

Dual Nature of Electrons



Here is a list of important questions on the **Dual Nature of Electrons** for Class 12 Physics, divided into **1-mark**, **3-mark**, and **5-mark** categories based on the NCERT syllabus:

1-Mark Questions (Objective/Short-Answer)

1. What is de Broglie wavelength?

- Answer: The de Broglie wavelength (λ) is the wavelength associated with a particle and is given by $\lambda = \frac{h}{p}$, where h is Planck's constant and p is the momentum of the particle.

2. State the significance of the Davisson-Germer experiment.

- Answer: The Davisson-Germer experiment confirmed the wave nature of electrons by demonstrating the diffraction of electrons, which was consistent with de Broglie's hypothesis.

3. Write the formula for the de Broglie wavelength.

- Answer: $\lambda = \frac{h}{p}$, where λ is the wavelength, h is Planck's constant, and p is the momentum.

4. What does Heisenberg's Uncertainty Principle state?

- Answer: It states that it is impossible to simultaneously know both the exact position and momentum of a particle. $\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$.

5. What is the wave-particle duality of electrons?

- Answer: Electrons exhibit both wave-like and particle-like properties, depending on the experiment being conducted.

3-Mark Questions (Short-Answer)

1. Explain the concept of de Broglie wavelength. Derive the formula for it.

- Answer: The de Broglie hypothesis suggests that matter, such as electrons, exhibits both wave and particle characteristics. The wavelength associated with a particle is inversely proportional to its momentum. The formula is derived as:

$$\lambda = \frac{h}{p}$$

Where h is Planck's constant, and p is the particle's momentum, given by $p = mv$ for a particle of mass m and velocity v .

2. State the Heisenberg Uncertainty Principle and give an example.

- Answer: Heisenberg's Uncertainty Principle states that it is impossible to simultaneously determine the exact position and exact momentum of a particle. Mathematically:

$$\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$$

Example: For an electron moving with very high speed in an atom, if we try to precisely measure its position, its momentum becomes highly uncertain and vice versa.

3. Describe the Davisson-Germer experiment and its significance.

- Answer: In the Davisson-Germer experiment, a beam of electrons was fired at a nickel crystal, and the scattered electrons produced a diffraction pattern, just like waves would. This experiment verified de Broglie's hypothesis of matter waves and showed that electrons exhibit wave-like properties under certain conditions, such as diffraction.

5-Mark Questions (Long-Answer/Descriptive)

1. Derive the expression for the de Broglie wavelength for an electron. What is the wavelength of an electron that has been accelerated through a potential difference of 150V?

- **Derivation:** The de Broglie wavelength is given by:

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

Using the relationship between energy and potential difference for an electron:

$$E = eV = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2eV}{m}}$$

Substituting into the de Broglie equation:

$$\lambda = \frac{h}{\sqrt{2meV}}$$

For an electron with charge $e = 1.6 \times 10^{-19} C$, mass $m = 9.1 \times 10^{-31} kg$, and $V = 150V$, calculate the wavelength:

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 150}} = 1.002 \times 10^{-10} m$$

2. What is the Heisenberg Uncertainty Principle? Derive the uncertainty relation for position and momentum. Also, explain its significance using an example.

- **Explanation:** The Heisenberg Uncertainty Principle is a fundamental concept of quantum mechanics that sets a limit on the accuracy of simultaneous measurements of certain pairs of physical quantities, such as position and momentum.
- **Derivation:** The uncertainty in position (Δx) and the uncertainty in momentum (Δp) are related by:

$$\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$$

- **Significance:** This principle implies that for very small particles, like electrons, the act of measuring one property (such as position) disturbs the other property (such as momentum). For example, if we try to observe an electron's exact position, we lose precision in its momentum, making it impossible to predict its future path accurately.

3. Explain the wave-particle duality of electrons and describe the experimental verification provided by the Davisson-Germer experiment.

- **Explanation:** According to the wave-particle duality, particles like electrons can behave as waves or particles depending on the experimental setup. The de Broglie hypothesis suggests that all matter has a wave associated with it.
- **Davisson-Germer Experiment:** In this experiment, electrons were fired at a nickel crystal, and the scattered electrons produced a diffraction pattern, just like light waves do when they pass through a diffraction grating. This confirmed that electrons exhibit wave-like properties, thereby verifying de Broglie's hypothesis of matter waves.
- **Significance:** This experiment was one of the first to show that microscopic particles like electrons behave as waves under certain conditions, providing experimental evidence for the wave-particle duality.

These questions cover important concepts from the chapter on **Dual Nature of Electrons** and will help in preparing for board exams as well as competitive exams like NEET and JEE.