B.Sc. (Semester - 6)
Subject: Physics
Course: US06CPHY01
Title: Quantum Mechanics

Question Bank
UNIT-1: Formulation of the Schrodinger Equation

Multiple choice questions:

(1) The concept of matter wave was suggested by__________
 (a) Heisenberg (b) **de Broglie**
 (c) Schrodinger (d) Laplace

(2) The intensity of the diffraction pattern is proportional to ______ of the wave function
 (a) forth power (b) cube
 (c) sixth power (d) **square**

(3) The function representing matter waves must be _________
 (a) **complex** (b) real
 (c) zero (d) infinity

(4) The total probability of finding the particle in space must be ___________
 (a) zero (b) **unity**
 (c) infinity (d) double

(5) The normalized wave function must have _________ norm
 (a) infinite (b) zero
 (c) **finite** (d) complex

(6) The Non-normalized wave function must have _________ norm
 (a) **infinite** (b) zero
 (c) finite (d) complex

(7) For normalized wave function $\psi \rightarrow 0$ as $r \rightarrow$___
 (a) 0 (b)1
 (c) **α** (d) -1

(8) The square of the magnitude of the wave function is called__________
 (a) current density (b) **probability density**
 (c) zero density (d) volume density

(9) The operator ∇^2 is called ________ operator
 (a) Hamiltonian (b) **Laplacian**
 (c) Poisson (d) vector

(10) __________ principle states that the actual path taken by the light ray is one which minimizes the integral
 (a) Heisenberg (b) Hamilton's
 (c) **Maupertuis'** (d) Fermat's

Short Questions:

1. State the de Broglie hypothesis
2. What is the Schrodinger's postulate?
3. Define group velocity of the wave packet

4. State the Heisenberg's uncertainty principle
5. State the Fermat's principle
6. State the Maupertuis' principle
7. Write the energy-momentum relation for a free particle
8. What is the boundary condition for normalized wave function?
9. What you mean by $|\Psi|^2$
10. Write the three dimensional Schrodinger equation for free particle

Long Questions:

1. Discuss the concept of matter wave and show the experimental agreement for electron
2. Discuss the motion of a wave packet and derive the expression of group velocity of wave packet
3. Discuss the Heisenberg's uncertainty principle and show how it is introduced in the process of measurement
4. Prove that motion of a wave packet in a slowly varying field is approximately the motion of a classical particle
5. Derive the one dimensional Schrodinger equation for a free particle
6. Derive the three dimensional Schrodinger equation for the motion of a particle under the action of a force using operator
7. Discuss the normalization and probability interpretation of a wave function
8. Discuss the Non-normalized wave function and box normalization

UNIT: 2 Stationary States and Energy Spectra

Multiple choice questions:

(1) The operator operating on the wave function should always standing on _____ side

(a) Middle (b) **Right**

(c) Left (d) Upper

(2) According to the wave function and it first partial derivative should be _______ functions for all values of $\vec{X}$

(a) Zero (b) **Continuous**

(c) Infinity (d) discontinuous

(3) If the particle moving in a _____ potential then the solution of the wave equation are describe as a stationary states

(a) **time independent** (b) time dependent

(c) velocity dependent (d) velocity independent

(4) Any particle with energy _____ cannot enter in the regions I and III

(a) $E = 0$ (b) $E = \propto$

(c) $\boldsymbol{E} < 0$ (d) $E > 0$

(5) For bound state of a particle in a square well the energy is _______

(a) $E = 0$ (b) $E = \propto$

(c) $\boldsymbol{E} < 0$ (d) $E > 0$

(6) The limit of a region-I for a square well potential is __________

(a) $-\propto < x < 0$ (b) $a < x < \propto$

(c) $-a < x < a$ (d) $-\propto < x < -a$

(7) The limit of a region-II for a square well potential is ___________

(a) $-\propto < x < 0$ (b) $a < x < \propto$

(c) $\boldsymbol{-a} < x < a$ (d) $-\propto < x < -a$

(8) The limit of a region-III for a square well potential is ___________

(a) $-\propto < x < 0$ (b) $\boldsymbol{a} < x < \propto$

(c) $-a < x < a$ (d) $-\propto < x < -a$

(9) $\frac{V_0}{\Delta}$ is a measure the _________ of the potential

(a) Height (b) Width

(c) **Strength** (d) Length

(10) There exists at least ________ bound state, however weak the potential may be

(a) Two (b) **One**

(c) Three (d) Infinite

(11) Any wave function having symmetry property is said to be of ______ parity

(a) Zero (b) **Even**

(c) Odd (d) Infinite

(12) Any wave function having anti-symmetry property is said to be of ______ parity

(a) Zero (b) Even

(c) **Odd** (d) Infinite

(13) For non-localized states of the square well potential ________

(a) $E = 0$ (b) $E = \propto$

(c) $E < 0$ (d) $\boldsymbol{E} > 0$

(14) For $E > 0$, the particle has a ______ kinetic energy

(a) Zero (b) **Positive**

(c) Negative (d) Infinity

Short Questions:

1. Define stationary states of the wave function
2. Write the time independent Schrodinger equation
3. State the physical significance of time independent Schrodinger equation
4. Write the admissible solution for a particle in a square well potential
5. Define square well potential
6. What is the condition of the total probability of the wave function

Long Questions:

1. Describe the stationary states and energy spectra of the quantum mechanical system
2. Derive the time independent Schrodinger equation and explain their physical significance
3. Discuss the motion of a particle in a square well for bound state and derive the admissible solutions of the time independent Schrodinger equations
4. Derive the expression of energy eigen values for a particle in a square well using the admissible solutions
5. Derive the energy eigen function for a particle in a square well potential
6. Discuss the square well potential for non-localized states($E > 0$) with the physical interpretation and suitable boundary conditions

UNIT: 3 General Formalism of Wave Mechanics

Multiple choice questions:

(1) For the wave functions $\emptyset$ and ψ and operator A the shorter notation of the integral $\int \phi^* A\psi d\tau \equiv$ ________

(a) (ϕ, ψ) (b) $(\phi^*, A\psi)$

(c) **$(\boldsymbol{\phi}, \boldsymbol{A\psi})$** (d) $(A\phi,\ \psi)$

(2) For adjoint operator A, $(\phi, A\psi)$= __________

(a) **$(\boldsymbol{A^{+}\emptyset}, \boldsymbol{\psi})$** (b) $(\phi^*, A\psi)$

(c) $(\phi, A\psi)$ (d) $(A\phi,\ \psi)$

(3) For the adjoint of the product of two operators *A* and *B*, $(AB)^{\dagger}$ = ______

(a) **$B^{\dagger}A^{\dagger}$** (b) AB

(c) $A^{\dagger}B^{\dagger}$ (d) 1

(4) If there exist only one eigen function corresponding to a given eigen value, then the eigen value is called ____________

(a) Non degenerate (b) **degenerate**

(c) discrete (d) continuum

(5) If there exist more than one eigen function corresponding to a given eigen value, then the eigen value is called ____________

(a) **Non degenerate** (b) degenerate

(c) discrete (d) continuum

(6) The set of eigen function $(C_1\emptyset_a + C_2\psi_a)$ forms _________ space

(a) configuration (b) **eigen**

(c) phase (d) imaginary

(7) If A is an operator and $A^{\dagger}$ is an adjoint operator of A then $(A^{\dagger})^{\dagger}$ = ______

(a) **A** (b) A^*

(c) $A^{\dagger}$ (d) 1

(8) If A and B are non-commutative self adjoint operators then $(AB)^{\dagger}$ = ______

(a) **BA** (b) AB

(c) $A^{\dagger}B^{\dagger}$ (d) 1

(9) Eigen values of a self adjoint operator is _______

(a) always 0 (b) infinite

(c) **Real** (d) imaginary

(10) For any operator A and a wave function ϕ_a if $A\phi_a = a\phi_a$ then a is called _______

(a) Eigen function (b) **Eigen value**

(c) Probability density (d) Probability amplitude

(11) Any two eigen functions belonging to unequal eigen values of a self adjoint operator are _________

(a) Non orthogonal (b) parallel

(c) **orthogonal** (d) imaginary

(12) If $\delta_{m,n}$ is Kronecker delta function then $\delta_{m,n} = 0$ when _______

(a) $m = n$ (b) $m > n$

(c) $m < n$ (d) $\boldsymbol{m \neq n}$

(13) If $\delta_{m,n}$ is Kronecker delta function then $\delta_{m,n} = 1$ when _______

(a) $\boldsymbol{m = n}$ (b) $m > n$

(c) $m < n$ (d) $m \neq n$

(14) An operator representing observable dynamical variable has ________ value

(a) always 0 (b) infinite

(c) **real** (d) imaginary

(15) Position operator in a momentum space is given by r_{op} = ________

(a) $\mathbf{i\hbar\vec{\nabla}_p}$ (b) $i\hbar r_{op}$

(c) $\left(\frac{\partial}{\partial x}\hat{\imath} + \frac{\partial}{\partial y}\hat{\jmath} + \frac{\partial}{\partial z}\hat{k}\right)$ (d) $\frac{2m}{\hbar^2}\vec{\nabla}$

(16) According to general statement of uncertainty principle if ΔA and ΔB give the uncertainty in the measurement of A and B then $(\Delta A)^2(\Delta B)^2 \geq$ _______

(a) $\boldsymbol{\frac{1}{4}\langle[A,B]\rangle^2}$ (b) ħ

(c) iħ (d) $\frac{1}{2}\langle[A,B]\rangle^2$

(17) If A & B are a canonically conjugate pair of operator, then $[A,B]$ = _______

(a) *Iħ/2* (b) ***iħ***

(c) ħ (d) *2iħ*

(18) The same state of all the components of _____ operator is impossible

(a) $\vec{P}$ (b) $\boldsymbol{\vec{L}}$

(c) $\vec{K}$ (d) $\vec{\nabla}$

(19) The value of constant of integration for Box normalized momentum eigen function is __________

(a) $1/2\sqrt{L}$ (b) $\mathbf{1/\sqrt{L}}$

(c) $1/\sqrt{\pi}$ (d) $1/\sqrt{2\pi}$

(20) The value of constant of integration for δ function normalized momentum eigen function is __________

(a) $1/2\sqrt{L}$ (b) $1/\sqrt{L}$

(c) $1/\sqrt{\pi}$ (d) $\mathbf{1/\sqrt{2\pi}}$

Short Questions:

1. Explain adjoint and self adjoint operator
2. Write the properties of an adjoint operator
3. Define degenerate and non-degenerate eigen values
4. Explain briefly Dirac delta function
5. What is observable? Also state expansion postulate
6. Show that eigen value of a self adjoint operator is real
7. Show that if ϕ_a is eigen function of an operator A and an operator B is commuting with the operator A then ϕ_a is also eigen function of the operator B
8. Obtain eigen function in momentum space
9. Show that if the components of angular momentum Lx and Ly have the same eigen function than they are commutative operators
10. State the uncertainty principle for operators A and B

Long Questions:

1. Discuss the adjoint of operator with their properties
2. Discuss the eigen value problem for degeneracy
3. Define self adjoint operator and describe its eigen values and eigen functions
4. Show that any two eigen functions belonging to distinct (unequal) eigenvalues of a self adjoint operator are mutually orthogonal
5. Show that the eigen function belonging to discrete eigen values are normalizable and the eigen functions belonging to continuous eigenvalues are of infinite norm.
6. Discuss the physical interpretation of eigen values, eigen functions and expansion coefficients
7. Write a detailed note on Dirac delta function
8. Discuss the completeness and normalization of eigen functions for observables
9. Derive eigen function in momentum space and normalized it by box normalization
10. Derive eigen function in momentum space and normalized it by δ function normalization method
11. State uncertainty principle and discuss it for quantum mechanical observables.
12. Prove that the same state of all the component of $\vec{L}$ is impossible

UNIT: 4 Exactly Soluble Eigen Value Problem

Multiple choice questions:

(1) Time dependent Schrodinger equation in shorter form is given by Hu = ________

(a) Eu^2 (b) E
(c) EH (d) **Eu**

(2) Force acting on the pendulum is proportional to __________

(a) velocity (b) **displacement**
(c) time (d) acceleration

(3) Hamiltonian operator for simple harmonic oscillator is $H =$ ___________

(a) $\boldsymbol{\frac{p^2}{2m} + \frac{1}{2}kx^2}$ (b) $\frac{p^2}{2m}$
(c) $\frac{1}{2}kx^2$ (d) $\frac{p^2}{2m} + kx$

(4) Potential of harmonic oscillator is $V =$ ___________

(a) mgh (b) $\boldsymbol{\frac{1}{2}kx^2}$
(c) $\frac{p^2}{2m}$ (d) kx

(5) Energy eigen value of simple harmonic oscillator is given by E = __________

(a) $\hbar\nu$ (b) $\boldsymbol{\left(n + \frac{1}{2}\right)\hbar\omega}$
(c) $N\hbar\nu$ (d) $\hbar\omega$

(6) The zero point energy for simple harmonic oscillator is E = __________

(a) $\hbar\omega$ (b) $\boldsymbol{\frac{1}{2}}\hbar\omega$
(c) $\frac{3}{2}\hbar\omega$ (d) $\frac{5}{2}\hbar\omega$

(7) The ground state energy for simple harmonic oscillator is E = __________

(a) $\hbar$⍰

(b) $\frac{1}{2}\hbar\omega$

(c) $\frac{3}{2}\hbar\omega$

(d) $\frac{5}{2}\hbar\omega$

(8) Energy eigen value of an isotropic oscillator is given by E = __________

(a) $\hbar\nu$

(b) $\hbar\omega$

(c) $N\hbar\nu$

(d) $\left(\boldsymbol{n}+\frac{3}{2}\right)\hbar\boldsymbol{\omega}$

(9) Angular momentum is defined as $L =$ ________

(a) $\vec{r}\cdot\vec{p}$

(b) $\vec{r}\times\vec{p}^2$

(c) $\vec{\boldsymbol{r}}\times\vec{\boldsymbol{p}}$

(d) mv

(10) In a rigid rotator distance between two particles is _______

(a) Variable

(b) Zero

(c) Infinite

(d) **constant**

(11) The quantum mechanical energy for a particle in one dimension square well potential is ____________

(a) $E = \frac{l(l+1)\hbar^2}{I}$

(b) $\boldsymbol{E = \frac{l(l+1)\hbar^2}{2I}}$

(c) $E = \frac{(l+1)\hbar^2}{I}$

(d) $E = \frac{(l+1)\hbar^2}{2I}$

(12) Central potential is a function of ___________

(a) r

(b) θ

(c) $\emptyset$

(d) $\boldsymbol{r\ and\ \theta}$

(13) Energy of an isotropic oscillator is __________

(a) Continues

(b) **Discrete**

(c) 0

(d) hv

(14) For a rigid rotator the differences of energy levels are govern by $\Delta E =$ _________

(a) $\left(n+\frac{1}{2}\right)\hbar\omega$

(b) $N\hbar\nu$

(c) $\left(n+\frac{3}{2}\right)\hbar\omega$

(d) $\boldsymbol{\frac{\hbar^2}{I}l}$

(15) The energy eigen value for isotropic oscillator is E= __________

(a) $\left(n+\frac{1}{2}\right)\hbar\omega$

(b) $E = \frac{(l+1)\hbar^2}{2I}$

(c) $\left(\boldsymbol{n}+\frac{3}{2}\right)\hbar\boldsymbol{\omega}$

(d) $E = \frac{l(l+1)\hbar^2}{2I}$

Short Questions:

1. Set up the Hamiltonian for simple harmonic oscillator
2. Write the dimension less Schrodinger equation for simple harmonic oscillator
3. Draw the energy level diagram of simple harmonic oscillator
4. Find the components of angular momentum
5. Write down expression for ∇^2 in spherical polar coordinates

6. Write the expression of angular momentum operator L^2 in terms of spherical polar coordinates
7. What is rigid rotator? State the expression for its energy level separation. What is importance of studying rigid rotator?
8. Define central potential? Write down the expression for Hamiltonian of a particle moving in a central potential field
9. Write the radial equation for a particle in central potential
10. Write the Hamiltonian for anisotropic oscillator
11. Write the energy eigen value for anisotropic oscillator
12. What is isotropic oscillator? Write down expressions for its energy

Long Questions:

1. Derive the dimension less Schrodinger equation for simple harmonic oscillator
2. Set up the Hamiltonian of simple harmonic oscillator and derive the expression of its energy eigen value
3. Derive the expression of angular momentum operator L^2 in terms of spherical polar coordinates
4. Set up the Hamiltonian for a particle in one dimension square well and obtain its energy eigen value
5. What is rigid rotator? Show that the spacing between two energy level is increases with l
6. Derive the radial equation for a particle in central potential
7. Set up the Hamiltonian of anisotropic oscillator and derive its energy eigen value
8. What is an isotropic oscillator? Obtain the expression of its energy eigen value