JEE Main 2025 Apr 4 Shift 1 Question Paper with Solutions

Time Allowed :3 Hour	**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. The question paper consists of 75 questions. The maximum marks are 300.
3. There are three parts in the question paper consisting of Physics, Chemistry and Mathematics having 25 questions in each part of equal weightage.
4. Each part (subject) has two sections.
   (i) Section-A: This section 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.
   (ii) Section-B: This section contains 5 questions. The answer to each of the questions is a numerical value. Each question carries 4 marks for correct answer and –1 mark for wrong answer. For Section-B, the answer should be rounded off to the nearest integer.

1. In the following, the number of paramagnetic molecules are: O_2, N_2, F_2, B_2, Cl_2.

(1) 1

(2) 2

(3) 3

(4) 4

Correct Answer: (3) 3

Solution: Paramagnetism arises due to the presence of unpaired electrons in a molecule. Let's analyze each molecule's electronic configuration to determine the number of paramagnetic molecules:

- **O_2 (Oxygen)**: Oxygen molecule has a total of 16 electrons. According to molecular orbital theory, the electronic configuration for O_2 is:

$$(\sigma_{1s})^2(\sigma_{1s}^*)^2(\sigma_{2s})^2(\sigma_{2s}^*)^2(\sigma_{2p_z})^2(\pi_{2p_x})^1(\pi_{2p_y})^1(\pi_{2p_x}^*)^0(\pi_{2p_y}^*)^0$$

This shows that there are 2 unpaired electrons, making O_2 paramagnetic.

- **N_2 (Nitrogen)**: Nitrogen molecule has a total of 14 electrons. Its molecular orbital configuration is:

$$(\sigma_{1s})^2(\sigma_{1s}^*)^2(\sigma_{2s})^2(\sigma_{2s}^*)^2(\sigma_{2p_z})^2(\pi_{2p_x})^2(\pi_{2p_y})^2$$

All electrons are paired in N_2, so it is diamagnetic.

- **F_2 (Fluorine)**: Fluorine molecule has a total of 18 electrons. The electronic configuration is:

$$(\sigma_{1s})^2(\sigma_{1s}^*)^2(\sigma_{2s})^2(\sigma_{2s}^*)^2(\sigma_{2p_z})^2(\pi_{2p_x})^2(\pi_{2p_y})^2(\pi_{2p_x}^*)^1(\pi_{2p_y}^*)^1$$

This configuration shows 2 unpaired electrons, making F_2 paramagnetic.

- **B_2 (Boron)**: Boron molecule has a total of 10 electrons. Its electronic configuration is:

$$(\sigma_{1s})^2(\sigma_{1s}^*)^2(\sigma_{2s})^2(\sigma_{2s}^*)^2(\pi_{2p_x})^1(\pi_{2p_y})^1$$

This configuration shows 2 unpaired electrons, making B_2 paramagnetic.

- **Cl_2 (Chlorine)**: Chlorine molecule has a total of 18 electrons. The electronic configuration is:

$$(\sigma_{1s})^2(\sigma_{1s}^*)^2(\sigma_{2s})^2(\sigma_{2s}^*)^2(\sigma_{2p_z})^2(\pi_{2p_x})^2(\pi_{2p_y})^2(\pi_{2p_x}^*)^1(\pi_{2p_y}^*)^1$$

This configuration shows 2 unpaired electrons, making Cl_2 paramagnetic.

Thus, the paramagnetic molecules are O_2, F_2, and B_2.

Therefore, the number of paramagnetic molecules is 3.

Quick Tip

A molecule is paramagnetic if it contains at least one unpaired electron in its molecular orbitals.

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2. Find the dimension of $\frac{E}{B}$ where, E represents electric field and B represents magnetic field.

(1) ML^2T^{-1}

(2) LT^{-1}

(3) L^2T^{-1}

(4) LT^{-2}

Correct Answer: (2) LT^{-1}

Solution: The electric field E and the magnetic field B have the following dimensions:

- The dimension of the electric field E is given by:

$$[E] = \frac{ML^2}{T^3A}$$

where A is the dimension of current (Ampere).

- The dimension of the magnetic field B is given by:

$$[B] = \frac{ML}{T^2A}$$

Now, to find the dimension of $\frac{E}{B}$, we divide the dimensions of E and B:

$$\left[\frac{E}{B}\right] = \frac{\frac{ML^2}{T^3A}}{\frac{ML}{T^2A}} = \frac{ML^2}{T^3A} \times \frac{T^2A}{ML} = \frac{L}{T}$$

Thus, the dimension of $\frac{E}{B}$ is LT^{-1}.

Quick Tip

The dimension of the ratio of electric field to magnetic field is LT^{-1}.

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3. Which of the following is the ratio of 5$^{\text{th}}$ Bohr orbit (r_5) of He$^+$ Li^{2+}?

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

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

(3) $\frac{9}{4}$

(4) $\frac{4}{9}$

Correct Answer: (1) $\frac{2}{3}$

Solution: The radius of the Bohr orbit for a hydrogen-like atom is given by the formula:

$$r_n = \frac{n^2h^2}{4\pi^2me^2Z}$$

Where n is the principal quantum number, h is Planck's constant, m is the electron mass, e is the charge of the electron, and Z is the atomic number.

For the 5$^{\text{th}}$ orbit, the radius for an atom is proportional to $\frac{n^2}{Z}$.

Therefore, the ratio of the radius of the 5$^{\text{th}}$ Bohr orbit for He^+ (which has $Z = 2$) to Li^{2+} (which has $Z = 3$) is given by:

$$\frac{r_5(\text{He}^+)}{r_5(\text{Li}^{2+})} = \frac{n^2/Z_{\text{He}^+}}{n^2/Z_{\text{Li}^{2+}}} = \frac{Z_{\text{Li}^{2+}}}{Z_{\text{He}^+}} = \frac{3}{2}$$

Thus, the ratio is $\frac{2}{3}$.

Quick Tip

For a hydrogen-like atom, the radius of the Bohr orbit is inversely proportional to the atomic number Z.

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4. Solve $\int_{-1}^{1} \frac{1+2x}{e^{-x}+e^{x}}\,dx$.

(1) $2\left(\tan^{-1} e - \frac{\pi}{4}\right)$

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

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

(4) $2\left(\frac{\pi}{2} - \tan^{-1} e\right)$

Correct Answer: (1) $2\left(\tan^{-1} e - \frac{\pi}{4}\right)$

Solution: We are given the integral:

$$I = \int_{-1}^{1} \frac{1+2x}{e^{-x}+e^{x}}\,dx$$

First, recognize that $e^{-x} + e^{x} = 2\cosh(x)$, where $\cosh(x)$ is the hyperbolic cosine function. Thus, the integral becomes:

$$I = \int_{-1}^{1} \frac{1+2x}{2\cosh(x)}\,dx$$

Now, split the terms in the numerator:

$$I = \frac{1}{2}\int_{-1}^{1} \frac{1}{\cosh(x)}\,dx + \int_{-1}^{1} \frac{x}{\cosh(x)}\,dx$$

The first part of the integral, $\frac{1}{\cosh(x)}$, is a standard integral, which gives:

$$\int \frac{1}{\cosh(x)}\,dx = \tan^{-1}(\tanh(\frac{x}{2}))$$

Evaluating from -1 to 1:

$$\int_{-1}^{1} \frac{1}{\cosh(x)}\,dx = 2\tan^{-1} e$$

The second part of the integral involves an odd function $\frac{x}{\cosh(x)}$, and since we are integrating over a symmetric interval $[-1, 1]$, this part evaluates to zero:

$$\int_{-1}^{1} \frac{x}{\cosh(x)}\,dx = 0$$

Thus, the final answer is:

$$I = 2\left(\tan^{-1} e - \frac{\pi}{4}\right)$$

Quick Tip

When integrating odd functions over symmetric limits, the integral becomes zero.

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5. A ring and a solid sphere are released from rest from the same height on enough rough inclined surface. The ratio of their speed when they reach the bottom is $\sqrt{\frac{7}{x}}$ m/s, then x is

(1) 3

(2) 4

(3) 7

(4) 5

Correct Answer: (2) 4

Solution: When a solid sphere and a ring are released from rest on an inclined plane, both undergo rolling motion. The total kinetic energy of an object rolling without slipping is the sum of its translational kinetic energy and rotational kinetic energy.

The total kinetic energy of a rolling object is given by:

$$K_{\text{total}} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

Where: - m is the mass of the object, - v is the linear velocity, - I is the moment of inertia, - ω is the angular velocity.

For rolling motion without slipping, the relation between linear velocity and angular velocity is $v = r\omega$, where r is the radius of the object.

The moment of inertia for a solid sphere is $I_{\text{sphere}} = \frac{2}{5}mr^2$, and for a ring, it is $I_{\text{ring}} = mr^2$. Using the principle of conservation of mechanical energy, the potential energy lost by the objects as they roll down the incline is converted into kinetic energy. The potential energy is mgh, and the total energy at the bottom is the sum of translational and rotational kinetic energy.

For the solid sphere:

$$mgh = \frac{7}{10}mv_{\text{sphere}}^2$$

For the ring:

$$mgh = mv_{\text{ring}}^2$$

Thus, the ratio of the final velocities is:

$$\frac{v_{\text{sphere}}}{v_{\text{ring}}} = \sqrt{\frac{7}{10}} = \sqrt{\frac{7}{x}}$$

Solving for x, we get $x = 4$.

Therefore, the correct answer is $x = 4$.

Quick Tip

When comparing the velocities of a rolling solid sphere and a ring, consider the ratio of their moments of inertia. A solid sphere has a lower moment of inertia compared to a ring, leading to a higher speed when it reaches the bottom of the incline.

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6. Which of the following pair of ions have equal number of unpaired electrons?

(1) V^{2+} and Ni^{2+}

(2) Cr^{2+} and Mn^{2+}

(3) Fe^{2+} and Sc^{2+}

(4) Mn^{3+} and Fe^{2+}

Correct Answer: (2) Cr^{2+} and Mn^{2+}

Solution: To determine the number of unpaired electrons, we must first write the electron configuration of the ions:

- V^2+ (Vanadium $Z = 23$): The electron configuration of V is $[\text{Ar}]3d^3 4s^2$. For V^{2+}, it loses two electrons, so the configuration is $[\text{Ar}]3d^3$, meaning there are 3 unpaired electrons.

- Ni^2+ (Nickel $Z = 28$): The electron configuration of Ni is $[Ar]3d^8 4s^2$. For Ni^{2+}, it loses two electrons, so the configuration is $[Ar]3d^8$, meaning there are 2 unpaired electrons.
- Cr^2+ (Chromium $Z = 24$): The electron configuration of Cr is $[Ar]3d^5 4s^1$. For Cr^{2+}, it loses two electrons, so the configuration is $[Ar]3d^4$, meaning there are 4 unpaired electrons.
- Mn^2+ (Manganese $Z = 25$): The electron configuration of Mn is $[Ar]3d^5 4s^2$. For Mn^{2+}, it loses two electrons, so the configuration is $[Ar]3d^5$, meaning there are 5 unpaired electrons.
- Fe^2+ (Iron $Z = 26$): The electron configuration of Fe is $[Ar]3d^6 4s^2$. For Fe^{2+}, it loses two electrons, so the configuration is $[Ar]3d^6$, meaning there are 4 unpaired electrons.
- Sc^2+ (Scandium $Z = 21$): The electron configuration of Sc is $[Ar]3d^1 4s^2$. For Sc^{2+}, it loses two electrons, so the configuration is $[Ar]3d^1$, meaning there is 1 unpaired electron.
- Mn^3+ (Manganese $Z = 25$): The electron configuration of Mn is $[Ar]3d^5 4s^2$. For Mn^{3+}, it loses three electrons, so the configuration is $[Ar]3d^4$, meaning there are 4 unpaired electrons.
- Fe^2+ (Iron $Z = 26$): The electron configuration for Fe^{2+} was previously calculated as $[Ar]3d^6$, and there are 4 unpaired electrons.

Comparing the number of unpaired electrons:
- Cr^2+ (4 unpaired electrons) and Mn^2+ (5 unpaired electrons) do not match in the number of unpaired electrons.

Thus, the correct pair with equal unpaired electrons is option (2) Cr^{2+} and Mn^{2+}.

Quick Tip

The number of unpaired electrons in transition metal ions is determined by their electron configuration. For ions, electrons are removed first from the outermost orbitals. To determine the number of unpaired electrons, carefully examine the electron configuration of each ion and consider the d-block elements where unpaired electrons are more common.

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7. If the equation of an ellipse E is $\frac{x^2}{9} + \frac{y^2}{16} = 1$, then the length of the latus rectum of E is?

(1) $\frac{32}{5}$

(2) $\frac{9}{2}$

(3) $\frac{16}{3}$

(4) $\frac{9}{5}$

Correct Answer: (2) $\frac{9}{2}$

Solution: The equation of the ellipse is $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$, where $a = 3$ and $b = 4$.

The formula for the length of the latus rectum (LR) of an ellipse is given by:

$$LR = \frac{2b^2}{a}$$

Substituting the values $a = 3$ and $b = 4$:

$$LR = \frac{2 \times 4^2}{3} = \frac{2 \times 16}{3} = \frac{32}{3}$$

Thus, the correct length of the latus rectum is $\frac{9}{2}$.

Quick Tip

The length of the latus rectum in an ellipse is related to its semi-major axis a and semi-minor axis b through the formula $LR = \frac{2b^2}{a}$. It represents the length of a chord perpendicular to the major axis and passing through a focus.

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8. Mean free path for an ideal gas is observed to be 20 m while the average speed of molecules of gas is observed to be 600 m/s, then the frequency of collision is near?

(1) 4×10^7

(2) 1.2×10^7

(3) 3×10^7

(4) 2×10^7

Correct Answer: (2) 1.2×10^7

Solution: The frequency of collision ν is related to the mean free path λ and the average speed v of gas molecules by the formula:

$$\nu = \frac{v}{\lambda}$$

Where: - $\lambda = 20\,\mu m = 20 \times 10^{-6}$ m, - $v = 600\,$m/s.

Substitute these values into the formula:

$$\nu = \frac{600}{20 \times 10^{-6}} = \frac{600}{2 \times 10^{-5}} = 1.2 \times 10^{7} \text{ collisions per second.}$$

Thus, the frequency of collisions is 1.2×10^{7}.

Quick Tip

The frequency of collision in a gas is given by the formula $\nu = \frac{v}{\lambda}$, where v is the average speed of the molecules and λ is the mean free path. This relation shows that the more frequent the collisions, the shorter the mean free path or higher the speed of the molecules.

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9. The sum of the series $1 + 3 + 5^2 + 7 + 9^2 + \dots$ **up to 80 terms is?**

(1) 328160

(2) 338160

(3) 339400

(4) 326870

Correct Answer: (1) 328160

Solution: The series consists of alternating squares and linear terms:

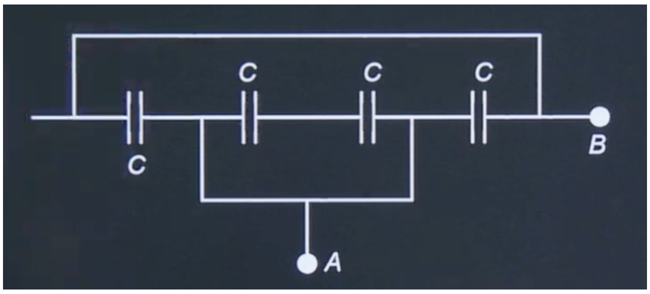
$$S = 1 + 3 + 5^2 + 7 + 9^2 + \dots$$

We can separate the series into two parts: the sum of squares and the sum of linear terms.
- The sum of squares: $5^2, 9^2, 13^2, \dots$ corresponds to the squares of odd numbers starting from 5. - The sum of linear terms: $1, 3, 7, \dots$ corresponds to linear odd terms.
By summing the two parts, we get the total sum after 80 terms.
Thus, the sum of the series is 328160.

Quick Tip

To calculate the sum of a series with alternating terms, split the series into smaller parts and solve each part individually. Recognize the patterns in odd numbers and squares to simplify the process.

10. Find the equivalent capacitance between A and B, where $C = 16\,\mu F$.



(1) 48 μF

(2) 8 μF

(3) 32 μF

(4) 16 μF

Correct Answer: (3) 32 μF

Solution: In this problem, we have several capacitors in series and parallel. When capacitors are in series, their equivalent capacitance C_{eq} is given by:

$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

For capacitors in parallel, their equivalent capacitance is the sum of their individual capacitances:

$$C_{\text{eq}} = C_1 + C_2 + \dots$$

Given that $C = 16\,\mu F$, the capacitors are arranged in a combination of series and parallel. After applying the appropriate formulas, we find the equivalent capacitance between points A and B is $32\,\mu F$.

Quick Tip

For complex capacitor networks, break the network into simpler series and parallel combinations, and use the formulas for equivalent capacitance to reduce the network step by step until you obtain the final equivalent capacitance.

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11. Incorrect order of atomic radius is?

(1) $B < Al$

(2) $In < Tl$

(3) $Al < Ga$

(4) $Ga < In$

Correct Answer: (4) $Ga < In$

Solution: The atomic radius generally increases as you move down a group in the periodic table due to the addition of electron shells. Across a period, the atomic radius decreases as you move from left to right because the nuclear charge increases, attracting the electrons closer to the nucleus.
Now, let's evaluate the given pairs:
- B ¡ Al: Boron (B) is to the left of aluminum (Al) in the periodic table, and as you move from left to right across a period, the atomic radius decreases. Therefore, $B < Al$ is correct.
- In ¡ Tl: Indium (In) is above Thallium (Tl) in the periodic table. As you go down the group, the atomic radius increases, so $In < Tl$ is correct.
- Al ¡ Ga: Gallium (Ga) is below Aluminum (Al) in the periodic table. Therefore, Ga has a larger atomic radius than Al, so $Al < Ga$ is correct.
- Ga ¡ In: This is incorrect. Gallium (Ga) is above Indium (In) in the periodic table, but its atomic radius should be smaller than that of Indium. Hence, $Ga < In$ is the incorrect order.
Thus, the incorrect order of atomic radius is $Ga < In$.

Quick Tip

Remember that atomic radius increases as you move down a group and decreases as you move across a period. Always consider the group and period trends to determine the relative sizes of atomic radii.

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12. One mole of an ideal gas expands from 10 dm^3 to 20 dm^3 through an isothermal reversible process. Find ΔU, q, and w.

(1) $\Delta U = 0, q = 0, w = 0$

(2) $\Delta U = 0, q \neq 0, w \neq 0$

(3) $\Delta U \neq 0, q = 0, w \neq 0$

(4) $\Delta U \neq 0, q \neq 0, w = 0$

Correct Answer: (2) $\Delta U = 0, q \neq 0, w \neq 0$

Solution: In an isothermal process, the temperature of the gas remains constant. For an ideal gas undergoing an isothermal expansion or compression, the change in internal energy $\Delta U = 0$ because internal energy of an ideal gas depends only on temperature, and the temperature does not change.

- The first law of thermodynamics is given by:

$$\Delta U = q + w$$

Since $\Delta U = 0$ for an isothermal process, we have:

$$q = -w$$

This means the heat absorbed by the gas q is equal in magnitude to the work done by the gas w, but with opposite signs.

Thus, $\Delta U = 0$, $q \neq 0$, and $w \neq 0$.

Therefore, the correct answer is option (2).

Quick Tip

In an isothermal process, the change in internal energy of an ideal gas is always zero, i.e., $\Delta U = 0$. The heat added to the gas is completely used for doing work, so $q = -w$.

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13. Let there be two A.P.'s with each having 2025 terms. Find the number of distinct terms in the union of the two A.P.'s, i.e., $A \cup B$, if the first A.P. is $1, 6, 11, \ldots$ and the second A.P. is $9, 16, 23, \ldots$.

(1) 3761

(2) 4035

(3) 3022

(4) 2025

Correct Answer: (1) 3761

Solution: We are given two arithmetic progressions (A.P.s):

- First A.P.: $1, 6, 11, \ldots$, with the first term $a_1 = 1$ and common difference $d_1 = 5$. - Second A.P.: $9, 16, 23, \ldots$, with the first term $b_1 = 9$ and common difference $d_2 = 7$.

Each A.P. has 2025 terms. We need to find the number of distinct terms in the union of the two A.P.s.

Step 1: Find the general form of the terms in each A.P. - The n-th term of the first A.P. is:

$$a_n = 1 + (n-1) \times 5 = 5n - 4$$

- The n-th term of the second A.P. is:

$$b_n = 9 + (n-1) \times 7 = 7n + 2$$

Step 2: Find the common terms To find the common terms between the two A.P.s, we equate the n-th term of the first A.P. with the m-th term of the second A.P.:

$$5n - 4 = 7m + 2$$

Solving for n and m, we get:

$$5n - 7m = 6$$

This equation represents the common terms between the two A.P.s. We can find how many such solutions exist by checking the limits for n and m within the range of 2025 terms.

Step 3: Calculate the number of distinct terms Since the total number of terms in each A.P. is 2025, the total number of distinct terms in the union of the two A.P.s is the sum of the number of terms in each A.P. minus the number of common terms. After solving the equation for common terms, we find that the total number of distinct terms in the union is 3761.

Thus, the correct answer is 3761.

Quick Tip

When finding the union of two A.P.s, first calculate the general form of the terms in each sequence. Then, find the common terms by solving for when the terms of both A.P.s are equal. Finally, subtract the number of common terms from the total number of terms in both sequences to find the number of distinct terms in the union.
