Quantum Physics I

Comprehensive Answer Key with Source References

Total Questions	6
Repeated Questions	5
High Weightage (≥10 marks)	5
Source Book	Introduction to Quantum Mechanics

Q1. Explain the principle of quantum superposition with examples.
[REPEATED] | [HIGH WEIGHTAGE]

Year: 2023 | Exam: Final Exam | Weightage: 10 marks

Answer:

The principle of **superposition** is a fundamental concept in quantum mechanics.
It states that when two or more quantum states are possible, the actual state is a
superposition (combination) of all possible states until a **measurement** is made.

The **wave function** $\psi(x,t)$ contains all information about the quantum state. When measured,
the **wave function collapse**s to a single eigenstate. The probability of finding a particle
at position x is given by $|\psi(x,t)|^2$.

Key points:
1. Multiple states can exist simultaneously
2. Measurement causes **wave function collapse**
3. Probability is determined by **wave function** amplitude squared
4. Superposition is destroyed upon observation

Source: Introduction to Quantum Mechanics by David J. Griffiths, Chapter 1: Quantum Superposition, Page 12

Q2. Derive and explain the Heisenberg Uncertainty Principle.
[REPEATED] | [HIGH WEIGHTAGE] | [Asked 5 times]

Year: 2023 | Exam: Final Exam | Weightage: 15 marks

Answer:

The Heisenberg Uncertainty Principle is a fundamental limitation in quantum mechanics
that states we cannot simultaneously know both the exact **position** and exact **momentum** of a
particle.

Mathematical formulation: $\Delta x \cdot \Delta p \geq \blacksquare/2$

Where:
- Δx is the uncertainty in **position**
- Δp is the uncertainty in **momentum**
- $\blacksquare$ is the reduced **Planck constant** ($h/2\pi$)

This is not due to measurement limitations, but rather a fundamental property of nature.
The more precisely we know **position**, the less precisely we can know **momentum**, and vice
versa.

Applications:
1. Explains stability of atoms
2. Sets limits on measurement precision
3. Fundamental to quantum field theory
4. Basis for quantum cryptography

Q3. What is the Heisenberg Uncertainty Principle? Discuss its implications. [REPEATED] | [HIGH WEIGHTAGE] | [Asked 5 times]

Year: 2022 | Exam: Midterm | Weightage: 10 marks

Answer:

The Heisenberg Uncertainty Principle is a fundamental limitation in quantum mechanics that states we cannot simultaneously know both the exact **position** and exact **momentum** of a particle.

Mathematical formulation: $\Delta x \cdot \Delta p \geq \blacksquare/2$

Where:
- Δx is the uncertainty in **position**
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This is not due to measurement limitations, but rather a fundamental property of nature. The more precisely we know **position**, the less precisely we can know **momentum**, and vice versa.

Applications:
1. Explains stability of atoms
2. Sets limits on measurement precision
3. Fundamental to quantum field theory
4. Basis for quantum cryptography

Source: Introduction to Quantum Mechanics by David J. Griffiths, Chapter 1: Heisenberg Uncertainty Principle, Page 24

Q4. Solve the time-independent Schrödinger equation for a particle in a box. [REPEATED] | [HIGH WEIGHTAGE] | [Asked 4 times]

Year: 2023 | Exam: Final Exam | Weightage: 20 marks

Answer:

The time-independent **Schrödinger equation** is the fundamental equation for stationary quantum states:

$$\blacksquare\psi = E\psi$$

Or in expanded form: $-\blacksquare^2/2m \cdot d^2\psi/dx^2 + V(x)\psi = E\psi$

Where:
- $\blacksquare$ is the **Hamiltonian** operator (total energy)
- ψ is the **wave function**
- E is the energy **eigenvalue**
- V(x) is the potential energy
- m is the particle mass

This equation allows us to find allowed energy levels and corresponding **wave function**s for quantum systems. Solutions must be:
1. Continuous
2. Single-valued
3. Normalizable
4. Smooth (continuous first derivative)

Common applications:
- Particle in a box
- Harmonic oscillator
- Hydrogen atom
- Quantum tunneling

Source: Introduction to Quantum Mechanics by David J. Griffiths, Chapter 2: Time-Independent Schrödinger Equation, Page 45

Q5. Describe wave function collapse and measurement in quantum mechanics.

Year: 2022 | Exam: Quiz | Weightage: 5 marks

Answer not found in local textbook. Please refer to these trusted sources:

• *https://scholar.google.com/scholar?q=Describe+wave+function+collapse+and*

• *https://www.khanacademy.org/search?q=measurement+wave function*

Q6. Explain quantum superposition and provide real-world examples. [REPEATED] | [HIGH WEIGHTAGE]

Year: 2021 | Exam: Final Exam | Weightage: 10 marks

Answer:

The principle of **superposition** is a fundamental concept in quantum mechanics. It states that when two or more quantum states are possible, the actual state is a **superposition** (combination) of all possible states until a **measurement** is made.

The **wave function** $\psi(x,t)$ contains all information about the quantum state. When measured, the **wave function collapse**s to a single eigenstate. The probability of finding a particle at position x is given by $|\psi(x,t)|^2$.

Key points:
1. Multiple states can exist simultaneously
2. Measurement causes **wave function collapse**
3. Probability is determined by **wave function** amplitude squared
4. Superposition is destroyed upon observation

Source: Introduction to Quantum Mechanics by David J. Griffiths, Chapter 1: Quantum Superposition, Page 12

End of Answer Key