function to a sine function is:

$$\cos \theta = \sin\left(\theta + \frac{\pi}{2}\right)$$

Step 1: Analyzing the phase of the first given SHM equation.

The first simple harmonic wave equation is given as:

$$x_1 = A \sin \omega t$$

Here, the phase angle of the first wave is:

$$\phi_1 = \omega t \quad \cdots(1)$$

Step 2: Converting the second SHM equation to a matching sine format.

The second wave equation is given in the cosine form:

$$x_2 = A\cos\omega t$$

Using the reduction formula $\cos\theta = \sin\left(\theta + \frac{\pi}{2}\right)$, let's rewrite x_2:

$$x_2 = A\sin\left(\omega t + \frac{\pi}{2}\right)$$

Now that it matches the sine function format of x_1, we can identify its phase angle:

$$\phi_2 = \omega t + \frac{\pi}{2} \quad \cdots(2)$$

Step 3: Calculating the absolute phase difference between the two motions.

The phase difference $\Delta\phi$ between the two oscillations is found by subtracting ϕ_1 from ϕ_2:

$$\Delta\phi = \phi_2 - \phi_1 = \left(\omega t + \frac{\pi}{2}\right) - \omega t$$

$$\Delta\phi = \frac{\pi}{2}$$

This configuration perfectly matches option (C).

Quick Tip: To remember phase conversions visually, think of sine and cosine curves. A standard cosine wave starts at its maximum value at $t = 0$, while a sine wave starts at zero. Because the cosine wave reaches its peaks earlier, it always leads the corresponding sine wave by exactly a quarter cycle, which is a phase angle of $\pi/2$ radians (90°)!

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9. A particle executes SHM with amplitude 0.1 m and angular frequency 10 rad/s. Maximum acceleration is:

(A) 1 m/s^2

(B) 5 m/s^2

(C) 10 m/s^2

(D) 100 m/s^2

Correct Answer: (C) 10 m/s^2

Solution:

Concept: In Simple Harmonic Motion (SHM), the acceleration a of a particle at any instant is directly proportional to its displacement x from the mean position and acts in the opposite direction. The governing kinematic equation is:

$$a = -\omega^2 x$$

where ω represents the angular frequency of the system.

To find the magnitude of the maximum acceleration (a_{max}), we consider the point where the displacement is at its absolute maximum value. This maximum displacement is defined as the amplitude A of the oscillation:

$$a_{max} = \omega^2 A$$

Step 1: Extracting the given kinematic parameters from the problem text.

From the question statement, we have:

- Amplitude of oscillation, $A = 0.1$ m
- Angular frequency, $\omega = 10$ rad/s

Step 2: Substituting the parameters into the maximum acceleration formula.

Apply the values directly to the equation:

$$a_{max} = (10)^2 \cdot (0.1)$$

Evaluating the square of the angular frequency:

$$(10)^2 = 100$$

Now, performing the multiplication:

$$a_{max} = 100 \cdot 0.1 = 10 \text{ m/s}^2$$

Our calculation gives:

$$a_{\text{max}} = 10 \text{ m/s}^2$$

This perfectly matches option (C).

Quick Tip: Keep your position boundaries clear in SHM! The velocity is maximum at the mean position ($x = 0$) where acceleration is zero. Conversely, acceleration reaches its peak magnitude ($\omega^2 A$) at the extreme endpoints ($x = \pm A$) where the velocity drops to zero!

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10. A wave is represented by $y = 0.1\sin(200t - 10x)$. Find wave velocity.

(A) 10 m/s

(B) 20 m/s

(C) 5 m/s

(D) 2 m/s

Correct Answer: (B) 20 m/s

Solution:

Concept: A progressive harmonic wave travelling along the positive x-direction is mathematically described by the general wave equation:

$$y(x,t) = A\sin(\omega t - kx)$$

where:

- A represents the amplitude of the wave.
- ω is the angular frequency, defined as $\omega = 2\pi f$.
- k is the angular wave number (or propagation constant), defined as $k = \frac{2\pi}{\lambda}$.

The wave velocity v (the speed at which the wave profile moves through the medium) is given by the relation:

$$v = \frac{\omega}{k}$$

Step 1: Comparing the given wave equation with the standard progressive wave form.

The given equation of the wave is:

$$y = 0.1\sin(200t - 10x)$$

By comparing this directly with the standard formula $y = A\sin(\omega t - kx)$, we can extract the following values:

- Angular frequency, $\omega = 200$ rad/s
- Wave number, $k = 10$ rad/m

Step 2: Calculating the wave velocity using the extracted coefficients.
Substitute the values of ω and k into the wave velocity formula:

$$v = \frac{\omega}{k} = \frac{200}{10}$$

$$v = 20 \text{ m/s}$$

This calculated value corresponds exactly to option (B).

Quick Tip: To find the wave speed from any sinusoidal wave equation instantly, simply divide the coefficient of time (t) by the coefficient of position (x):

$$\text{Wave Velocity} = \frac{\text{Coefficient of } t}{\text{Coefficient of } x}$$

This shortcut avoids any risk of mixing up basic definitions during an exam!

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11. The IUPAC name of the complex shown below is $K_3[Co(ox)_3]$:

(A) Trispotassium trioxalatocobaltate (III)
(B) Potassium trioxalate cobaltate(III)
(C) Potassium trioxalatecobalt(III)
(D) Potassium trioxalatocobaltate(III)

Correct Answer: (D) Potassium trioxalatocobaltate(III)

Solution:

Concept: According to the IUPAC nomenclature rules for coordination compounds:

1. Order of Naming: The cation is named first, followed by the anion, regardless of which one is complex. No numerical prefixes (like di, tri) are used for simple counter-ions outside the coordination sphere.
2. Naming Coordination Sphere: Ligands are named first in alphabetical order, followed by the central metal atom.
3. Prefixes for Ligands: For simple anionic ligands like oxalate (ox^{2-}), numerical prefixes like 'tri-' are used to denote quantity. The suffix of the anionic ligand changes from '-ate' to '-ato'. Thus, oxalate becomes trioxalato.
4. Name of Central Metal: If the coordination complex ion is an anion (negatively charged sphere), the name of the central metal atom ends with the suffix -ate. Cobalt becomes cobaltate.
5. Oxidation State: The oxidation state of the central metal atom is calculated and indicated by a Roman numeral in parentheses directly after the metal name without any spaces.

Step 1: Determining the charge of the coordination sphere and the oxidation state of Cobalt.

The formula of the complex is $K_3[Co(ox)_3]$. When dissociated in water, it yields:

$$K_3[Co(ox)_3] \rightarrow 3K^+ + [Co(ox)_3]^{3-}$$

The coordination sphere carries a net charge of -3, making it an anionic complex.

Oxalate (ox) is a bidentate ligand with a charge of -2. Let the oxidation state of Cobalt (Co) be x:

$$x + 3(-2) = -3$$

$$x - 6 = -3 \quad \Rightarrow \quad x = +3$$

Thus, the oxidation state of cobalt is III.

Step 2: Assembling the complete IUPAC name according to the structural rules.

- Cation: K^+ is named simply as Potassium (no prefix 'tri').

- Anionic Sphere: Three oxalate ligands give trioxalato. Since the complex is anionic, cobalt is named as cobaltate. Adding the oxidation state gives cobaltate(III).

Combining the cation and anion names with a space separating them gives:

Potassium trioxalatocobaltate(III)

This corresponds precisely to option (D).

Quick Tip: To eliminate options in coordination nomenclature questions instantly, always check the suffix of the metal! If the complex is preceded by an active metal counter-ion (like K, Na), the complex sphere is guaranteed to be an anion, meaning the metal name must end in -ate!

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12. Match the following complexes in List-1 with their hybridisation in List-2:

LIST - 1	LIST - 2
1. $[Ni(CO)_4]$	a. sp^3d^2
2. $[Ni(CN)_4]^{2-}$	b. d^2sp^3
3. $[Co(NH_3)_6]^{3+}$	c. dsp^2
4. $[CoF_6]^{3-}$	d. sp^3

(A) 1-c, 2-d, 3-a, 4-b

(B) 1-d, 2-c, 3-a, 4-b

(C) 1-d, 2-c, 3-b, 4-a

(D) 1-c, 2-d, 3-b, 4-a

Correct Answer: (C) 1-d, 2-c, 3-b, 4-a

Solution:

Concept: According to Valence Bond Theory (VBT) for coordination complexes:

- Strong Field Ligands (SFL): Ligands like CN^- and CO cause pairing of unpaired electrons in the inner d-orbitals if necessary. NH_3 acts as a strong field ligand with higher oxidation states like Co^{3+}.
- Weak Field Ligands (WFL): Ligands like F^- do not cause electron pairing; hence, outer

d-orbitals are used for hybridisation.

- Coordination Number 4: Leads to either tetrahedral (sp^3) or square planar (dsp^2) geometry.
- Coordination Number 6: Leads to octahedral geometry, which can be inner orbital (d^2sp^3) or outer orbital (sp^3d^2).

Step 1: Analyzing complex 1: $[Ni(CO)_4]$.

The oxidation state of Ni in $[Ni(CO)_4]$ is 0. The electronic configuration of Ni(0) is $[Ar]3d^8 4s^2$. Since CO is a very strong field ligand, it forces the two electrons from the 4s orbital into the 3d orbital to pair up completely. The configuration becomes $3d^{10}$. Since the 3d subshell is completely filled, the vacant 4s and three 4p orbitals hybridise to form sp^3 hybridisation. Thus, 1 matches with d.

Step 2: Analyzing complex 2: $[Ni(CN)_4]^{2-}$.

Let the oxidation state of Ni be x: $x + 4(-1) = -2 \Rightarrow x = +2$. The electronic configuration of Ni^{2+} is $[Ar]3d^8 4s^0$. CN^- is a strong field ligand, forcing the 8 electrons in the 3d orbital to pair up, leaving one inner 3d orbital vacant. The vacant orbitals involved in hybridisation are one 3d, one 4s, and two 4p, resulting in dsp^2 hybridisation (Square Planar). Thus, 2 matches with c.

Step 3: Analyzing complex 3: $[Co(NH_3)_6]^{3+}$.

The oxidation state of Co is +3. The electronic configuration of Co^{3+} is $[Ar]3d^6 4s^0$. With Co^{3+}, NH_3 behaves as a strong field ligand and causes pairing of the 6 electrons in the 3d subshell into three paired pairs (t_{2g}^6). This leaves two inner 3d orbitals completely empty. These two vacant 3d orbitals, along with one 4s and three 4p orbitals, form d^2sp^3 hybridisation (Inner orbital octahedral). Thus, 3 matches with b.

Step 4: Analyzing complex 4: $[CoF_6]^{3-}$.

The oxidation state of Co is +3. The electronic configuration of Co^{3+} is $[Ar]3d^6 4s^0$. F^- is a weak field ligand and cannot cause electron pairing. The 3d configuration remains unpaired with maximum spin. Therefore, outer 4s, three 4p, and two 4d orbitals are used for hybridisation, resulting in sp^3d^2 hybridisation (Outer orbital octahedral). Thus, 4 matches with a.

Combining all matches: 1-d, 2-c, 3-b, 4-a, which matches option (C).

Quick Tip: To solve matching questions on hybridisation instantly, look for outer-orbital vs inner-orbital diagnostic markers: Fluoride (F^-) complexes with Co^{3+} are iconic classic examples of outer-orbital weak field complexes (sp^3d^2). Identifying just this single link (4 → a) immediately eliminates two options!

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13. Which of the following pairs of ions will have same spin only magnetic moment values within the pair?

A. Zn^{2+}, Ti^{2+}

B. Cr^{2+}, Fe^{2+}

C. Ti^{3+}, Cu^{2+}

D. V^{2+}, Cu^{+}

Choose the correct answer from the options given below:

(A) C and D only
(B) A and D only
(C) A and B only
(D) B and C only

Correct Answer: (D) B and C only

Solution:

Concept: The spin-only magnetic moment (μ) of a transition metal ion depends exclusively on the number of its unpaired electrons (n). It is calculated using the formula:

$$\mu = \sqrt{n(n+2)} \text{ B.M.}$$

where B.M. stands for Bohr Magneton.

For two ions to exhibit the exact same spin-only magnetic moment value, they must possess the identical number of unpaired electrons (n) in their valence d-orbitals.

Step 1: Analyzing pair A: Zn^{2+} and Ti^{2+}.

- Zn (Atomic Number = 30): Electronic configuration is $[Ar]3d^{10}4s^2$. For Zn^{2+}, configura-

tion is $3d^{10}$. All electrons are completely paired, so $n = 0$.

- Ti (Atomic Number = 22): Electronic configuration is $[Ar]3d^2 4s^2$. For Ti^{2+}, configuration is $3d^2$. According to Hund's rule, these electrons are unpaired, so $n = 2$.

Since $0 \neq 2$, pair A does not have the same magnetic moment.

Step 2: Analyzing pair B: Cr^{2+} and Fe^{2+}.

- Cr (Atomic Number = 24): Electronic configuration is $[Ar]3d^5 4s^1$. For Cr^{2+}, configuration is $3d^4$. Arranging these in five degenerate d-orbitals yields $n = 4$ unpaired electrons.
- Fe (Atomic Number = 26): Electronic configuration is $[Ar]3d^6 4s^2$. For Fe^{2+}, configuration is $3d^6$. Arranging 6 electrons results in one paired orbital and four singly occupied orbitals, giving $n = 4$ unpaired electrons.

Since both have $n = 4$, pair B has the same magnetic moment.

Step 3: Analyzing pair C: Ti^{3+} and Cu^{2+}.

- For Ti^{3+}, configuration is $3d^1$, which gives $n = 1$ unpaired electron.
- Cu (Atomic Number = 29): Electronic configuration is $[Ar]3d^{10} 4s^1$. For Cu^{2+}, configuration is $3d^9$. Arranging 9 electrons leaves exactly one orbital singly occupied, giving $n = 1$ unpaired electron.

Since both have $n = 1$, pair C has the same magnetic moment.

Step 4: Analyzing pair D: V^{2+} and Cu^{+}.

- V (Atomic Number = 23): Electronic configuration is $[Ar]3d^3 4s^2$. For V^{2+}, configuration is $3d^3$, giving $n = 3$ unpaired electrons.
- For Cu^{+}, configuration is $3d^{10}$, which means all electrons are paired up, giving $n = 0$.

Since $3 \neq 0$, pair D does not have the same magnetic moment.

Therefore, only statements B and C are correct, which corresponds to option (D).

Quick Tip: To quickly find the number of unpaired electrons for a $3d^m$ configuration where $m > 5$, simply subtract the number of electrons from 10 ($n = 10 - m$). For example, for Fe^{2+} ($3d^6$), $n = 10 - 6 = 4$. This allows an instant matching shortcut with Cr^{2+} ($3d^4$) without drawing orbital diagrams!

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14. The correct order of the wavelength of light absorbed by the following complexes is:

A. $[Co(NH_3)_6]^{3+}$

B. $[Co(CN)_6]^{3-}$

C. $[Cu(H_2O)_4]^{2+}$

D. $[Ti(H_2O)_6]^{3+}$

Choose the correct answer from the options given below:

(A) C < D < A < B

(B) C < A < D < B

(C) B < D < A < C

(D) B < A < D < C

Correct Answer: (D) B < A < D < C

Solution:

Concept: According to Crystal Field Theory (CFT), the color of a coordination complex arises from electronic transitions between split d-orbitals (d-d transitions). The energy absorbed during this transition (Δ) is inversely proportional to the wavelength (λ) of the absorbed light:

$$\Delta = \frac{hc}{\lambda} \implies \lambda \propto \frac{1}{\Delta}$$

The magnitude of crystal field splitting (Δ) depends primarily on:

1. The Spectrochemical Series (Ligand Strength): Strong field ligands split orbitals further apart, resulting in a higher Δ value:

$$I^- < Br^- < S^{2-} < Cl^- < F^- < OH^- < H_2O < NH_3 < en < NO_2^- < CN^- < CO$$

2. Oxidation State of Central Metal: A higher positive charge on the metal ion increases

electrostatic attraction for the ligands, increasing Δ.

3. Nature of Central Metal: Elements belonging to different groups or transition series split fields differently under similar constraints.

Step 1: Comparing the Cobalt complexes (A and B) using ligand strength.

Let us compare $[Co(NH_3)_6]^{3+}$ (A) and $[Co(CN)_6]^{3-}$ (B). Both complexes feature the same central metal ion (Co^{3+}) in an octahedral environment.

- In the spectrochemical series, Cyanide (CN^-) is a significantly stronger field ligand than Ammonia (NH_3).
- Therefore, the crystal field splitting energy (Δ_o) follows the order: $\Delta_o(B) > \Delta_o(A)$.
- Since $\lambda \propto \frac{1}{\Delta}$, the order of wavelength absorbed is: $\lambda(B) < \lambda(A)$.

Step 2: Comparing splitting between different metal ions with aqua ligands (C and D).

Let us evaluate $[Ti(H_2O)_6]^{3+}$ (D) and compare its parameters with the others.

- Ti^{3+} belongs to the early part of the $3d$ series ($3d^1$). It has a higher oxidation state (+3) compared to Cu^{2+}, causing stronger ligand-metal overlap than typical M^{2+} complexes.
- For $[Cu(H_2O)_4]^{2+}$ (C), Copper has a lower oxidation state (+2), and the coordination number is 4. Splitting energies for tetrahedral or square planar complexes with weak ligands like water are fundamentally lower than those of octahedral M^{3+} ions.
- Additionally, the spectrochemical field splitting sequence for identical ligands across these configuration changes trends such that:

$$\Delta_o(Co^{3+}) > \Delta_o(Ti^{3+}) > \Delta(Cu^{2+})$$

Step 3: Establishing the comprehensive overall order.

Combining the splitting field magnitudes derived across the configurations:

$$\text{Splitting Energy } (\Delta): \quad B\ (Co^{3+}, CN^-) > A\ (Co^{3+}, NH_3) > D\ (Ti^{3+}, H_2O) > C\ (Cu^{2+}, H_2O)$$

Taking the inverse relation to arrive at the correct sequence for absorbed wavelengths (λ):

$$\lambda: \quad B < A < D < C$$

This precisely matches option (D).

Quick Tip: To solve wavelength absorption questions instantly, look at the extremes of the spectrochemical series. Since CN^- is one of the strongest field ligands available, it maximizes splitting (Δ), which guarantees it will absorb the shortest wavelength. Thus, complex B must be at the starting end of a increasing order sequence, letting you narrow options down immediately!

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15. The greater the valence of the flocculating ion added, the greater is its power to cause precipitation of a colloid. This rule is:

(A) Hund's rule

(B) Pauling's rule

(C) Henry's rule

(D) Hardy - Schulze rule

Correct Answer: (D) Hardy - Schulze rule

Solution:

Concept: Colloidal solutions carry a net electric charge on their dispersed phase particles, which keeps them stable by mutual electrostatic repulsion. Adding an electrolyte introduces oppositely charged ions that neutralize this surface charge, leading to aggregation, coagulation, or precipitation.

The Hardy-Schulze rule states two key guidelines regarding this process:

1. Only the ions carrying a charge opposite to that of the colloidal particles are effective in causing coagulation. These are called flocculating or active ions.
2. The coagulating or flocculating power of an active ion increases sharply with an increase in its valence (charge magnitude).

Step 1: Analyzing the relationship between ion valence and flocculating power.

According to the rule, the higher the charge magnitude on the active ion, the more efficiently it neutralizes the double-layer potential around the colloid.

For instance, to coagulate a negatively charged sol (like arsenic sulfide, As_2S_3), the active ions

are cations. Their flocculating power increases drastically following the order of their valency:

$$Al^{3+} > Mg^{2+} > Na^{+}$$

Similarly, to coagulate a positively charged sol (like ferric hydroxide, $Fe(OH)_3$), the active ions are anions. Their flocculating power trends as:

$$[Fe(CN)_6]^{4-} > PO_4^{3-} > SO_4^{2-} > Cl^{-}$$

Step 2: Matching the statement with the given options.
Let us briefly review the other rules mentioned:

- Hund's rule: Dictates that electron pairing in degenerate subshells cannot occur until each orbital is singly occupied.
- Henry's rule: Relates the solubility of a gas in a liquid directly to the partial pressure of that gas above the liquid.
- Hardy-Schulze rule: Perfectly matches the definition linking flocculation power to ion valence.

Therefore, the statement describes the Hardy-Schulze rule, corresponding to option (D).

Quick Tip: Remember that coagulating power is inversely proportional to the coagulation value (the minimum concentration of electrolyte required to cause precipitation). An ion with a high valence has massive coagulating power, meaning its required coagulation value is extremely small!
