# BUDDHA SERIES

**(Unit Wise Solved Question & Answers)**

**Programme – B.Sc. Maths 3rd year 5th Semester**

**College – Buddha Degree College**

**(DDU Code-859)**

**Department: Science**

**Course code: PHY 302**

**Course title: Quantum Mechanics and Spectroscopy**

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# Unit-1

**1. Which of the following is a scalar operator in quantum mechanics?**

A. Momentum operator $\widehat{p}$ B. Angular momentum operator $\widehat{L}$ C. Identity operator $\widehat{I}$ D. Position operator $\widehat{x}$ **Answer:** C

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**2. An operator $\widehat{A}$ acting on a vector space must satisfy:**

A. Linearity B. Hermiticity C. Unitarity D. Normality **Answer:** A

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**3. The matrix representation of an operator depends on:**

A. The choice of basis B. The energy eigenvalues C. Whether the operator is Hermitian D. Commutation relations **Answer:** A

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**4. A projector operator satisfies:**

A. $\widehat{P}^2 = \widehat{I}$ B. $\widehat{P}^2 = 0$ C. $\widehat{P}^2 = \widehat{P}$ D. $\widehat{P}^\dagger = -\widehat{P}$ **Answer:** C

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**5. The commutator $[\widehat{x}, \widehat{p}]$ equals:**

A. 0 B. $i\hbar$ C. $-i\hbar$ D. $i\hbar\widehat{I}$ **Answer:** D *(same as B, but operator form)*

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**6. Which is true: $[\widehat{L}_x, \widehat{L}_y] =$**

A. 0 B. $i\hbar\widehat{L}_z$ C. $-i\hbar\widehat{L}_z$ D. $i\hbar(\widehat{L}_x + \widehat{L}_y)$ **Answer:** B

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**7. Commutator algebra follows:**

A. Bilinearity B. Jacobi identity C. Antisymmetry D. All of the above **Answer:** D

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**8.** $[\widehat{H}, t] =$

A. $i\hbar$ B. 0 C. $-i\hbar\widehat{I}$ D. Undefined **Answer:** B *(since time is a parameter, not operator)*

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**9. A non-degenerate eigenvalue has:**

A. One eigenvector B. Two eigenvectors C. No eigenvectors D. Infinite eigenvectors **Answer:** A

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**10. Two eigenstates with same eigenvalue are:**

A. Orthogonal B. Degenerate C. Non-orthogonal D. Unique **Answer:** B

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**11. Eigenvalue equation: $\widehat{A}\psi = a\psi$. Here $a$ is:**

A. Operator B. Eigenfunction C. Eigenvalue D. Expectation value **Answer:** C

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**12. Expectation value: $\langle\widehat{A}\rangle =$**

A. $\int \psi^* A\psi \, dx$ B. $\psi^*\widehat{A}\psi$ C. $\int \psi^*\widehat{A}\psi \, dx$ D. $\widehat{A}\psi$ **Answer:** C

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**13. Which of these is true for a Hermitian operator $\widehat{A}$?**

A. $\widehat{A}^\dagger = -\widehat{A}$ B. $\widehat{A}^\dagger = \widehat{A}$ C. $\widehat{A}^2 = \widehat{I}$ D. $\widehat{A}^* = \widehat{A}$ **Answer:** B

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**14. Hermitian operators have:**

A. Complex eigenvalues B. Pure imaginary eigenvalues C. Real eigenvalues D. No eigenvalues **Answer:** C

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**15. The momentum operator in one dimension:**

A. $-i\hbar\frac{d}{dx}$ B. $i\hbar\frac{d}{dx}$ C. $-\hbar^2\frac{d^2}{dx^2}$ D. $i\hbar x$ **Answer:** A

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**16. The raising operator $\widehat{L}_+$ is defined as:**

A. $\widehat{L}_x - i\widehat{L}_y$ B. $\widehat{L}_x + i\widehat{L}_y$ C. $\widehat{L}_y + i\widehat{L}_z$ D. $\widehat{L}_x + \widehat{L}_z$ **Answer:** B

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**17. The commutator $[\widehat{p}_x, \widehat{p}_y] =$**

A. $i\hbar$ B. $-i\hbar$ C. 0 D. Depends on coordinates **Answer:** C

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**18. If $\widehat{A}|a\rangle = a|a\rangle$ and $\widehat{B}|a\rangle = b|a\rangle$, with $[A, B] = 0$, then $|a\rangle$ is:**

A. Degenerate B. Simultaneous eigenstate C. Superposition D. Orthogonal **Answer:** B

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**19. Expectation value interpretation:**

A. Most probable value B. Fixed measurement result C. Average over many measurements D. Variance of operator **Answer:** C

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**20. Which operator is guaranteed Hermitian in quantum mechanics?**

A. $i\hbar\frac{d}{dx}$ B. $-\hbar^2\frac{d^2}{dx^2}$ C. Position operator $\widehat{x}$ D. Time evolution operator $e^{-iHt/\hbar}$ **Answer:** C

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**21. Proof of Hermitian nature requires:**

A. Integration by parts B. Real wavefunctions C. Non-normalizable wavefunctions D. Ignoring boundary terms **Answer:** A

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**22. A Hermitian operator's expectation value is:**

A. Always imaginary B. Always negative C. Always real D. Unpredictable **Answer:** C

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**23. The commutator $[\widehat{H}, \widehat{p}]$ determines:**

A. Energy levels B. $[\widehat{x}(t)$, dynamics] Time evolution of momentum via Heisenberg eqn C. Conservation of mass D. Degeneracy **Answer:** B

**24. Linear superposition of eigenfunctions also satisfies:**

A. Momentum eigenvalue for each B. Schrödinger equation only if degenerate C. Time-independence D. Orthogonality automatically **Answer:** B

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**25. In position basis, $\widehat{x}$ is:**

A. Multiplication by $x$ B. Derivative w.r.t $x$ C. Fourier transform D. Second derivative **Answer:** A

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**26. The operator $\widehat{L}^2 = \widehat{L}_x^2 + \widehat{L}_y^2 + \widehat{L}_z^2$ commutes with:**

A. Each of $\widehat{L}_x, \widehat{L}_y, \widehat{L}_z$ B. None of them C. Only $\widehat{L}_z$ D. Momentum **Answer:** A

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**27. The time–energy commutator $[\widehat{H}, \widehat{t}]$:**

A. Is zero because $t$ isn't an operator B. Equals $i\hbar$ C. Equals $-i\hbar$ D. Defines time operator analogously to position **Answer:** A

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**28. Degenerate subspace:**

A. Contains only one eigenvector B. Contains eigenvectors of distinct eigenvalues C. Contains multiple eigenvectors with same eigenvalue D. Is always two-dimensional **Answer:** C

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**29. For Hermitian $\widehat{A}$, eigenstates corresponding to different eigenvalues are:**

A. Always orthogonal B. Never orthogonal C. May be orthogonal if degenerate D. Always degenerate **Answer:** A

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**30. Which is NOT a property of Hermitian operators?**

A. Real eigenvalues B. Orthogonal eigenstates C. Generate unitary evolution D. Expectation value real **Answer:** C *(Unitary evolution is generated by $i\widehat{H}$, not $\widehat{H}$ alone)*

# Unit-2

1. The Heisenberg uncertainty principle stems fundamentally from which property? A) Time dependence of operators B) Non-commutativity of Hermitian operators C) Orthogonality of eigenstates D) Normalization of wavefunctions

   **Answer**: B. Non-commutativity underlies the general uncertainty relation

   The Robertson uncertainty relation is: A) $\Delta A \Delta B \leq |\langle [A,B] \rangle|$ B) $\Delta A \Delta B \geq \frac{1}{2}|\langle [A,B] \rangle|$ C) $\Delta A \Delta B \geq |\langle \{A,B\} \rangle|$ D) $\Delta A \Delta B \leq \frac{1}{2}|\langle \{A,B\} \rangle|$

   **Answer**: B

2. The more general Schrödinger form includes which component? A) Commutator squared B) Anticommutator term C) Determinant of operators D) Energy eigenvalues

   **Answer**: B

3. Kennard's form for position & momentum is: A) $\Delta x \, \Delta p \geq \hbar$ B) $\Delta x \, \Delta p \geq \hbar/2$ C) $\Delta x \, \Delta p \geq 2\hbar$ D) $\Delta x \, \Delta p \geq 2\hbar^2$

   **Answer**: B

4. **Which derivation tool is used for the general uncertainty principle?** A) Integration by parts B) Cauchy–Schwarz (Schwarz) inequality C) Taylor series D) Fourier transform

   **Answer**: B

5. **For non-commuting operators A and B, the commutator [A,B] equals:** A) AB + BA B) AB – BA C) BA – AB D) 0

   **Answer**: B

6. **Which conjugate pair demonstrates the minimum uncertainty in ground state?** A) Energy–time B) Position–momentum C) Angular momentum–angle D) Spin–magnetic field

   **Answer**: B.

7. **Harmonic oscillator ground state saturates uncertainty because $\Delta x \, \Delta p$ =:** A) $\hbar$ B) $\hbar(n + 1/2)$ C) $\hbar/2$ D) $\hbar(n)$

   **Answer**:

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9. Time-dependent Schrödinger equation is: A) $\hat{H}\psi = E\psi$ B) $i\hbar\partial\psi/\partial t = \hat{H}\psi$ C) $-\hbar^2\nabla^2\psi = E\psi$ D) $\partial\psi/\partial x = \hat{H}\psi$

   **Answer**: B.

10. **Time-independent Schrödinger equation for energy eigenstates:** A) $\hat{H}\psi = i\hbar\partial\psi/\partial t$ B) $\hat{H}\psi = E\psi$ C) $\hat{H}\psi = \nabla^2\psi$ D) $\hat{H}\psi = 0$

    **Answer**: B.

11. **In Schrödinger representation, continuity equation $\partial\rho/\partial t + \nabla\cdot J = 0$ expresses:** A) Conservation of energy B) Conservation of probability C) Conservation of momentum D) Conservation of linearity

    **Answer**: B.

12. **The operator equation of motion in Schrödinger picture is expressed by:** A) Heisenberg equation of motion B) Newton's second law C) Probability conservation D) Dirac equation

    **Answer**: A.

13. In an infinite square well ($0 \leq x \leq L$), $\psi$ is: A) Sin(kx)+cos(kx) B) Zero outside 0–L C) An exponential inside D) Constant inside

    **Answer**: B

14. **Allowed wavefunctions in infinite well must satisfy $\psi(0) = \psi(L) = 0$ because:** A) Operator Hermiticity B) Continuity & infinite barrier C) Probability normalization D) Discreteness of energy

    **Answer**: B

15. Energy levels in infinite well are proportional to $n^2$ because: A) Length quantization B) $k = n\pi/L \rightarrow E \propto k^2$ C) Angular momentum rules D) Potential is zero

    **Answer**: B

16. **In the ground state of infinite well, $\langle x \rangle =$:** A) 0 B) L/2 C) L D) Undefined

    **Answer**: B

17. **Wavefunction for finite square well outside the well decays:** A) As sine B) As cosine C) Exponentially D) Oscillatory

**Answer**: C

18. **A finite well allows which phenomenon not present in infinite well?** A) Zero energy ground state B) Tunneling C) No bound states D) Infinite discrete levels

    **Answer**: B

19. **In finite well bound states require $E < V_0$ so solutions are:** A) Oscillatory everywhere B) Oscillatory inside, exponential outside C) Exponential everywhere D) Oscillatory outside only

    **Answer**: B

20. **The minimum non-zero energy in infinite well follows from uncertainty because $E= p^2/2m$ and $p \approx \hbar/\Delta x$. This forbids E = 0.** A) True B) False

    **Answer**: A

21. **Rectangular barrier above particle energy leads to:** A) Full reflection only B) Tunneling with finite probability C) No quantum effect D) Infinite penetration

    **Answer**: B.

22. **Potential step with E > V step gives:** A) Only reflection B) Only transmission C) Partial reflection and transmission D) Zero chance of crossing

    **Answer**: C.

23. **1D Harmonic oscillator eigenfunctions are**: A) Sines & cosines B) Hermite polynomials × Gaussian C) Laguerre polynomials D) Legendre functions

    **Answer**: B.

24. **Energy eigenvalues for 1D oscillator:** A) $E_n \propto n^2$ B) $E_n = \hbar\omega(n + ½)$ C) $E_n = n\hbar\omega$ D) $E_n$ continuous

    **Answer**: B.

25. **Particle in a 3D box has energies separable as:** A) Sum of 1D energies in x, y, z B) Product of sine functions only C) Single-n quantum number D) Degenerate in all states

    **Answer**: A.

26. **Radial part of hydrogen atom wavefunction uses:** A) Hermite polynomials B) Associated Legendre functions C) Associated Laguerre polynomials D) Bessel functions

    **Answer**: C.

27. **3D hydrogen radial probability distribution peaks at bohr radius $a_0$ for n = 1:** A) True B) False

    **Answer**: A.

28. **Which equation defines the radial probability?** A) $|\psi(r)|^2$ B) $|R(r)|^2 r^2$ C) $|Y(\theta,\phi)|^2$ D) $|\psi(r)|^2 r$

    **Answer**: B.

29. **Solving associated Laguerre differential equation yields hydrogen bound states** A) True B) False

    **Answer**: A.

30. **Non-commutativity of operators is unrelated to energy quantization:** A) True B) False

    **Answer**: B – it's crucial for deriving uncertainty which underpins quantization.