KEAM 2026 Engineering April 22

Question Paper with Solution (memory based)

Conducted by CEE Kerala

General Instructions

- **Duration:** The total duration of the examination is 3 hours (180 minutes).
- **Total Marks:** The complete paper carries a maximum of 600 marks.
- **Structure:** The paper has 3 Sections:
  - **Section A:** 45 Multiple Choice Questions (Physics).
  - **Section B:** 30 Multiple Choice Questions (Chemistry).
  - **Section B:** 75 Multiple Choice Questions (Mathematics).
- **Compulsory Questions:** All 150 questions are compulsory.
- Each question has four options. Only **one** option is correct.
- **Correct Answer:** +4 marks.
- **Incorrect Answer:** −1 (Negative marking).
- **Unanswered/Marked for Review:** 0 marks.

MATHEMATICS

1. $\int(\tan^2(2x)-\cot^2(2x))dx =$

(a) $-\frac{1}{2}(\tan 2x+\cot 2x)+C$

(b) $2(\tan 2x+\cot 2x)+C$

(c) $\frac{1}{2}(\tan 2x-\cot 2x)+C$

(d) $-\frac{1}{2}(\tan 2x-\cot 2x)+C$

(e) $\frac{1}{2}(\tan 2x + \cot 2x) + C$

Correct Answer: (e) $\frac{1}{2}(\tan 2x + \cot 2x) + C$

Solution:

Step 1: Understanding the Concept:

The integral involves the squares of the tangent and cotangent functions.

Since there are no direct, simple standard formulas for integrating $\tan^2(kx)$ or $\cot^2(kx)$ directly, we must transform the integrand using fundamental trigonometric identities.

By converting these into secant and cosecant squared functions, the integration becomes straightforward because they are standard derivatives.

Step 2: Key Formula or Approach:

We will utilize the fundamental Pythagorean trigonometric identities:

1. $\tan^2\theta = \sec^2\theta - 1$
2. $\cot^2\theta = \csc^2\theta - 1$

The standard integral formulas required are:

1. $\int \sec^2(kx)dx = \frac{1}{k}\tan(kx) + C$
2. $\int \csc^2(kx)dx = -\frac{1}{k}\cot(kx) + C$

Step 3: Detailed Explanation:

Let the given integral be I.

$$I = \int (\tan^2(2x) - \cot^2(2x))dx$$

Apply the trigonometric identities to replace $\tan^2(2x)$ and $\cot^2(2x)$:

$$I = \int \left((\sec^2(2x) - 1) - (\csc^2(2x) - 1)\right)dx$$

Distribute the negative sign and simplify the terms inside the integral:

$$I = \int (\sec^2(2x) - 1 - \csc^2(2x) + 1)dx$$

The -1 and $+1$ cancel each other out, leaving:

$$I = \int (\sec^2(2x) - \csc^2(2x))dx$$

Now, use the linearity property of integrals to split it into two separate integrals:

$$I = \int \sec^2(2x)dx - \int \csc^2(2x)dx$$

Apply the standard integration formulas as stated in Step 2, noting that our coefficient k is 2:

$$I = \left(\frac{1}{2}\tan(2x)\right) - \left(-\frac{1}{2}\cot(2x)\right) + C$$

Simplify the signs:

$$I = \frac{1}{2}\tan(2x) + \frac{1}{2}\cot(2x) + C$$

Factor out the common $\frac{1}{2}$:

$$I = \frac{1}{2}(\tan 2x + \cot 2x) + C$$

Step 4: Final Answer:

The integrated expression is $\frac{1}{2}(\tan 2x + \cot 2x) + C$.

Quick Tip: Whenever you encounter an integral with $\tan^2 x$ or $\cot^2 x$, your immediate first step should always be converting them to $\sec^2 x - 1$ and $\csc^2 x - 1$. This turns a seemingly complex integral into basic standard forms.

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2. If $x + 13y = 40$ is normal to the curve $y = 5x^2 + ax + \beta$ at the point $(1, 3)$, then the value of $a\beta$ is equal to:

(a) 15

(b) -6

(c) 6

(d) 13

(e) -15

Correct Answer: (e) -15

Solution:

Step 1: Understanding the Concept:

The problem relates a given curve to its normal line at a specific point of contact.

The normal line is always perpendicular to the tangent line at the point of tangency.

Therefore, the slope of the normal and the slope of the tangent are negative reciprocals of each other.

We can find the tangent's slope using the derivative of the curve's equation.

Step 2: Key Formula or Approach:

1. **Point condition:** If a line is normal/tangent to a curve at point (x_1, y_1), that point must satisfy the equation of the curve $y = f(x)$.
2. **Slope of Normal (m_n):** Extracted from the linear equation $y = m_n x + c$.
3. **Slope of Tangent (m_t):** Given by $m_t = \left.\frac{dy}{dx}\right|_{(x_1,y_1)}$.
4. **Perpendicularity condition:** $m_t \times m_n = -1$, which implies $m_t = -\frac{1}{m_n}$.

Step 3: Detailed Explanation:

First, since the normal is at the point $(1,3)$, this point lies exactly on the given curve $y = 5x^2 + ax + \beta$.

Substitute $x = 1$ and $y = 3$ into the curve's equation to create our first relation:

$$3 = 5(1)^2 + a(1) + \beta$$

$$3 = 5 + a + \beta$$

$$a + \beta = 3 - 5$$

$$a + \beta = -2 \quad \text{— (Equation 1)}$$

Next, let's find the slope of the normal line. The equation is given as $x + 13y = 40$.

Rearrange it into the slope-intercept form ($y = mx + c$):

$$13y = -x + 40$$

$$y = -\frac{1}{13}x + \frac{40}{13}$$

From this, the slope of the normal line is $m_n = -\frac{1}{13}$.

Using the perpendicularity condition, the slope of the tangent line m_t is the negative reciprocal:

$$m_t = -\frac{1}{m_n} = -\frac{1}{-\frac{1}{13}} = 13$$

Now, we find the slope of the tangent analytically by taking the derivative of the curve $y = 5x^2 + ax + \beta$ with respect to x:

$$\frac{dy}{dx} = \frac{d}{dx}(5x^2 + ax + \beta) = 10x + a$$

Evaluate this derivative specifically at the point of tangency, where $x = 1$:

$$\left.\frac{dy}{dx}\right|_{x=1} = 10(1) + a = 10 + a$$

Equate this evaluated derivative to the tangent slope m_t we found from the normal line:

$$10 + a = 13$$

Solving for a:

$$a = 3$$

Now, substitute the value of $a = 3$ back into Equation 1 to solve for β:

$$3 + \beta = -2$$

$$\beta = -2 - 3$$

$$\beta = -5$$

The problem asks for the product of a and β:

$$a\beta = (3)(-5) = -15$$

Step 4: Final Answer:

The product $a\beta$ is equal to -15.

Quick Tip: Always use all pieces of information given. The phrase "at the point (1,3)" provides two distinct mathematical facts: 1) the derivative evaluated at x=1 gives the slope, and 2) plugging x=1 and y=3 into the original equation provides a valid algebraic identity.

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3. Let $f(x) = \begin{cases} 3x+6, & \text{if } x \geq c \\ x^2-3x-1, & \text{if } x < c \end{cases}$**, where** $x \in \mathbb{R}$ **and** c **is a constant. The values of** c **for which** f **is continuous on** $\mathbb{R}$ **are:**

(a) -7, 1

(b) 1, 3

(c) -1, 7

(d) -1, 6

(e) 2, -3

Correct Answer: (c) -1, 7

Solution:

Step 1: Understanding the Concept:

A piecewise function is made up of different sub-functions over different intervals.

The sub-functions $3x+6$ (a line) and x^2-3x-1 (a parabola) are polynomials, which are continuous everywhere on their own domains.

The only possible point of discontinuity for the entire function $f(x)$ is at the boundary point $x = c$, where the rule defining the function changes.

To ensure $f(x)$ is continuous on the entire real line $\mathbb{R}$, we must enforce continuity specifically at this boundary $x = c$.

Step 2: Key Formula or Approach:

For a function $f(x)$ to be continuous at a point $x = c$, the following three conditions must hold:

1. $f(c)$ is defined.

2. The limit as x approaches c exists, meaning the left-hand limit equals the right-hand limit: $\lim_{x \to c^-} f(x) = \lim_{x \to c^+} f(x)$.

3. The limit equals the function value: $\lim_{x \to c} f(x) = f(c)$.

Step 3: Detailed Explanation:

Let's evaluate the left-hand limit, right-hand limit, and the exact function value at $x = c$.

1. **Left-Hand Limit (LHL):** Approaching c from the left ($x < c$), we use the bottom piece:

$$\lim_{x \to c^-} f(x) = \lim_{x \to c^-} (x^2 - 3x - 1) = c^2 - 3c - 1$$

2. **Right-Hand Limit (RHL):** Approaching c from the right ($x > c$), we use the top piece:

$$\lim_{x \to c^+} f(x) = \lim_{x \to c^+} (3x + 6) = 3c + 6$$

3. **Function Value at c:** Since the top condition is $x \geq c$, we plug $x = c$ into the top piece:

$$f(c) = 3(c) + 6 = 3c + 6$$

For the function to be continuous at $x = c$, the LHL must exactly equal the RHL (and thus equal $f(c)$):

$$\lim_{x \to c^-} f(x) = \lim_{x \to c^+} f(x)$$

$$c^2 - 3c - 1 = 3c + 6$$

We must solve this equation for c. Move all terms to one side to form a standard quadratic equation equal to zero:

$$c^2 - 3c - 3c - 1 - 6 = 0$$

$$c^2 - 6c - 7 = 0$$

Now, factor the quadratic equation. We look for two factors of -7 that add up to -6. These are -7 and +1:

$$(c - 7)(c + 1) = 0$$

Set each factor to zero to find the possible values for c:

$$c - 7 = 0 \implies c = 7$$

$$c+1=0 \implies c=-1$$

Therefore, the function will be continuous everywhere if the constant c is either -1 or 7.

Step 4: Final Answer:

The values of c are -1, 7.

Quick Tip: When checking continuity for simple piecewise functions, you can generally just substitute the breakpoint value directly into both formulas and set them equal to each other. This rapidly creates the equation needed to solve for any unknown constants.

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4. In a box there are four marbles and each of them is marked with distinct number from the set $\{1,2,5,10\}$. If one marble is randomly selected four times with replacement and the number on it noted, then the probability that the sum of numbers equals 18 is:

(a) $\frac{1}{64}$
(b) $\frac{3}{16}$
(c) $\frac{5}{32}$
(d) $\frac{3}{32}$
(e) $\frac{1}{32}$

Correct Answer: (d) $\frac{3}{32}$

Solution:

Step 1: Understanding the Concept:

We are conducting an experiment of drawing a marble 4 independent times, putting it back after each draw (with replacement).

The set of available numbers is $\{1,2,5,10\}$.

We need to find the theoretical probability of a specific event occurring: the sum of the four drawn numbers being exactly 18.

To do this, we compute the total possible outcomes and count how many of those outcomes

result in a sum of 18.

Step 2: Key Formula or Approach:

1. **Total Outcomes:** If an experiment has n possible outcomes and is repeated k times with replacement, the total number of sequences is n^k.

2. **Permutations with Repetition:** The number of distinct ways to arrange N items where there are duplicates (like n_1 of one kind, n_2 of another) is $\frac{N!}{n_1!n_2!\ldots}$.

3. **Probability:** $P(E) = \frac{\text{Number of favorable outcomes}}{\text{Total number of possible outcomes}}$.

Step 3: Detailed Explanation:

Let's find the total number of outcomes in the sample space.

Since there are 4 marbles and we draw 4 times with replacement, each draw has 4 possibilities.

$$\text{Total Outcomes} = 4 \times 4 \times 4 \times 4 = 4^4 = 256$$

Next, we must find the favorable combinations of four numbers from the set $\{1, 2, 5, 10\}$ that sum to exactly 18.

Let the drawn numbers be x_1, x_2, x_3, x_4. We want $x_1 + x_2 + x_3 + x_4 = 18$.

We analyze this by considering how many times the largest number, 10, can be drawn.

Case 1: The number 10 is drawn twice or more.

If we draw two 10s, the sum is already $10 + 10 = 20$, which is strictly greater than 18. This is impossible.

Case 2: The number 10 is drawn exactly once.

If one draw is a 10, the remaining three draws must sum to $18 - 10 = 8$.

We need three numbers from $\{1, 2, 5\}$ that add to 8.

Let's test using the next largest number, 5.

If we use one 5, the remaining two numbers must sum to $8 - 5 = 3$.

From $\{1, 2, 5\}$, the only two numbers that sum to 3 are 1 and 2.

So, a valid set of four numbers is $\{10, 5, 2, 1\}$.

Are there other ways to make 8?

- If we use two 5s, the sum is 10 (too large).

- If we use zero 5s, the maximum sum with three numbers from $\{1, 2\}$ is $2 + 2 + 2 = 6$ (too small).

Thus, the only specific set of numbers that works is $\{10, 5, 2, 1\}$.

Because all four drawn numbers are distinct, any permutation of these 4 numbers represents a different valid sequence of draws.

The number of distinct arrangements of 4 unique items is 4!.

$$\text{Favorable outcomes from Case 2} = 4! = 4 \times 3 \times 2 \times 1 = 24$$

Case 3: The number 10 is drawn zero times.

We must make a sum of 18 using four numbers strictly from $\{1, 2, 5\}$.

The maximum possible sum using four numbers from this restricted set is by picking the largest number, 5, four times.

Max sum $= 5 + 5 + 5 + 5 = 20$.

We need to reduce this sum from 20 down to 18.

If we replace one '5' with a '2', the sum drops to $5 + 5 + 5 + 2 = 17$. This is strictly less than 18.

Since replacing even a single 5 with the next largest number makes the sum fall below 18, it is completely impossible to get a sum of 18 without using the number 10.

Final Calculation:

The total number of favorable outcomes is exclusively the 24 outcomes found in Case 2.

$$\text{Probability} = \frac{\text{Favorable Outcomes}}{\text{Total Outcomes}} = \frac{24}{256}$$

Simplify the fraction by dividing the numerator and denominator by their greatest common divisor, which is 8:

$$\frac{24 \div 8}{256 \div 8} = \frac{3}{32}$$

Step 4: Final Answer:

The probability is $\frac{3}{32}$.

Quick Tip: To quickly find combinations that hit a specific target sum, always start by testing the largest available numbers first. This limits the "search space" dramatically, as larger numbers quickly overstep the target, eliminating many branches of possibilities.

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5. Three fair dice are rolled simultaneously. Let a, b, c be the numbers on the top of the dice.

Then the probability that $\min(a, b, c) = 6$ **is:**

(a) $\frac{1}{216}$
(b) $\frac{1}{36}$
(c) $\frac{1}{6}$
(d) $\frac{11}{216}$
(e) $\frac{5}{6}$

Correct Answer: (a) $\frac{1}{216}$

Solution:

Step 1: Understanding the Concept:
We are considering an event where three standard fair dice are rolled at once.
The variables a, b, and c denote the discrete outcomes of each individual die, meaning they can only take integer values from 1 to 6.
The mathematical function $\min(a, b, c)$ evaluates to the smallest value among the three numbers.
We need to compute the probability of the specific condition where this smallest value is exactly equal to 6.

Step 2: Key Formula or Approach:
1. **Total Outcomes:** For rolling n dice, the total number of elementary events in the sample space is 6^n.
2. **Inequality Logic for Min Function:** The condition $\min(x_1, x_2, \ldots, x_n) \geq k$ mathematically requires that every single variable satisfies the condition $x_i \geq k$.
3. **Probability:** $P(E) = \frac{\text{Number of favorable outcomes}}{\text{Total number of possible outcomes}}$.

Step 3: Detailed Explanation:
Let's first determine the total number of possible outcomes when rolling three dice.
Since each die operates independently and has 6 faces, the fundamental counting principle applies:

$$\text{Total Outcomes} = 6 \times 6 \times 6 = 216$$

Now, let's analyze the favorable condition: $\min(a, b, c) = 6$.
By definition, if the minimum of a set of numbers is 6, it means that absolutely no number in that set can be smaller than 6.
Mathematically, this forces the following simultaneous inequalities:

$$a \geq 6$$

$$b \geq 6$$

$$c \geq 6$$

However, we know that a, b, and c are the results of standard dice rolls, so their maximum possible value is constrained to 6.
Therefore, the inequalities strictly collapse into equalities:

$$a = 6, \quad b = 6, \quad c = 6$$

This signifies that all three dice must independently land on the number 6.
There is only one specific outcome that satisfies this requirement, which is the triplet $(6, 6, 6)$.

$$\text{Number of favorable outcomes} = 1$$

Finally, compute the probability by dividing the favorable outcomes by the total outcomes:

$$P = \frac{1}{216}$$

Step 4: Final Answer:
The probability is $\frac{1}{216}$.

Quick Tip: When working with minimums or maximums in probability, convert the function into logical inequalities. "The minimum is 6" translates immediately to "ALL variables are greater than or equal to 6". Since 6 is the upper bound of a die, it strictly forces all to be exactly 6.

CHEMISTRY

1. Oxidation number of potassium in K_2O, K_2O_2 and KO_2, respectively, is:

(a) +2, +1 and $+\frac{1}{2}$

(b) +1, +1 and +1

(c) +1, +4 and +2

(d) +1, +2 and +4

Correct Answer: (b) +1, +1 and +1

Solution:

Step 1: Understanding the Concept:

The question asks for the oxidation state of potassium (K) in three different oxygen-containing compounds.

Potassium is an alkali metal, belonging to Group 1 of the periodic table.

A fundamental rule of assigning oxidation numbers is that alkali metals always have an oxidation state of +1 in all of their compounds.

Step 2: Key Formula or Approach:

1. The oxidation state of Group 1 metals (Li, Na, K, Rb, Cs) in their compounds is strictly +1.
2. The algebraic sum of oxidation states of all atoms in a neutral molecule must be zero.

We can use the second rule to verify the varying oxidation states of oxygen in these compounds, while K remains constant.

Step 3: Detailed Explanation:

According to the rules, since potassium is a Group 1 element, its oxidation state must be +1 in K_2O, K_2O_2, and KO_2.

Let's verify this by calculating the oxidation state of oxygen in each compound to see how they differ:

1. In Potassium oxide (K_2O): Let the oxidation state of O be x.

$$2(+1) + x = 0 \implies x = -2$$

Here, oxygen is a normal oxide ion (O^{2-}). Potassium is +1.

2. In Potassium peroxide (K_2O_2): Let the oxidation state of O be y.

$$2(+1)+2y=0 \implies 2y=-2 \implies y=-1$$

Here, oxygen is a peroxide ion (O_2^{2-}). Potassium is +1.

3. In Potassium superoxide (KO_2): Let the oxidation state of O be z.

$$1(+1)+2z=0 \implies 2z=-1 \implies z=-\frac{1}{2}$$

Here, oxygen is a superoxide ion (O_2^-). Potassium is +1.

In every single case, regardless of the type of oxide formed, the oxidation state of potassium remains fixed at +1.

Step 4: Final Answer:

The oxidation numbers of potassium are +1, +1, and +1 respectively.

Quick Tip: Never calculate the oxidation state of an alkali metal based on oxygen! Oxygen can exhibit various oxidation states (-2 in oxides, -1 in peroxides, -1/2 in superoxides, etc.), but Group 1 metals are unconditionally +1 in their compounds. Use the metal to find oxygen's state, not the other way around.

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2. Which one of the following is not an allylic halide?

(a) 4-bromopent-2-ene

(b) 3-bromo-2-methylbut-1-ene

(c) 1-bromobut-2-ene

(d) 4-bromobut-1-ene

(e) 3-bromo-2-methylpropene

Correct Answer: (d) 4-bromobut-1-ene

Solution:

Step 1: Understanding the Concept:

The problem requires identifying which compound does not fit the classification of an "allylic

halide".

An allylic halide is a specific type of organic halide where the halogen atom (like bromine, chlorine) is bonded to an sp^3-hybridized carbon atom that is immediately adjacent to a carbon-carbon double bond ($C=C$).

The general structure is $C=C-C-X$, where the $-C-X$ carbon is the allylic carbon.

Step 2: Key Formula or Approach:

To classify these compounds, follow these steps for each option:

1. Draw the structural formula based on the IUPAC name.
2. Locate the halogen atom (bromine in this case).
3. Check the hybridization of the carbon bonded to the halogen (it must be sp^3, meaning it has all single bonds).
4. Check if that specific sp^3 carbon is directly attached to a carbon atom that is part of a double bond.

Step 3: Detailed Explanation:

Let's analyze each option systematically:

(a) 4-bromopent-2-ene: The structure is $CH_3-CH=CH-CH(Br)-CH_3$.

The Br is attached to C-4. Carbon-4 is sp^3 hybridized and is directly adjacent to C-3, which is part of the $C=C$ double bond. Therefore, this is an allylic halide.

(b) 3-bromo-2-methylbut-1-ene: The structure is $CH_2=C(CH_3)-CH(Br)-CH_3$.

The Br is attached to C-3. Carbon-3 is sp^3 hybridized and is directly adjacent to C-2, which is part of the $C=C$ double bond. Therefore, this is an allylic halide.

(c) 1-bromobut-2-ene: The structure is $Br-CH_2-CH=CH-CH_3$.

The Br is attached to C-1. Carbon-1 is sp^3 hybridized and is directly adjacent to C-2, which is part of the $C=C$ double bond. Therefore, this is an allylic halide.

(d) 4-bromobut-1-ene: The structure is $CH_2=CH-CH_2-CH_2-Br$.

The Br is attached to C-4. Carbon-4 is sp^3 hybridized. However, it is adjacent to C-3, which is also an sp^3 carbon, not a double-bonded carbon. The double bond is between C-1 and C-2. Since the halogen-bearing carbon is separated from the double bond by another saturated carbon, this is an ordinary alkyl halide (specifically, a homoallylic halide), not an allylic halide.

(e) 3-bromo-2-methylpropene: The structure is $CH_2=C(CH_3)-CH_2-Br$.

The Br is attached to C-3. Carbon-3 is sp^3 hybridized and is directly adjacent to C-2, which is

part of the $C = C$ double bond. Therefore, this is an allylic halide.

Step 4: Final Answer:

The compound 4-bromobut-1-ene is not an allylic halide.

Quick Tip: Always sketch out the carbon skeleton when dealing with IUPAC nomenclature to visualize the relative positions of functional groups. Look for the distinct $C = C - C - X$ pattern to confirm an allylic halide.

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3. A neutral molecule XF_3 has a zero dipole moment. The element X is most likely:

(a) chlorine

(b) boron

(c) nitrogen

(d) carbon

(e) bromine

Correct Answer: (b) boron

Solution:

Step 1: Understanding the Concept:

The dipole moment of a molecule is the vector sum of its individual bond dipoles.

For a molecule with polar bonds (like $X - F$) to have a net dipole moment of exactly zero, its geometry must be perfectly symmetrical so that the individual bond dipole vectors cancel each other out completely.

According to VSEPR theory, an AB_3 type molecule is symmetrical and non-polar only if it has a trigonal planar geometry, meaning there are no lone electron pairs on the central atom.

Step 2: Key Formula or Approach:

1. Determine the number of valence electrons for the proposed central atom X.
2. Determine the steric number (Number of bonding pairs + Number of lone pairs) for the

XF_3 molecule.

3. Predict the molecular geometry using VSEPR theory.

4. Assess if that geometry allows for the cancellation of dipole moments.

Step 3: Detailed Explanation:

Let's evaluate each option to see which central atom leads to a trigonal planar geometry with zero lone pairs.

(a) Chlorine (Group 17): Has 7 valence electrons. In ClF_3, there are 3 bonding pairs and $(7-3)/2 = 2$ lone pairs. Steric number $= 5$ (sp^3d). The geometry is T-shaped. This is an asymmetrical shape, so ClF_3 has a non-zero dipole moment.

(b) Boron (Group 13): Has 3 valence electrons. In BF_3, it shares all 3 electrons with fluorine, resulting in 3 bonding pairs and 0 lone pairs. Steric number $= 3$ (sp^2). The geometry is perfectly trigonal planar. Because all three $B-F$ bonds are identical and arranged symmetrically at 120-degree angles, their dipole moments cancel out exactly. Net dipole moment is zero.

(c) Nitrogen (Group 15): Has 5 valence electrons. In NF_3, there are 3 bonding pairs and $(5-3)/2 = 1$ lone pair. Steric number $= 4$ (sp^3). The geometry is trigonal pyramidal. Because of the lone pair at the apex, the bond dipoles do not cancel out. Net dipole moment is non-zero.

(d) Carbon (Group 14): Has 4 valence electrons. A neutral CF_3 would be a radical species with an unpaired electron, not a stable, standard neutral molecule in this context. It generally forms stable molecules with 4 bonds like CF_4.

(e) Bromine (Group 17): Similar to chlorine, BrF_3 has 3 bonding pairs and 2 lone pairs, resulting in a T-shaped geometry and a non-zero dipole moment.

Step 4: Final Answer:

The element X is most likely Boron.

Quick Tip: For AB_n type molecules where all B atoms are identical, a zero dipole moment strongly indicates the absence of lone pairs on the central atom, leading to a highly symmetrical shape (linear for $n = 2$, trigonal planar for $n = 3$, tetrahedral for $n = 4$, etc.).

4. Among the following species, identify the pair having same bond order CN^-, O_2^-, NO^+, CN^+:

(a) CN^- and O_2^-

(b) O_2^- and NO^+

(c) CN^- and NO^+

(d) CN^- and CN^+

(e) NO^+ and CN^+

Correct Answer: (c) CN^- and NO^+

Solution:

Step 1: Understanding the Concept:

Bond order is an indicator of the stability and strength of a chemical bond.

According to Molecular Orbital (MO) theory, bond order is calculated as half the difference between the number of bonding electrons and anti-bonding electrons.

A highly useful shortcut in MO theory is that isoelectronic species (molecules or ions with the exact same total number of electrons) generally possess identical bond orders because their molecular orbital filling patterns are the same.

Step 2: Key Formula or Approach:

1. Calculate the total number of electrons for each given species by adding the atomic numbers of the constituent atoms and adjusting for any charge (add for negative charge, subtract for positive).

2. Use the standard correlation between total electron count and bond order for diatomic molecules:

- 14 electrons → Bond Order 3
- 15 or 13 electrons → Bond Order 2.5
- 16 or 12 electrons → Bond Order 2
- 17 or 11 electrons → Bond Order 1.5

Step 3: Detailed Explanation:

Let's determine the total electron count and the corresponding bond order for each species:

1. CN^- (Cyanide ion):

Total electrons = 6 (from Carbon) +7 (from Nitrogen) +1 (for the negative charge) = 14 electrons.

Species with 14 electrons are isoelectronic with N_2 and have a bond order of 3.

2. O_2^- (Superoxide ion):

Total electrons = 8 (from Oxygen) +8 (from Oxygen) +1 (for the negative charge) = 17 electrons.

Species with 17 electrons have a bond order of 1.5.

3. NO^+ (Nitrosonium ion):

Total electrons = 7 (from Nitrogen) +8 (from Oxygen) −1 (for the positive charge) = 14 electrons.

Species with 14 electrons are isoelectronic with N_2 and have a bond order of 3.

4. CN^+ (Cyanogen cation):

Total electrons = 6 (from Carbon) +7 (from Nitrogen) −1 (for the positive charge) = 12 electrons.

Species with 12 electrons are isoelectronic with C_2 and have a bond order of 2.

Comparing the results, we can see that both CN^- and NO^+ possess exactly 14 electrons and consequently share the same bond order of 3.

Step 4: Final Answer:

The pair with the same bond order is CN^- and NO^+.

Quick Tip: Memorize the "magic number" 14 for total electrons, which corresponds to the maximum bond order of 3 (like in N_2). For every electron added or removed from 14, the bond order drops by 0.5. This trick saves significant time compared to drawing full MO diagrams.

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5. Which one of the following conditions will favour maximum formation of the product in the reaction, $A_2(g) + B_2(g) \rightleftharpoons X_2(g) \quad \Delta_r H = -x$ kJ:

(a) Low temperature and high pressure

(b) Low temperature and low pressure

(c) High temperature and low pressure

(d) High temperature and high pressure

Correct Answer: (a) Low temperature and high pressure

Solution:

Step 1: Understanding the Concept:

The problem asks for conditions that maximize product formation, which means we want to shift the chemical equilibrium to the right (forward direction).

This behavior is governed by Le Chatelier's Principle, which states that if a system at equilibrium is subjected to a change in conditions (temperature, pressure, or concentration), the system will shift its equilibrium position to counteract that change.

Step 2: Key Formula or Approach:

We must analyze two distinct effects according to Le Chatelier's Principle:

1. **Effect of Temperature:** Look at the sign of the enthalpy change (ΔH).

- Exothermic ($\Delta H < 0$): Lowering temperature favors the forward reaction.

- Endothermic ($\Delta H > 0$): Raising temperature favors the forward reaction.

2. **Effect of Pressure:** Look at the change in the number of gaseous moles (Δn_g).

- Δn_g = moles of gaseous products − moles of gaseous reactants.

- Increasing pressure favors the direction that produces fewer gaseous moles.

Step 3: Detailed Explanation:

Let's analyze the given equilibrium reaction:

$$A_2(g) + B_2(g) \rightleftharpoons X_2(g)$$

Analyzing Temperature:

The enthalpy of reaction is given as $\Delta_r H = -x$ kJ.

The negative sign definitively indicates that the forward reaction is exothermic (it releases heat).

According to Le Chatelier's Principle, to favor an exothermic reaction (and thus maximize the product X_2), we must remove the heat it produces. This is achieved by maintaining a **low temperature**.

Analyzing Pressure:

First, count the number of moles of gas on each side of the balanced equation:

- Reactants: 1 mole of A_2 + 1 mole of B_2 = 2 moles of gas total.

- Products: 1 mole of $X_2 = 1$ mole of gas total.

The reaction proceeds with a decrease in the number of gaseous moles (from 2 down to 1).

According to Le Chatelier's Principle, an increase in system pressure will cause the equilibrium to shift toward the side with fewer moles of gas in an attempt to reduce that pressure.

Therefore, to shift the reaction forward to the product side (which has fewer moles), a **high pressure** must be applied.

Combining these two favorable conditions, we need low temperature and high pressure.

Step 4: Final Answer:

The maximum formation of the product is favored by low temperature and high pressure.

Quick Tip: Always treat heat as a chemical reagent to simplify temperature effects. For an exothermic reaction ($\Delta H < 0$), think of heat as a product: Reactants $\rightleftharpoons$ Products + Heat. To make more products, you must pull away the heat (lower the temperature).

PHYSICS

1. A light ray enters from medium 1 to medium 2. Its velocity in medium 1 is 2×10^8 m/s and in medium 2 is 1.5×10^8 m/s. The critical angle for the pair of media is:

(a) $\sin^{-1}(0.75)$

(b) $\sin^{-1}(0.5)$

(c) $\sin^{-1}(0.66)$

(d) $\sin^{-1}(0.8)$

Correct Answer: (a) $\sin^{-1}(0.75)$

Solution:

Step 1: Understanding the Concept:

The critical angle is defined when light travels from a denser medium (lower velocity) to a rarer medium (higher velocity). It is the angle of incidence for which the angle of refraction is 90°.

Step 2: Key Formula or Approach:

Using Snell's Law at the critical angle C:

$$n_{\text{denser}} \sin C = n_{\text{rarer}} \sin 90^\circ$$

Since refractive index $n = \frac{c}{v}$, we can write:

$$\sin C = \frac{n_{\text{rarer}}}{n_{\text{denser}}} = \frac{v_{\text{denser}}}{v_{\text{rarer}}}$$

Step 3: Detailed Explanation:

Given velocities:

Velocity in medium 1, $v_1 = 2 \times 10^8$ m/s (higher speed, so it is the rarer medium).

Velocity in medium 2, $v_2 = 1.5 \times 10^8$ m/s (lower speed, so it is the denser medium).

Substituting the values into the formula:

$$\sin C = \frac{1.5 \times 10^8}{2 \times 10^8} = \frac{1.5}{2} = 0.75$$

Therefore, the critical angle is:

$$C = \sin^{-1}(0.75)$$

Step 4: Final Answer:

The critical angle for the pair of media is $\sin^{-1}(0.75)$.

Quick Tip: Always remember that $\sin C$ must be less than or equal to 1. So, when dealing with velocities, always put the smaller velocity in the numerator and the larger velocity in the denominator: $\sin C = \frac{v_{\text{min}}}{v_{\text{max}}}$.

2. A container with a pin hole at the bottom is filled with water and kerosene (specific gravity 0.8). The height of the water layer is 10 cm and the kerosene layer is 20 cm. The velocity of efflux of water is:

(a) 2.3 m/s

(b) 4.5 m/s

(c) 1.5 m/s

(d) 3.2 m/s

Correct Answer: (a) 2.3 m/s

Solution:

Step 1: Understanding the Concept:

The velocity of efflux from a hole at the bottom of a container can be found using Torricelli's law, which is derived from Bernoulli's principle. When there are multiple layers of immiscible liquids, we calculate the equivalent head of water or use the total pressure at the hole.

Step 2: Key Formula or Approach:

The pressure P at the bottom of the container just inside the hole is:

$$P = P_{atm} + \rho_w g h_w + \rho_k g h_k$$

Applying Bernoulli's equation between the top free surface and the pinhole:

$$P_{atm} + \rho_k g h_k + \rho_w g h_w = P_{atm} + \frac{1}{2}\rho_w v^2$$

This gives the velocity of efflux v:

$$v = \sqrt{2g\left(h_w + \frac{\rho_k}{\rho_w} h_k\right)}$$

Step 3: Detailed Explanation:

Given values:

Height of water, $h_w = 10$ cm $= 0.1$ m

Height of kerosene, $h_k = 20$ cm $= 0.2$ m

Specific gravity of kerosene $= \frac{\rho_k}{\rho_w} = 0.8$

Taking acceleration due to gravity, $g = 9.8$ m/s^2 (or 10 m/s^2 for approximation):

$$v = \sqrt{2 \times 10 \times (0.1 + 0.8 \times 0.2)}$$

$$v = \sqrt{20 \times (0.1 + 0.16)}$$

$$v = \sqrt{20 \times 0.26}$$

$$v = \sqrt{5.2} \approx 2.28 \text{ m/s}$$

Using $g = 9.8$ m/s^2, we get $v = \sqrt{2 \times 9.8 \times 0.26} = \sqrt{5.096} \approx 2.26$ m/s.

Rounding to one decimal place, it matches 2.3 m/s.

Step 4: Final Answer:

The velocity of efflux of water is approximately 2.3 m/s.

Quick Tip: For multiple liquid layers, calculate the "equivalent height" of the bottom-most liquid. Here, $h_{eq} = h_w + (\text{specific gravity of top liquid}) \times h_k$. Then simply use $v = \sqrt{2gh_{eq}}$.

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3. In a Young's double slit experiment, the intensity at a point where the path difference is $\frac{\lambda}{6}$ (λ being the wavelength of light used) is I. If I_0 denotes the maximum intensity, I/I_0 is equal to:

(a) 1/2

(b) $\sqrt{3}/2$

(c) 3/4

(d) 1/4

Correct Answer: (c) 3/4

Solution:

Step 1: Understanding the Concept:

In Young's double slit experiment, the intensity at any point on the screen depends on the phase difference between the two interfering light waves.

Step 2: Key Formula or Approach:

The relation between phase difference (ϕ) and path difference (Δx) is:

$$\phi = \frac{2\pi}{\lambda} \times \Delta x$$

The intensity I at a point is given by the formula:

$$I = I_0 \cos^2\left(\frac{\phi}{2}\right)$$

where I_0 is the maximum intensity.

Step 3: Detailed Explanation:

Given path difference, $\Delta x = \frac{\lambda}{6}$.

Calculate the phase difference ϕ:

$$\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{6} = \frac{\pi}{3} \text{ radians}$$

Now, calculate the ratio I/I_0:

$$\frac{I}{I_0} = \cos^2\left(\frac{\phi}{2}\right) = \cos^2\left(\frac{\pi/3}{2}\right) = \cos^2\left(\frac{\pi}{6}\right)$$

Since $\cos\left(\frac{\pi}{6}\right) = \frac{\sqrt{3}}{2}$:

$$\frac{I}{I_0} = \left(\frac{\sqrt{3}}{2}\right)^2 = \frac{3}{4}$$

Step 4: Final Answer:

The ratio I/I_0 is equal to $3/4$.

Quick Tip: Remember the standard trigonometric values and the relation between phase and path difference: $\frac{\text{Phase Difference}}{2\pi} = \frac{\text{Path Difference}}{\lambda}$.

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4. A particle of mass m is moving in a circular path of constant radius r such that its centripetal acceleration a_c is varying with time t as $a_c = k^2 r t^2$, where k is a constant. The power delivered to the particle by the forces acting on it is:

(a) $2\pi m k^2 r^2 t$

(b) $m k^2 r^2 t$

(c) $\frac{1}{3} m k^4 r^2 t^5$

(d) 0

Correct Answer: (b) $m k^2 r^2 t$

Solution:

Step 1: Understanding the Concept:

Power is the rate at which work is done by forces. In circular motion, the net force has a centripetal component and a tangential component. Only the tangential force does work because it is in the direction of velocity.

Step 2: Key Formula or Approach:

Centripetal acceleration: $a_c = \frac{v^2}{r}$

Tangential acceleration: $a_t = \frac{dv}{dt}$

Power delivered: $P = \vec{F} \cdot \vec{v} = (F_t \hat{t} + F_c \hat{n}) \cdot (v \hat{t}) = F_t v = m a_t v$

where F_t is the tangential force and v is the velocity.

Step 3: Detailed Explanation:

Given $a_c = k^2 r t^2$.

We know $a_c = \frac{v^2}{r}$, so:

$$\frac{v^2}{r} = k^2 r t^2 \implies v^2 = k^2 r^2 t^2 \implies v = krt$$

Now, find the tangential acceleration a_t by differentiating velocity v with respect to time t:

$$a_t = \frac{dv}{dt} = \frac{d}{dt}(krt) = kr$$

The tangential force is:

$$F_t = ma_t = mkr$$

The power P delivered is:

$$P = F_t \cdot v = (mkr) \cdot (krt) = mk^2 r^2 t$$

The centripetal force acts perpendicular to the velocity, so it delivers zero power.

Step 4: Final Answer:

The power delivered to the particle is $mk^2 r^2 t$.

Quick Tip: In any curved path, power is always $P = F_{\text{tangential}} \times v$. The normal/centripetal force never contributes to power since $\cos(90^\circ) = 0$.

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5. A source of frequency f gives 5 beats/sec when sounded with a source of frequency 200 Hz. The second harmonic of f gives 10 beats/sec when sounded with a source of frequency 420 Hz. The value of f is:

(a) 195 Hz

(b) 205 Hz

(c) 190 Hz

(d) 210 Hz

Correct Answer: (b) 205 Hz

Solution:

Step 1: Understanding the Concept:

The beat frequency is the absolute difference between the frequencies of two sounding sources. By using multiple conditions, we can eliminate ambiguities and find the exact frequency.

Step 2: Key Formula or Approach:

Beat frequency $n = |f_1 - f_2|$.

Second harmonic of a frequency f is $2f$.

Step 3: Detailed Explanation:

From the first condition, a frequency f gives 5 beats/sec with 200 Hz:

$$|f - 200| = 5$$

This gives two possible values for f:

$$f = 200 + 5 = 205 \text{ Hz} \quad \text{or} \quad f = 200 - 5 = 195 \text{ Hz}$$

From the second condition, the second harmonic ($2f$) gives 10 beats/sec with 420 Hz:

$$|2f - 420| = 10$$

This gives two possible values for $2f$:

$$2f = 420 + 10 = 430 \text{ Hz} \implies f = 215 \text{ Hz}$$

$$\text{or} \quad 2f = 420 - 10 = 410 \text{ Hz} \implies f = 205 \text{ Hz}$$

Comparing the possible values from both conditions, the only common frequency is

$f = 205$ Hz.

Step 4: Final Answer:

The value of f is 205 Hz.

Quick Tip: Always solve beat frequency problems by calculating both ± possibilities for each given condition, then find the intersection of the sets of possible values.
