Quantum Physics I

Comprehensive Answer Key with Source References

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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: $\Delta x \cdot \Delta p \geq$ ■/2

Where:
- Δx is the uncertainty in **position**
- Δp is the uncertainty in **momentum**
- ■ 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

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

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: $\Delta x \cdot \Delta p \geq$ ■$/2$

Where:
- Δx is the uncertainty in **position**
- Δp is the uncertainty in **momentum**
- ■ 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

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:

■$\psi = E\psi$

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

Where:
- ■ 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=wave function+measurement*

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