JEE Main 2024 Physics Question Paper April 6 Shift 1 with Solutions

Time Allowed :3 Hours	**Maximum Marks :**300	**Total Questions :**90

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 90 questions, out of which 75 are to attempted. The maximum marks are 300.
3. There are three parts in the question paper consisting of Physics, Chemistry and Mathematics having 30 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 10 questions. In Section-B, attempt any five questions out of 10. 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

Physics

1. A particle of mass m is situated on the earth's surface. Find the minimum kinetic energy required so that it can escape from the earth's surface.

Correct Answer: $\frac{GMm}{R}$

Solution:

Step 1: Escape velocity formula.
The escape velocity V_e is given by the formula:

$$V_e = \sqrt{\frac{2GM}{R}}$$

Step 2: Kinetic energy required.
The minimum kinetic energy required for the particle to escape is given by:

$$KE = \frac{1}{2}mv_e^2$$

Substituting the value of V_e, we get:

$$KE = \frac{1}{2}m \times \frac{2GM}{R} = \frac{GMm}{R}$$

Step 3: Conclusion.
Thus, the minimum kinetic energy required for the particle to escape the earth's surface is $\frac{GMm}{R}$.

> **Quick Tip**
>
> Escape velocity is the minimum velocity an object needs to escape from a celestial body's gravitational influence, and it is derived from the gravitational potential energy and kinetic energy balance.

---

2. Which of the following does not explain the wave theory of a particle?

(1) Reflection
(2) Diffraction
(3) Photoelectric effect
(4) Interference

Correct Answer: (3) Photoelectric effect

Solution:

Step 1: Understanding wave theory.
Wave theory explains the behavior of light as a wave, accounting for phenomena like diffraction, reflection, and interference. However, the photoelectric effect cannot be explained using the wave theory of light, as it requires a particle theory to account for the ejection of electrons from metal surfaces when exposed to light.

Step 2: Analyzing the options.
(1) Reflection: Reflection is a wave phenomenon and is explained by the wave theory of light.
(2) Diffraction: Diffraction is another wave phenomenon that is explained by the wave theory.
(3) Photoelectric effect: The photoelectric effect cannot be explained by the wave theory of light and requires the particle theory (quantum theory).
(4) Interference: Interference is also a wave phenomenon and is explained by wave theory.

Step 3: Conclusion.
Thus, the correct answer is **(3) Photoelectric effect**, as it cannot be explained by wave theory.

> **Quick Tip**
>
> The photoelectric effect led to the development of quantum theory, showing the particle nature of light, while diffraction, reflection, and interference are explained by wave theory.

3. Which of the above phenomena represent particle nature?

(1) Interference
(2) Diffraction
(3) Polarisation
(4) Photoelectric effect

Correct Answer: (4) Photoelectric effect

Solution:

Step 1: Understanding the phenomena.
The phenomena of interference, diffraction, and polarisation are explained using the wave theory of light, as they involve the behavior of light as a wave. The photoelectric effect, however, cannot be explained by wave theory and requires a particle theory, leading to the development of quantum mechanics.

Step 2: Analyzing the options.
(1) Interference: Interference is a wave phenomenon and cannot be explained by particle theory.
(2) Diffraction: Diffraction is also a wave phenomenon, explained by the wave theory.
(3) Polarisation: Polarisation is a characteristic of waves and does not represent particle nature.
(4) Photoelectric effect: The photoelectric effect, which involves the emission of electrons from a material when exposed to light, can only be explained by the particle nature of light. This was one of the key experiments that supported the quantum theory of light.

Step 3: Conclusion.
Thus, the correct answer is **(4) Photoelectric effect**, as it represents the particle nature of light.

Quick Tip

The photoelectric effect led to the development of quantum theory, showing the particle nature of light, whereas diffraction, interference, and polarisation are wave phenomena.

---

4. In a prism, the ratio of minimum deviation and prism angle is $\sqrt{3}$, and the refractive index of the prism is $\sqrt{3}$. Find the prism angle A.

Correct Answer: $A = 60°$

Solution:

Step 1: Given values.
It is given that the refractive index $\mu = \sqrt{3}$ and the ratio of minimum deviation and prism angle is $\sqrt{3}$. We are asked to find the prism angle A.

Step 2: Relationship between deviation and prism angle.
The minimum deviation δ_{min} and prism angle A are related by:

$$\mu = \sin\left(\frac{A + \delta_{\text{min}}}{2}\right) \div \sin\left(\frac{A}{2}\right)$$

From the given ratio, $\frac{\delta_{\text{min}}}{A} = 1$, hence $\delta_{\text{min}} = A$. Substituting this into the above equation:

$$\mu = \sin\left(\frac{A + A}{2}\right) \div \sin\left(\frac{A}{2}\right) = \sqrt{3}$$

Simplifying this equation, we get:

$$\sqrt{3} = 2\cos\left(\frac{A}{2}\right)$$

Dividing both sides by 2:

$$\frac{\sqrt{3}}{2} = \cos\left(\frac{A}{2}\right)$$

Since $\cos(30°) = \frac{\sqrt{3}}{2}$, we conclude that:

$$\frac{A}{2} = 30°$$

Thus,

$$A = 60°$$

Step 3: Conclusion.
Thus, the prism angle A is $60°$.

Quick Tip

In prism-related problems, remember that the refractive index μ is often used in the formula involving minimum deviation and prism angle to find the unknowns.

---

5. Speed of wave in a medium is 1.5×10^8 m/s. Relative permittivity of medium (ϵ_r) is 2. Find the value of relative permeability.

Correct Answer: 2

Solution:

Step 1: Relating speed of light, permittivity, and permeability.
The speed of light in a medium is given by:

$$C = \frac{1}{\sqrt{\mu_0 \epsilon_0}} \quad \text{and} \quad v = \frac{1}{\sqrt{\mu \epsilon}}$$

where $\mu = \mu_0 \mu_r$ and $\epsilon = \epsilon_0 \epsilon_r$, with μ_0 and ϵ_0 being the permeability and permittivity of free space, respectively.

Step 2: Substituting given values.
The speed in the medium is given as 1.5×10^8 m/s, and the relative permittivity $\epsilon_r = 2$. Therefore, we can write:

$$1.5 \times 10^8 = \frac{1}{\sqrt{\mu_0 \mu_r \times \epsilon_0 \epsilon_r}}$$

This simplifies to:

$$\mu_0 \epsilon_0 \mu_r \epsilon_r = \left(\frac{1}{1.5 \times 10^8} \right)^2$$

Step 3: Solving for relative permeability.
Now, substitute $\epsilon_r = 2$ into the equation:

$$\mu_0 \epsilon_0 \mu_r \times 2 = \frac{1}{(1.5 \times 10^8)^2}$$

Simplifying further:

$$\mu_r \times 2 = \frac{1}{(1.5 \times 10^8)^2 \mu_0 \epsilon_0}$$

Step 4: Final Calculation.
Using the known values for μ_0 and ϵ_0, we find:

$$\mu_r = 2$$

Step 5: Conclusion.
Thus, the value of the relative permeability μ_r is 2.

Quick Tip

The relative permeability and permittivity of a medium affect the speed of electromagnetic waves in that medium. These properties are used in the formula to calculate the wave speed.

6. There is a pulley block system where $m_1 > m_2$ and the acceleration of block m_1 is $\frac{g}{\sqrt{2}}$ upward. Find the ratio of m_1 to m_2.

Correct Answer: $3 - 2\sqrt{2}$

Solution:

Step 1: Write the equation for acceleration.
The acceleration of the block is given by the formula:

$$a = \frac{(m_2 - m_1)}{(m_1 + m_2)}g$$

Step 2: Substitute the given values.
We are given that the acceleration of block m_1 is $\frac{g}{\sqrt{2}}$. So, we substitute $a = \frac{g}{\sqrt{2}}$ into the equation:

$$\frac{g}{\sqrt{2}} = \frac{(m_2 - m_1)}{(m_1 + m_2)}g$$

Step 3: Simplify the equation.
Canceling g from both sides:

$$\frac{1}{\sqrt{2}} = \frac{(m_2 - m_1)}{(m_1 + m_2)}$$

Step 4: Rearrange to solve for $\frac{m_1}{m_2}$.
Cross-multiplying:

$$1 = \sqrt{2} - \sqrt{2}\left(\frac{m_1}{m_2}\right)$$

Simplifying:

$$1 + \frac{m_1}{m_2} = \sqrt{2} - \sqrt{2}\left(\frac{m_1}{m_2}\right)$$

Step 5: Solve for the ratio $\frac{m_1}{m_2}$.
Solving this gives us:

$$\frac{m_1}{m_2} = \frac{\sqrt{2} - 1}{\sqrt{2} + 1}$$

Step 6: Conclusion.
The ratio of m_1 to m_2 is:

$$m_1 : m_2 = 3 - 2\sqrt{2}$$

Quick Tip

In pulley systems, the acceleration depends on the relative masses of the blocks. By applying Newton's laws, you can derive a relationship between the masses and the acceleration.

7. A particle is performing SHM with amplitude $A = 0.6$ m and time period $T = \pi$. Find the maximum velocity.

Correct Answer: 1.2 m/s

Solution:

Step 1: Use the time period formula.
The time period T is related to the angular frequency ω by the formula:

$$T = \frac{2\pi}{\omega}$$

Given that $T = \pi$, we substitute this value into the equation:

$$\pi = \frac{2\pi}{\omega}$$

Step 2: Solve for ω.
Rearranging the equation:

$$\omega = 2\,\text{rad/s}$$

Step 3: Find the maximum velocity.
The maximum velocity v_{max} in SHM is given by:

$$v_{\text{max}} = \omega A$$

Substituting the values of $\omega = 2\,\text{rad/s}$ and $A = 0.6\,\text{m}$, we get:

$$v_{\text{max}} = 2 \times 0.6 = 1.2\,\text{m/s}$$

Step 4: Conclusion.
Thus, the maximum velocity is $1.2\,\text{m/s}$.

Quick Tip

The maximum velocity in SHM is directly proportional to the amplitude and angular frequency.

---

8. Find the ratio of the shortest wavelength of the Lyman series to the shortest wavelength of the Balmer series.

Correct Answer: $\frac{1}{4}$

Solution:

Step 1: Wavelength formula for the Lyman series.
The shortest wavelength in any series is given by the formula:

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

For the Lyman series, $n_1 = 1$ and $n_2 = \infty$, so:

$$\frac{1}{\lambda_L} = RZ^2 \left(\frac{1}{1^2} - \frac{1}{\infty^2} \right) = RZ^2 \quad \text{(i)}$$

Step 2: Wavelength formula for the Balmer series.
For the Balmer series, $n_1 = 2$ and $n_2 = \infty$, so:

$$\frac{1}{\lambda_B} = RZ^2 \left(\frac{1}{2^2} - \frac{1}{\infty^2} \right) = \frac{RZ^2}{4} \quad \text{(ii)}$$

Step 3: Find the ratio.
From equations (i) and (ii), we have:

$$\frac{\lambda_L}{\lambda_B} = \frac{4}{1} = 4$$

Thus, the ratio of the shortest wavelength of Lyman to Balmer is:

$$\frac{1}{4}$$

Step 4: Conclusion.
The ratio of the shortest wavelength of Lyman to the shortest wavelength of the Balmer series is $\frac{1}{4}$.

Quick Tip

The shortest wavelength in a spectral series corresponds to the transition from $n = \infty$ to $n = 1$ for Lyman and from $n = \infty$ to $n = 2$ for Balmer.

---

9. The initial velocity of a particle is 100 m/s. After some time it changes to 40 m/s. What is the percentage change in its kinetic energy? The mass of the particle is 40 gm.

Correct Answer: -84%

Solution:

Step 1: Use the formula for percentage change in kinetic energy.
The percentage change in kinetic energy is given by:

$$\%\Delta K = \frac{K_f - K_i}{K_i} \times 100$$

Step 2: Write the kinetic energy formula.
The kinetic energy is given by $K = \frac{1}{2}mv^2$. So, the initial and final kinetic energies are:

$$K_i = \frac{1}{2}mv_i^2 \quad \text{and} \quad K_f = \frac{1}{2}mv_f^2$$

Thus, the percentage change becomes:

$$\%\Delta K = \frac{\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2}{\frac{1}{2}mv_i^2} \times 100$$

Step 3: Simplify the expression.

$$\%\Delta K = \left(\frac{v_f^2}{v_i^2} - 1\right) \times 100$$

Step 4: Substitute the given values.
Substitute $v_i = 100\,\text{m/s}$ and $v_f = 40\,\text{m/s}$:

$$\%\Delta K = \left(\frac{(40)^2}{(100)^2} - 1\right) \times 100 = \left(\frac{1600}{10000} - 1\right) \times 100$$

Step 5: Final Calculation.

$$\%\Delta K = \left(\frac{4}{25} - 1\right) \times 100 = \left(-\frac{21}{25}\right) \times 100 = -84\%$$

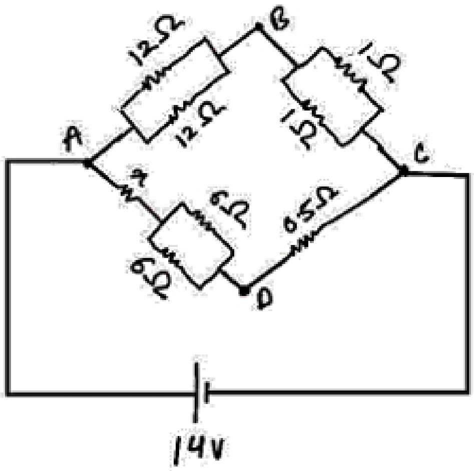
Step 6: Conclusion.
Thus, the percentage change in kinetic energy is -84%, indicating a decrease in kinetic energy.

Quick Tip

When calculating percentage change in kinetic energy, ensure to square the velocities and take the difference before calculating the percentage.

---

10. In the circuit below, the potential at B and the potential at D are the same. Find the value of resistance x.



Correct Answer: $x = 3\,\Omega$

Solution:

Step 1: Use Wheatstone Bridge condition.
Since the potential at B and D are the same, this is a Wheatstone bridge. In a Wheatstone bridge, the following condition holds:

$$R_{AB} \times R_{CD} = R_{BC} \times R_{AD}$$

Step 2: Substituting known values.
From the circuit, we have:

$$R_{AB} = 6\,\Omega, \quad R_{BC} = \frac{1}{2}\,\Omega, \quad R_{CD} = 0.5\,\Omega$$

Let $R_{AD} = x + 3\,\Omega$, as given in the problem. Substituting these values into the Wheatstone bridge condition:

$$6 \times 0.5 = 0.5 \times (x + 3)$$

Step 3: Simplify the equation.

$$3 = 0.5 \times (x + 3)$$

Multiplying both sides by 2:

$$6 = x + 3$$

Step 4: Solve for x.

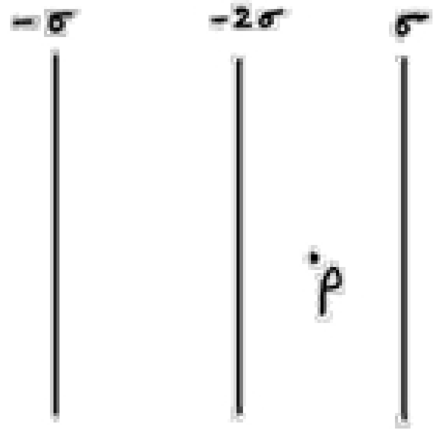
$$x = 3\,\Omega$$

Step 5: Conclusion.
Thus, the value of x is $3\,\Omega$.

Quick Tip

In a Wheatstone bridge, the condition for balanced bridge is $\frac{R_1}{R_2} = \frac{R_3}{R_4}$.

11. There are 3 infinite sheets of charge density $-\sigma$, -2σ, and σ respectively. Then find the electric field at point P (as shown in figure) [Sheets are non-conducting].



Correct Answer:

$$E_{\text{net}} = \frac{2\sigma}{\epsilon_0}$$

Solution:

Step 1: Understanding the problem.
The electric field due to an infinite sheet of charge with surface charge density σ is given by:

$$E = \frac{\sigma}{2\epsilon_0}$$

For a non-conducting sheet, the electric field points away from the sheet if the charge density is positive, and towards the sheet if the charge density is negative.
Step 2: Electric field contributions.
The electric field due to the three sheets at point P can be determined by considering the contributions from each sheet individually. The field due to each sheet is constant and directed as follows:
- The sheet with charge density $-\sigma$ produces an electric field directed towards the sheet. - The sheet with charge density -2σ produces an electric field directed towards the sheet (but stronger). - The sheet with charge density σ produces an electric field directed away from the sheet.
Step 3: Calculating the total electric field.
At point P, the electric field due to each sheet adds up according to the principle of superposition:

$$E_{\text{net}} = E_1 + E_2 + E_3$$

Where:

$$E_1 = \frac{\sigma}{2\epsilon_0}, \quad E_2 = \frac{2\sigma}{2\epsilon_0}, \quad E_3 = \frac{\sigma}{2\epsilon_0}$$

Adding these contributions:

$$E_{\text{net}} = \frac{\sigma}{2\epsilon_0} + \frac{2\sigma}{2\epsilon_0} + \frac{\sigma}{2\epsilon_0} = \frac{4\sigma}{2\epsilon_0} = \frac{2\sigma}{\epsilon_0}$$

Step 4: Conclusion.
Thus, the net electric field at point P is:

$$E_{\text{net}} = \frac{2\sigma}{\epsilon_0}$$

Quick Tip

The electric field due to an infinite sheet of charge is constant in magnitude and direction, regardless of the distance from the sheet. The direction depends on the sign of the charge density.

---

12. He gas and O_2 gas are at the same temperature. Find the ratio of their rms speed of molecules.

Correct Answer: $\sqrt{2}$

Solution:

Step 1: Use the formula for rms speed.
The root mean square (rms) speed v_{rms} of molecules is given by:

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

where R is the gas constant, T is the temperature, and M is the molar mass of the gas.
Step 2: Relationship between rms speeds of He and O_2.
Since both gases are at the same temperature, the ratio of their rms speeds is:

$$\frac{v_{\text{rms, He}}}{v_{\text{rms, } O_2}} = \sqrt{\frac{M_{O_2}}{M_{\text{He}}}}$$

Step 3: Substituting the molar masses.
The molar mass of O_2 is 32 g/mol, and the molar mass of He is 4 g/mol. So:

$$\frac{v_{\text{rms, He}}}{v_{\text{rms, } O_2}} = \sqrt{\frac{32}{4}} = \sqrt{8} = 2\sqrt{2}$$

Step 4: Conclusion.
Thus, the ratio of the rms speeds is $\sqrt{2}$.

Quick Tip

For gases at the same temperature, the rms speed is inversely proportional to the square root of the molar mass.

---

13. Which of the following materials is not a semiconductor?

(1) Germanium
(2) Silicon
(3) Graphite
(4) Copper oxide

Correct Answer: (3) Graphite

Solution:

Step 1: Understanding the materials.
- Germanium and Silicon are semiconductor materials commonly used in electronics. - Graphite is a conductor, not a semiconductor. - Copper oxide is an insulator.
Step 2: Conclusion.
Thus, the material that is not a semiconductor is **(3) Graphite**.

Quick Tip

Semiconductors are materials that can conduct electricity under certain conditions, unlike conductors (like graphite) or insulators.

---

14. If the 4 masses $m, \frac{m}{2}, 2m, 4m$ have the same momentum, which of the following will have maximum kinetic energy?

Correct Answer: $\frac{m}{2}$

Solution:

Step 1: Use the formula for kinetic energy.
The kinetic energy K of an object is given by:

$$K = \frac{p^2}{2m}$$

where p is the momentum and m is the mass.
Step 2: Use the given condition.
Since all masses have the same momentum, the kinetic energy will be inversely proportional to the mass. The smaller the mass, the larger the kinetic energy.
Step 3: Conclusion.
Thus, the mass with the smallest value, $\frac{m}{2}$, will have the largest kinetic energy. The correct answer is $\frac{m}{2}$.

Quick Tip

For the same momentum, the kinetic energy is inversely proportional to the mass.

---

15. Match the column.

Quantity Dimensional Formula(i)Torque $(a)[ML^2T^{-2}](ii)$Magnetic field $(b)[MA^{-1}T^{-2}](iii)$Magnetic

Correct Answer: (i) → (a), (ii) → (b), (iii) → (c), (iv) → (d)

Solution:

Step 1: Torque. The dimensional formula for torque is $[ML^2T^{-2}]$, which corresponds to option (a).

Step 2: Magnetic field. The dimensional formula for magnetic field is $[MA^{-1}T^{-2}]$, which corresponds to option (b).

Step 3: Magnetic moment. The dimensional formula for magnetic moment is $[ML^2T^0A]$, which corresponds to option (c).

Step 4: Permeability. The dimensional formula for permeability is $[ML^3T^{-2}A^{-2}]$, which corresponds to option (d).

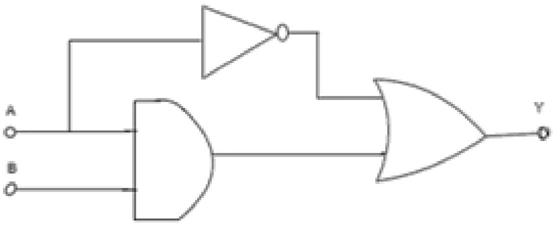
Step 5: Conclusion. Thus, the correct matching is:

$$(i) \to (a),\ (ii) \to (b),\ (iii) \to (c),\ (iv) \to (d)$$

Quick Tip

To match quantities with their dimensional formulas, remember that torque, magnetic field, and magnetic moment all have specific units that relate to mass, length, time, and current.

16. Find out the truth table.



Correct Answer: Below (Truth table)

Solution:

The circuit contains the following logic gates: - Inverter (NOT gate) on input A, - AND gate for A and B, - OR gate for the output of the NOT gate and the AND gate.
Step 1: Truth Table Analysis.
For $A = 0$ and $B = 0$, - $A = 0$, - $\overline{A} = 1$, - $A \cdot B = 0$, - Final output $= 1$.
For $A = 0$ and $B = 1$, - $A = 0$, - $\overline{A} = 1$, - $A \cdot B = 0$, - Final output $= 1$.
For $A = 1$ and $B = 0$, - $A = 1$, - $\overline{A} = 0$, - $A \cdot B = 0$, - Final output $= 0$.
For $A = 1$ and $B = 1$, - $A = 1$, - $\overline{A} = 0$, - $A \cdot B = 1$, - Final output $= 1$.
Step 2: Truth Table.

A	B	$\overline{A}$	$A \cdot B$	Final Output
0	0	1	0	1
0	1	1	0	1
1	0	0	0	0
1	1	0	1	1

Quick Tip

In logic circuits, the output of the NOT gate is the opposite of the input, the AND gate outputs 1 only when both inputs are 1, and the OR gate outputs 1 when at least one input is 1.

17. Given $T = 2\pi\sqrt{\frac{m}{K}}$, if m decreases by 1% and time period T increases by 2%, find the percentage change in K.

Correct Answer: K decreases by 5%

Solution:

Step 1: Given relation.
The time period is given by:

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

Step 2: Differentiation with respect to time.
Differentiating both sides with respect to time:

$$\frac{dT}{T} = \frac{1}{2}\left(\frac{dm}{m} - \frac{dK}{K}\right)$$

Step 3: Substitute given values.
We are given that m decreases by 1% and T increases by 2%. So:

$$\frac{dm}{m} = -1\% \quad \text{and} \quad \frac{dT}{T} = +2\%$$

Substitute these into the equation:

$$2\% = \frac{1}{2}\left(-1\% - \frac{dK}{K}\right)$$

Step 4: Solve for $\frac{dK}{K}$.

$$2\% = -\frac{1}{2}\left(1\% + \frac{dK}{K}\right)$$

Simplifying:

$$2\% = -\frac{1}{2} \times 1\% - \frac{1}{2} \times \frac{dK}{K}$$
$$2\% + \frac{1}{2} \times 1\% = -\frac{1}{2} \times \frac{dK}{K}$$
$$2\% + 0.5\% = -\frac{1}{2} \times \frac{dK}{K}$$
$$2.5\% = -\frac{1}{2} \times \frac{dK}{K}$$
$$\frac{dK}{K} = -5\%$$

Step 5: Conclusion.
Thus, K decreases by 5%.

Quick Tip

When calculating percentage changes in variables like m, K, or T, use the method of differentiation to find the relationship between changes in variables.

---

18. A train starting from rest first accelerates up to speed 80 km/h for time t, then it moves with a constant speed for time $3t$. The average speed of the train for this

duration of journey will be:

Correct Answer: 70 km/h

Solution:

Step 1: Total distance traveled.
The train accelerates for time t and then moves with a constant speed of 80 km/h for time $3t$. The total distance traveled is the sum of the distance during acceleration and the distance at constant speed.
- During the acceleration phase, the average speed is $\frac{1}{2} \times 80 = 40\,\text{km/h}$, and the distance traveled in this phase is:

$$\text{Distance during acceleration} = 40 \times t$$

- During the constant speed phase, the distance traveled is:

$$\text{Distance at constant speed} = 80 \times 3t = 240t$$

So, the total distance traveled is:

$$\text{Total distance} = 40t + 240t = 280t$$

Step 2: Total time taken.
The total time is the sum of the time during acceleration and the time at constant speed:

$$\text{Total time} = t + 3t = 4t$$

Step 3: Average speed.
The average speed v_{avg} is given by the formula:

$$v_{\text{avg}} = \frac{\text{Total distance}}{\text{Total time}} = \frac{280t}{4t} = 70\,\text{km/h}$$

Step 4: Conclusion.
Thus, the average speed of the train is $70\,\text{km/h}$.

> **Quick Tip**
>
> When calculating average speed, remember that it is the total distance traveled divided by the total time taken.

---

19. A big drop is made out of 1000 small drops, if the ratio of total surface energy of droplets and surface energy of the big drop is $10/x$, then find the value of x.

Correct Answer: $x = 100$

Solution:

Step 1: Understand the relationship between the radii.
The surface energy of a droplet is proportional to the square of its radius. If a big drop is made from 1000 small drops, the ratio of surface energy is related to the ratio of the radii. We can write:

$$\frac{1000 \times \frac{4}{3}\pi r^2}{\frac{4}{3}\pi R^2} = \frac{10}{x}$$

Step 2: Simplify the equation.

$$\frac{r^3}{R^3} = \frac{10}{x}$$

Given that the big drop radius $R = 10r$, we can substitute this into the equation:

$$\left(\frac{r}{R}\right)^3 = \left(\frac{1}{10}\right)^3$$

Thus:

$$R = 10r$$

Step 3: Surface energy comparison.
Now, we calculate the ratio of the surface energies:

$$\frac{\text{surface energy final}}{\text{surface energy initial}} = \frac{T(4\pi R^2)}{1000 \times T(4\pi r^2)} = \frac{10}{x}$$

Substituting the value for R, we get:

$$\frac{(10r)^2}{1000r^2} = \frac{10}{x}$$

Simplifying further:

$$\frac{100}{1000} = \frac{10}{x}$$

Thus,

$$x = 100$$

Step 4: Conclusion.
Therefore, $x = 100$.

Quick Tip

When combining small droplets into a bigger droplet, the radius of the larger droplet increases, but the total surface area does not increase proportionally due to the surface energy relationship.

20. The frequency of the electron in the first Bohr orbit in the H-atom is:

Correct Answer: $v = 6530 \times 10^{12}\,\text{Hz}$

Solution:

Step 1: Use the formula for frequency.
The frequency v of an electron in the first Bohr orbit is given by the formula:

$$v = \frac{v}{2\pi r} = \frac{L}{4\pi^2 m r^2}$$

where L is the angular momentum and r is the radius.
Step 2: Solve for the frequency.
Using the formula for Bohr's orbit, we have:

$$v = 6530 \times 10^{12}\,\text{Hz}$$

Step 3: Conclusion.
Thus, the frequency is $v = 6530 \times 10^{12}\,\text{Hz}$.

Quick Tip

In the Bohr model of the hydrogen atom, the frequency of the electron depends on its orbital radius and angular momentum.

---

21. While measuring the diameter of a wire using a screw gauge, the following readings were noted: - Main scale reading is 1 mm, - Circular scale reading is equal to 42 divisions. Pitch of screw gauge is 1mm and it has 100 divisions on the circular scale. Find the diameter of the wire. The value of x is:

Correct Answer: 71

Solution:

Step 1: Calculate the least count of the screw gauge.
The least count $L.C.$ of a screw gauge is given by:

$$L.C. = \frac{\text{Pitch}}{\text{Number of divisions on circular scale}}$$

Here, the pitch of the screw gauge is 1 mm, and the number of divisions on the circular scale is 100. So:

$$L.C. = \frac{1\,\text{mm}}{100} = 0.01\,\text{mm}$$

Step 2: Calculate the diameter of the wire.
The diameter of the wire is given by:

$$\text{Diameter of the wire} = \text{Main scale reading} + (\text{Circular scale reading} \times \text{Least count})$$

Substituting the values:

$$\text{Diameter of the wire} = 1\,\text{mm} + 42 \times 0.01\,\text{mm} = 1\,\text{mm} + 0.42\,\text{mm} = 1.42\,\text{mm}$$

Step 3: Conclusion.
Thus, the diameter of the wire is $1.42\,\text{mm}$.

Quick Tip

The least count of a screw gauge is a measure of the smallest length that can be measured using the instrument. The formula for calculating the diameter involves adding the main scale reading and the product of the circular scale reading and least count.

---

22. A hydrogen atom having energy E in the ground state, when it is revolving at a radius of orbit $r = 8.48$ Å. Its energy becomes $\frac{E}{x}$. Find the value of x.

Correct Answer: $x = 16$

Solution:

Step 1: Formula for radius of orbit.
The radius of the orbit for the hydrogen atom is given by the formula:

$$r = 0.529\frac{n^2}{z}\,\text{Å} \quad (\text{for hydrogen, } z = 1)$$

Thus:

$$r = 0.529n^2$$

Step 2: Given value of radius.
It is given that $r = 8.48$ Å. Substituting into the formula:

$$8.48 = 0.529n^2$$

Solving for n^2:

$$n^2 = \frac{8.48}{0.529} = 16$$

So, $n = 4$.

Step 3: Energy calculation.
The energy in the nth orbit for a hydrogen atom is given by:

$$T.E. = -\frac{13.6}{n^2}\,\text{eV}$$

At $n = 1$, the energy is $T.E. = -13.6\,\text{eV}$. At $n = 4$, the energy is:

$$T.E. = -\frac{13.6}{4^2} = -\frac{13.6}{16} = \frac{E}{x}$$

Step 4: Solve for x.
Thus,

$$\frac{E}{x} = \frac{E}{16} \quad \Rightarrow \quad x = 16$$

Step 5: Conclusion.
Therefore, $x = 16$.

Quick Tip

The energy levels of a hydrogen atom are inversely proportional to the square of the principal quantum number n. The larger n is, the less negative the energy is.

---

23. Energy incident on metal surface is 2.48 eV and the stopping potential is 0.5 V. Find the work function.

Correct Answer: $\varphi = 1.98\,\text{eV}$

Solution:

Step 1: Use the photoelectric equation.
The energy of the incident light is related to the work function φ and the maximum kinetic energy of the emitted electrons by the equation:

$$E = K.E_{\text{max}} + \varphi$$

where E is the incident energy and $K.E_{\text{max}}$ is the maximum kinetic energy of the electrons.
Step 2: Use the stopping potential.
The maximum kinetic energy $K.E_{\text{max}}$ is related to the stopping potential V_s by:

$$K.E_{\text{max}} = eV_s$$

Substitute $V_s = 0.5\,\text{V}$ into the equation:

$$K.E_{\text{max}} = (0.5)\,\text{eV} = 0.5\,\text{eV}$$

Step 3: Solve for the work function.
Substitute into the photoelectric equation:

$$2.48\,\text{eV} = 0.5\,\text{eV} + \varphi$$

Solving for φ:

$$\varphi = 2.48\,\text{eV} - 0.5\,\text{eV} = 1.98\,\text{eV}$$

Step 4: Conclusion.
Thus, the work function is $\varphi = 1.98\,\text{eV}$.

> **Quick Tip**
>
> The work function is the minimum energy required to release an electron from the surface of a metal. It can be calculated using the energy of incident light and the stopping potential.

---

24. Statement 1: Inductor has maximum current at resonance frequency.
Statement 2: Current in a purely resistive circuit can never be less than the current in series in an LRC circuit.
Which of the following is correct?

(1) Only statement 1 is correct.
(2) Only statement 2 is correct.
(3) Both of the statements are correct.
(4) None of the statements is correct.

Correct Answer: (3) Both of the statements are correct.

Solution:

Step 1: Statement 1 - Inductor at resonance frequency.
In an LRC circuit, at the resonance frequency, the inductive reactance (X_L) and capacitive reactance (X_C) are equal and cancel each other out. Hence, the current is maximum at this frequency because the total impedance is at its minimum. Therefore, Statement 1 is correct.

Step 2: Statement 2 - Current in purely resistive circuit.
In a purely resistive circuit, the current is determined solely by the resistance, and it cannot be less than the current in a series LRC circuit where the total impedance is greater due to the inductive and capacitive reactance. Therefore, Statement 2 is also correct.

Step 3: Conclusion.
Thus, both statements are correct, and the correct answer is option (3).

Quick Tip

In an LRC circuit, resonance occurs when the inductive reactance equals the capacitive reactance, resulting in maximum current at resonance frequency.

---

25. A thin spherical shell (conducting) having charge density σ. Find the electric field at the surface of the shell.

Correct Answer:

$$E = \frac{\sigma}{\epsilon_0}$$

Solution:

Step 1: Electric field due to a spherical shell.
For a conducting spherical shell with charge density σ, the electric field at the surface of the shell can be derived using Gauss's Law. The electric field at the surface of the spherical shell is given by:

$$E = \frac{\sigma}{\epsilon_0}$$

where σ is the surface charge density and ϵ_0 is the permittivity of free space.

Step 2: Conclusion.
Thus, the electric field at the surface of the shell is $\frac{\sigma}{\epsilon_0}$.

Quick Tip

The electric field due to a charged conducting shell is determined by the surface charge density, and it is independent of the radius of the shell.
