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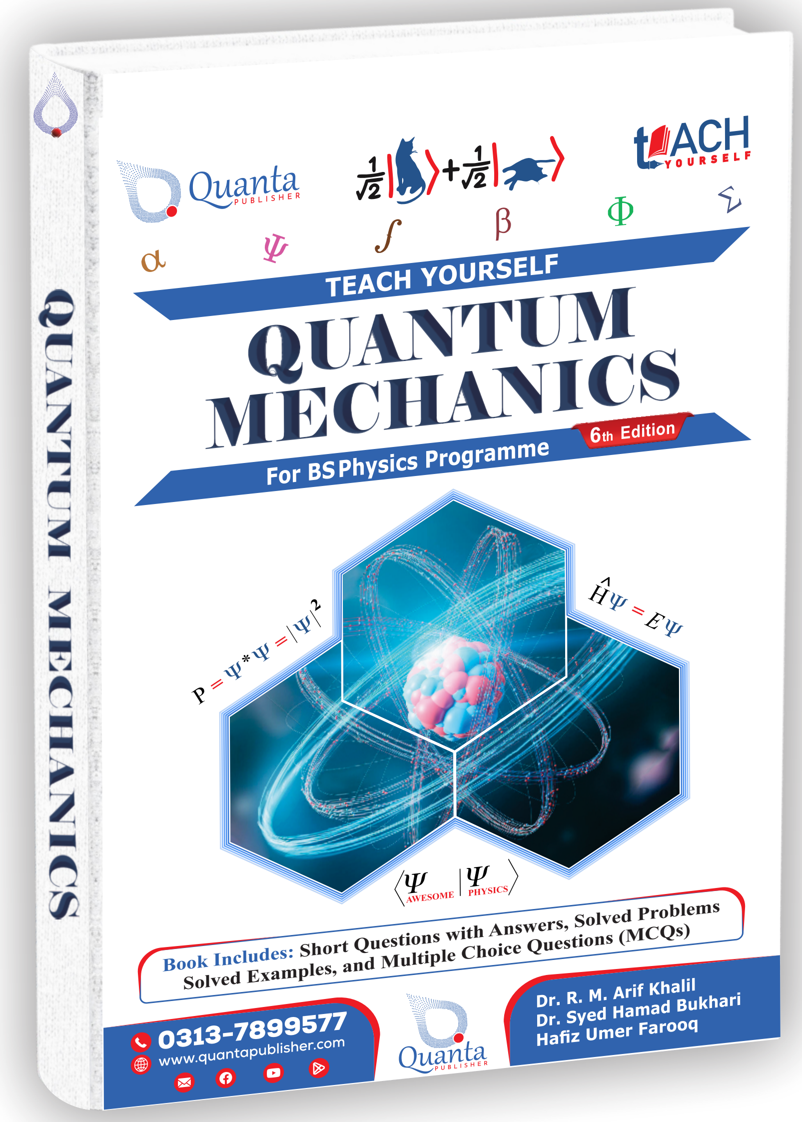
BS Physics

PAST PAPERS



ALEX Komi

DEPARTMENT of PHY

MSc-II & BS-VI (M & E) Midterm Examination

Quantum Mechanics-I (PHYS 6102) Time: 1 hour & 30 minutes

Session: 2012-14 & 201 Total Marks: 30

NOTE: Attempt all questions.

Q. 1: (a) Define wave function and explain its physical importance. Also gives the properties of Probability in terms of wave functions. (3)

(b) Let two functions ψ and φ be defined for $0 \leq x \leq \infty$. Explain why $\psi(x) = x$ cannot be a wave function but $\varphi(x) = e^{-x^2}$ could be a valid wave function. (3)

Q. 2: (a) Define and proof the 3-dimensional Time-Dependent Schrodinger wave equation. (6)

Q. 3: (a) Consider a particle is trapped in a region between 0 to ∞. If

$$\psi(x,t) = A\sin(kx)\exp(-iEt/\hbar)$$

then by using the Schrodinger wave equation find out $E = P^2/2m$ (4)

(b) The angular frequency for a wave is $\omega = kc\left[1 - \frac{\pi^2}{(b^2k^2)}\right]^{-1/2}$ Find the group velocity of the wave. (2)

Q. 4: (a) Show that $\psi(x) = e^{-x^2/2}$ is an eigenfunction of an operator

$$\hat{A} = \left(\frac{\partial^2}{\partial x^2} - x^2\right)$$ (3)

(b) For any operator $\hat{A}$, show that $\hat{A} = \left(\hat{A}^{\dagger}\right)^{\dagger}$ (3)

Q. 5: (a) Let $\hat{A}$ and $\hat{B}$ two Hermitian operators then prove that $i[\hat{A}, \hat{B}]$ is Hermitian. (3)

(b) Establish the following operator equation,

$$\left(\frac{\partial}{\partial x} + x\right)\left(\frac{\partial}{\partial x} - x\right) = \frac{\partial^2}{\partial x^2} - x^2 - 1$$ (3)

DEPARTMENT *of* PHYSICS

MSc-II & BS-VI (M & E) Final Examination | Quantum Mechanics-I (PHYS 6102) Time: 2 hour & 30 minutes | Session: 2012-14 & 2010-2014 Total Marks: 50

NOTE: Attempt only five questions.

Q. 1: (a) Prove that the eigenvalues of a Hermitian operator are real. (4)

(b) Consider a one-dimensional particle which is confined within the region $0 \le x \le a$ and whose wave function is $\Psi(x,t) = sin(\pi x/a)exp(-iwt)$.
(a) Find the potential $V(x)$.
(b) Calculate the probability of finding the particle in the interval $a/4 \le x \le 3a/4$. (6)

Q. 2: (a) If two operators are compatible, then show that they will commute to each other. (5)

(b) Establish the following operator equation.

$$\left[\frac{\partial}{\partial x}, x^n\right] = nx^{n-1} \quad (5)$$

Q. 3: (a) For $\langle \hat{A} \rangle$ to be constant in time. Then prove that $[\hat{H}, \hat{A}] = 0$. (5)

(b) Prove that $\Delta A\ \Delta B \ge \frac{1}{2}|<C>|$, if $\hat{A}$ and $\hat{B}$ are two non-commuting Hermitian operators. (5)

Q. 4: Solve the Schrodinger wave equation for a bound states of a particle in an infinite square potential well in the interval $-a/2 \le x \le a/2$, when energy of the incident particle is less than that of the potential barrier height. Calculate the energy eigenvalues and also draw the wave functions for even and odd parity functions. (10)

Q. 5: (a) If λ is degenerate eigenvalue of a Hermitian operator corresponding to linearly independent eigenfunctions $\Psi_1, \Psi_2, \ldots, \Psi_n$, then every linear combination of $\Psi_1, \Psi_2, \ldots, \Psi_n$ is an eigenfunction of the same operator corresponding to same eigenvalue. (5)

(b) Show that for a one-dimensional square integrable function

$$\int J(x,t)\,dx = \frac{<P>}{m} \quad (5)$$

Q. 6: (a) Show that the momentum operator is Hermitian. (4)

(b) An electron is moving freely inside a one-dimensional infinite potential box with walls at x = 0 and x = a. If the electron is in initially in ground state (n = 1) of the box and if the wall move from x = a to x = 5a. Calculate the probability of finding the electron in:
(a) the ground state of the new box and
(b) in the first excited state of the new box. (6)

DEPARTMENT OF PHYSICS

MSc-II (M & E) & BS-VI (M & E) Mid Term Exam	Quantum Mechanics-I (PHYS 309) Time: 1.5 hour	Session: 2015-17 & 2013-2017 Total Marks: 30

NOTE: Attempt all the questions.

Q. 1: (a) The eigenfunctions of a Hermitian operator corresponding to different eigenvalues are mutually orthogonal. (5)

(b) The Hamiltonian of a free particle of mass "m" and momentum "p" is $H = p^2/2m$, then calculate $[H, p]$. (5)

Q. 2: (a) If the Hamiltonian of the system is Hermitian, then prove that the total probability density is constant. (5)

(b) (i) Using the commutator $[X, p] = i\hbar$, show that $[X^m, P] = im\hbar X^m$, with $m > 1$. (2)

(ii) Use the result of (i) to show the general relation $[F(X), P] = i\hbar dF(X)/dx$, where $F(X)$ is a differentiable operator function of X. (3)

Q. 3: (a) When light of a given wavelength is incident on a metallic surface, the stopping potential for the photoelectrons is 3.2 V. If a second light source whose wavelength is double that of the first is used, the stopping potential drops to 0.8 V. From these data, calculate

(i) the wavelength of the first radiation and (2)

(ii) the work function and the cutoff frequency of the metal. (3)

(b) A particle has a wave-function

$$\Psi(x) = (\lambda/\pi)^{1/4}(e)^{-\lambda x^2/2}$$

Find the expectation value of its Kinetic Energy. (5)

DEPARTMENT O[...]

MSc-II (M & E) & BS-VI (M & E) Quantum Mechanics-I (PHYS 309) Session: 2015-17 & 2[...]
Final Term Exam Time: 2.5 hour Total Mar[...]

NOTE: Attempt all the questions.

Q. 1: (a) Explain the Eigen-value equations in the form of matrix representation and write for n = 3, 4, and 5. (6)

(b) Calculate only energy eigenvalues of a particle, when a particle is confined in a one dimensional box. (4)

Q. 2: Consider a particle which is confined to move along the positive x-axis and whose Hamiltonian is $H = -Ed^2/dx^2 + 16Ex^2$, where E is a real constant having the dimensions of energy.

(a) Find the wave function that corresponds to an energy eigenvalue of $9E$ (make sure that the function you find is finite everywhere along the positive x-axis and is square integrable). Normalize this wave function. (4)

(b) Calculate the probability of finding the particle in the region $0 \le x \le 15$. (3)

(c) Is the wave function derived in (a) an eigenfunction of the operator $A = d/dx - 7$?. (3)

Q. 3: (a) Consider a particle is moving in +ve x-direction then, calculate the time rate of change of the expectation value of its momentum operator. (6)

(b) (i) Express the commutator $[X^2, P^2]$ in terms of XP plus a constant in $\hbar^2$. (2)

(ii) Find the classical limit of $[X^2, P^2]$ for this expression. (2)

Q. 4: (a) In the finite square well potential, discuss the case when incident particle energy is less than that of potential barrier. (15)

(b) show that for a one-dimensional square integrable function function

$$\int J(x,t)\, dx = \langle P_x \rangle / m$$

Where J(x,t) is the probability current density. (5)

ALEX Nomi

DEPARTMENT Of PHYSICS

MSc-II (M & E) & BS-VI (M & E)
Mid Term Exam

Quantum Mechanics-I (PHYS 309)
Time: 1.5 hour

Session: 2015-17 & 2013-2017
Total Marks: 30

NOTE: Attempt all the questions.

Q. 1: (a) Explain the Classical and Quantum Concepts of Particles and Waves in detail. (6)

(b) Prove that $[H, P_x] = -\hbar/i(dV(x)/dx)$, where $H = P_x^2/2m + V(x)$ (4)

Q. 2: (a) Consider a photon that scatters from an electron at rest. If the Compton wavelength shift is observed to be triple the wavelength of the incident photon and if the photon scatters at 60^0, calculate

(i) the wavelength of the incident photon, (2)
(ii) the energy of the recoiling electron, and (2)
(iii) the angle at which the electron scatters. (2)

(b) A particle of mass "m" in 1-dimensional box is found to be the ground state normalized wave-function is

$$\Psi(x) = (2/a)^{1/2} \sin(\pi x/a) \text{ for } 0 \leq x \leq a,$$

then find that

$$\Delta P = \hbar\pi/a$$ (4)

Q. 3: (a) Find the state $\Psi(x)$ for which $A\Psi(x) = 0$ and normalize it, where operator A is $A = i(X^2+1)d/dx + iX$ is Hermitian operator. (2)

(b) Consider a one-dimensional particle which moves along the x-axis and whose Hamiltonian is $H = -Ed^2/dx^2 + 16EX^2$, where E is a real constant having the dimensions of energy. Is $\Psi(x) = Ae^{-2x^2}$, where A is a normalization constant that needs to be found, an eigenfunction of H? If yes, find the energy eigenvalue. (3)

(c) If $\Psi(x) = A(ax-x^2)$ for $0 \leq x \leq a$, then

(i) Normalized the wave-function, (2)
(ii) Find $\langle x\rangle$, $\langle x^2\rangle$, and $\langle\Delta x\rangle$ (3)

UNIVERSITY OF THE PUNJAB

Roll No. ....

Fifth Semester 2018

Examination: B.S. 4 Years Programme

PAPER: Quantum Mechanics-I
Course Code: PHY-305

TIME ALLOWED: 30 mins.
MAX. MARKS: 10

Attempt this Paper on this Question Sheet only.

SECTION – I (OBJECTIVE TYPE)

Q1: Choose (encircle) the best possible answer from the given: **(1x10 = 10)**

1- Conditions on wave function is that, it must be:

a) Single valued

b) Finite

c) Continuous

d) All above

2- Livi-civitia symbol ϵ_{ijk} for odd permutation of i, j, k is

a) 1

b) 0

c) −1

d) none of above

3- $[\hat{L}_z, \hat{L}_+]$

a) $\hbar L_+$

b) $i\hbar L_+$

c) $i\hbar L_-$

d) Zero

4- The Hamiltonian of harmonic oscillator in terms of Ladder operator:

a) $\hbar\omega(\hat{N} - \frac{1}{2})$

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

c) $\frac{1}{2}\hbar\frac{\omega}{4}$

d) $\hbar\omega(\hat{N} + \frac{1}{2})$

P.T.O

5- $\vec{L} \times \vec{L}$

a) Zero

b) $\hbar L_+$

c) $i\hbar \vec{L}$

d) None of above

6- If $[\hat{A}, \hat{B}] = 0$ then both operators can be determined

a) Simultaneously

b) Difficult to find

c) Both a & b

d) none of above

7- The raising operator $\hat{L}_+$ of angular momentum is defined as:

a) $\hat{L}_x + i\,\hat{L}_y$

b) $\hat{L}_x - i\,\hat{L}_y$

c) $\hat{L}_x + i\,\hat{L}_z$

d) $\hat{L}_z + i\,\hat{L}_y$

8- If two operators commute with each other, then operators have same set of:

a) Eigen values

b) Eigen spectrum

c) Eigen functions

d) None of above

9- Expression for Z-component of angular momentum is

a) $-i\hbar \frac{\partial}{\partial \theta}$

b) $-i\hbar \frac{\partial}{\partial \phi}$

c) $i\hbar \frac{\partial}{\partial \phi}$

d) $-i\hbar \frac{\partial}{\partial z}$

10- Applications of barrier tunneling are:

a) Radioactive decays

b) Semiconductor devices

c) Both a & b

d) None of these

UNIVERSITY OF THE PUNJAB

Fifth Semester 2018

Examination: B.S. 4 Years Programme

Roll No. ....

PAPER: Quantum Mechanics-I **TIME ALLOWED: 2 hrs. & 30 mins.**

Course Code: PHY-305 **MAX. MARKS: 50**

Attempt this Paper on Separate Answer Sheet provided.

SUBJECTIVE TYPE

i.

Q2: Give short answers to the following questions: **(4x5 = 20)**

i. What is zero point energy, If a classical oscillator has energy $\frac{1}{2}\hbar\omega$, What is its amplitude?

ii. Define degenerate eigen values, non-degenerate eigen values, linear dependent functions and linear independent functions.

iii. Describe Correspondence principle.

iv. State Hilbert space and give two of its examples.

v. Write physical significance of Uncertainty principle.

Q3: Define the term Central potential. Starting with the time independent Schrodinger's wave equation, obtain an expression of radial wave function. **(10)**

Q4: (a) If two operators have simultaneous eigen function, then these operators commute

(b) Write down three postulates of Quantum Mechanics. (7+3)

Q5: (a) Find eigen value and eigen function of z-component of angular momentum.

(b) Prove that $[\hat{L}_z, \sin\phi] = -i\hbar\cos\phi$ (7+3)

G.C University, Faisalabad

Final Term Examination Paper, Fall -2018

(For Affiliation Colleges)

Subjective Part

Subject Quantum Mechanics-I Course Code: PHY-504

Class: BS (PHY)6th Time Allowed: 150min Total Marks: 30

Name of Student: Roll No:

Note: Attempt All Questions.

Q#2 What is Matrix representation of angular momentum operators with examples.

Q#3 Explain Linear Vector Space and orthogonal systems.

Q#4 Explain the Schrodinger Equation in Three Dimensions and Separation of Schrodinger equation in Cartesian coordination.

Q#5 What is Dynamics variables and operators.

Q#6 Explain Heisenberg uncertainty relations and Functions and expectation values.

GOVERNMENT COLLEGE UNIVERSITY FAISALABAD
6th Semester(Final term) 2020

Course Code: PHY-504 Time Allowed: 90mins
Quantum Mechanics-1 Total Marks: 50

Question No. 1: Encircle the correct answer

1. The K.E of photo electron depends on
(a) Speed of light
(b) intensity of light
(c) No. of incident photons
(d) Photon frequency
2. Operator $(\hat{A} + \hat{A}^{\dagger})$ is
(a) Anti-Hermitian (b) Skew Hermitain (c) Hermitian (d) none of these
3. Hermitian operator that governs a dynamical variable in quantum mechanics is called
(a) intangible (b) intanglio (c) obtainable (d) observable
4. The square of angular momentum J^2 commutes with
(a) J_x (b) J_y (c) J_z (d) All of these
5. The commutator $[\hat{\Pi}, \hat{P}_x]$ is equal to
(a) $i\hbar$ (b) $\hbar^2$ (c) ... (d) Zero
6. The sum of two Hermitian operators is
(a) Anti-Hermitian (b) Simultaneous (c) Hermitian (d) Commutator
7. The action of parity operator on e^x is
(a) e^x (b) e^{ix} (c) e^{-x} (d) $-e^x$
8. The zero point energy of a particle in one dimensional box is
(a) $\frac{h^2}{8ma^2}$ (b) $\frac{8ma^2}{h^2}$ (c) h^2 (d) $\frac{\hbar^2}{8ma^2}$
9. The zero point energy of harmonic oscillator is
(a) $E_o = \frac{3}{2}\hbar\omega$ (b) $E_o = \frac{1}{2}\hbar\omega$ (c) $E_o = \frac{5}{2}\hbar\omega$ (d) $E_o = \hbar\omega$
10. The function $f(x) = x^3$ is
(a) Systematic (b) Anti-symmetric (c) Harmonic (d) none of these
11. The number operator $\hat{N}$ is defined as
(a) 1 (b) $\hat{a}\hat{a}^{\dagger}$ (c) $\hat{a}^{\dagger}\hat{a}$ (d) $\hat{a}$
12. Expectation value of L^2 is equal to
(a) imaginary (b) zero (c) real (d) all of these
13. $[\hat{x}, \hat{L}_y] =$
(a) $i\hbar\hat{L}_z$ (b) $i\hbar\hat{L}_x$ (a) $i\hbar\hat{L}_x$ (a) Zero
14. The electron proton and neutron are
(a) Fermions (b) Boson (c) Photons (d) None of these
15. The charge on electron is represented by e. Which of the following charges can exist?
(a) 2.0 e (b) 2.5 e (c) 3.6 e (d) 5.2 e
16. The energy of photon depends upon
(a) amplitude (b) speed (c) pressure (d) temperature
17. Dynamical variables are real quantities that are measurable and so they are represented by
(a) Hermitian Operator
(b) Anti-Hermitian Operator
(c) Linear Operator
(d) non- linear Operator
18. A set of vectors in a vector is called
(a) Dimension (b) Basis (c) Modulus (d) none of these
19. The eigen values of Hermitian operator are always
(a) Complex (b) Real (c) Imaginary (d) all of these
20. The bra space is ______ to ket space
(a) Hilbert space (b) Vector space (c) Dual space (d) All of these

21. If two vectors are normalized and orthogonal, we call them ____ vectors

(a) Normalized (b) Orthogonal (c) Orthonormal (d) None of these

22. Expectation value of an observable is always

(a) imaginary (b) Complex (c) Real (d) Commutative

23. The sum of Reflection (R) and Transmission (T) coefficients is equal to

(a) 0 (b) 1 (c) Both a and b (d) none of these

24. The square of angular momentum is

(a) Hermitian (b) Anti-Hermitian (c) Linear (d) Projection operator

25. Components of angular momentum are do not commute

a) orthogonal b) normal c) commute d) none

26. When V(x) is even, the corresponding Hamiltonian is:

a) odd b) even c) degenerate d) non-degenerate

27. As $\hat{P}_x$ and $\hat{T}$ have common eigenfunction so they

a) Commute b) Anti-commute c) Orthogonal d) Orthonormal

28. Which one of following is not an observable?

a) Energy b) wave function c) position d) momentum

29. The expectation value of $\hat{x}$ in nth eigen state ϕ_n is

(a) $\langle\hat{x}\rangle = 0$ (b) $\langle\hat{x}\rangle = m\omega^2$ (c) $\langle\hat{P}_x\rangle = m\omega^2$ (d) $\langle\hat{P}_x\rangle = 0$

30. The linear momentum of free particle is

(a) $2mE$ (b) $\sqrt{2mE^2}$ (c) $\sqrt{8mE}$ (d) $\sqrt{2mE}$

31. The quantity $|\psi|^2$ is

(a) wave function (b) one (c) normalization condition (d) probability density

32. The simultaneous eigen function of $\frac{d}{dx}$ and $\frac{d^2}{dx^2}$

(a) e^{2x} (b) Sin x (c) Cos x (d) Sinx Cosx

33. The momentum operator in multiple dimensions can be written as

(a) $-i\hbar\nabla$ (b) $-\hbar^2\nabla^2$ (c) $-i\hbar\,\partial/\partial x$ (d) none of these

34. Angular momentum operator acts on the state $\psi(r,\theta,\phi)$ as

(a) $L^2\psi = l(l+1)\hbar^2\psi$

(b) $L\psi = l(l+1)\hbar^2\psi$

(c) $L\psi = l(l+1)\hbar\psi a$

(d) none of above

35. Expression of z-component of angular momentum is

(a) $-i\hbar\,\partial/\partial\phi$ (b) $-i\hbar\,\partial/\partial\theta$ (c) $-i\hbar\,\partial/\partial z$ (d) none of these

36. Applications of barrier tunneling are

(a) radioactive decay (b) semiconductor devices (c) both a and b (d) none of these

37. It is necessary for two operators to commute with each others for having a

(a) degenerate eigen value (b) simultaneous eigen value (c) orthogonal eigen value (d) all of these

38. In Heisenberg picture, the operators are time dependent while ____ are time independent.

(a) wave functions (b) operators (c) Eigen values (d) none

39. For Hydrogen atom that are in ground state, the orbital angular momentum will be

(a) 1 (b) 2 (c) 0 (d) unknown

40. Position and momentum operators are always

(a) Commutative (b) Anti commutative (c) Normalized (d) orthogonal

2/3

41. The momentum operator in one dimension is

(a) $\hbar\, \partial/\partial x$ (b) $\frac{\hbar}{i}\, \partial/\partial x$ (c) $\frac{i}{\hbar}\, \partial/\partial t$ (d) $\frac{i}{\hbar}\, \partial/\partial x$

42. Quantized energy of rigid rotator is

(a) $\frac{\hbar^2 l(l+1)}{2I}$ (b) $\frac{\hbar^2 l^2(l+1)}{2I}$ (c) $\frac{\hbar^2 l(2l+1)}{2I}$ (d) $\frac{\hbar^2 l^2(2l+1)}{2I}$

43. The Pauli spin operator is defined as

(a) $\hat{\sigma} = \frac{1}{\hbar}\hat{S}$ (b) $\hat{\sigma} = \frac{4}{\hbar}\hat{S}$ (c) $\hat{\sigma} = \frac{\hbar}{2}\hat{S}$ (d) $\hat{\sigma} = \frac{2}{\hbar}\hat{S}$

44. The raising operator L_+ of angular momentum is defined as

(a) $\hat{L}_x - i\hat{L}_y$ (b) $\hat{L}_x - i\hat{L}_z$ (c) $\hat{L}_x + i\hat{L}_y$ (d) $\hat{L}_z + i\hat{L}_y$

45. Spin does not depend upon

(a) S (b) m_s (c) spatial degrees of freedom (d) all of these

46. The states correspoding to discrete spectra are called

(a) bound states (b) unbound states (c) stationary states (d) all of these

47. In transformation from one orthonormal set into other is unitary, such transformation is

(a) Linear (b) non linear (c) unitary (c) similarity.

48. The physical requirement of a wavefunction is that it should be

(a) reliable (b) square integrable (c) zero (d) discrete

49. The value of $L \times L$ is

(a) 0 (b) 1 (c) $i\hbar L$ (d) none of these

50. The quantity $\langle \phi|\psi \rangle$ represents

(a) probability amplitude (b) orthonormality (c) orthogonality (d) none of these

GOVERNMENT COLLEGE UNIVERSITY FAISALABAD Roll No.________

6th Semester(Final term) 2020

Course Code: PHY-504 **Time Allowed: 50mins**

Quantum Mechanics-1 **Total Marks: 25**

Question No. 2: Answer the following questions

i) What are characteristics of well behaved wave function?

ii) Differentiate between degenerate eigen states and non-degenerate eigen states.

iii) Define correspondence principle and complementarity principle.

iv) Why a particle trapped in a box cannot be at rest?

v) Define probablity current density. 3

UNIVERSITY OF THE PUNJAB

B.S. 4 Years Program : Third Semester – Fall 2021

Roll No. 95.12.33..

Paper: Quantum Physics Course Code: PHYS-2001 Time: 3 Hrs. Marks: 60

Q.1. Answer the following short questions: (15x2=30)

(i) Define ultraviolet catastrophe.
(ii) Write down Einstein equation of photoelectric effect and explain the term work function.
(iii) Define pair annihilation. How much amount of energy is required to take place this process?
(iv) Differentiate between a wave and a particle.
(v) What are matter waves. Explain your answer on the behalf of debroglie's hypothesis.
(vi) Explain energy time uncertainty.
(vii) According to Bohr what key points should follow an electron to move in a circular orbit.
(viii) Define zeeman effect.
(ix) Write down mathematical form of following operators (a) total energy (b) linear momentum
(x) What is zero-point energy? Is this numerical value be zero for harmonic oscillator?
(xi) Define magnetic quantum number. If j=1 calculate all possible values of magnetic quantum numbers.
(xii) Define spin orbit coupling.
(xiii) Define pauli's exclusion principle.
(xiv) State correspondence principle.
(xv) Write down some properties of laser light.

Answer the following questions.

Question no2. Define compton's effect. Write down it's experimental setup in detail. What is Compton's shift. Derive its mathematical expression. Show that compton's shift is maximum for head on collision between electron and photon. (10)

Question 3. (a) Use Davison Germer experiment to verify debroglie's hypothesis about dual nature of radiation and matter.

(b) what is normalization condition? Consider a function

$$\Psi = A\sin kx$$

Calculate normalization constant A. (5+5=10)

Question no4. (a) Define tunneling. Discuss tunneling is purely quantum mechanical phenomenon and can't explain by classical mechanics.

(b) Define angular momentum. What do you know about space quantization of angular momentum?

(5+5=10)

GOVERNMENT COLLEGE UNIVERSITY, FAISALABAD
External Semester Examination Spring 2022
BS. Physics (6th Semester)

Roll No.

Course Code: PHY-504 | Maximum Marks: 100
Course Title: Quantum Mechanics-I | Cr. Hr.: 3(3-0)
Objective Marks: 20 | Time Allowed: 00:30 hours

ROLL No.:------------------------- Signature:-----------------------------

Q1. Based on your concepts of this course, Select and Tick the best possible answer. (20×1=20)

(i) The wave function of a particle in a box is given by ______________:
(a) Asin(kx) + Bcos(kx) (b) Asin(kx) - Bcos(kx) (c) Asin(kx) (d) Acos(kx)

(ii) Tunnel effect is notebly observed in the case of ______________:
(a) Gamma rays (b) Beta reys (c) Alpha particle (d) All of These

(iii) The Hermitian conjugate of the operator $\lambda\,|\varphi\rangle\langle\chi|\psi\rangle\langle l|A$ (with λ a scaler and A an operator) is:
a) $\lambda\,|\varphi\rangle\langle\chi|\psi\rangle\langle l|A$ b) $\lambda\,|\varphi\rangle\langle\chi|\psi\rangle\langle l|A^{*}$
c) $A^{*}\,|l\rangle\langle\psi|\chi\rangle\langle\varphi|\lambda^{*}$ d) $A^{*}\,|\varphi\rangle\langle\psi|\chi\rangle\langle l|\lambda^{*}$

(iv) Ehrenfest's theorem partially shows the connection between quantum mechanics and:
a) Photonics. b) Classical mechanics. c) Special relativity. d) General relativity.

(v) The free particle energy eigenfunctions are not physical states that a particle can actually be in because they:
a) Can't be normalized (i.e., they arn't square-integrable). b) Don't exist.
c) Can be normalized (i.e., they are square-integrable) d) Do exist

(vi) What are the conditions for observable Q to be a constant of the motion?
b. [H,Q] = 0 and ∂Q/∂t = 0.
c. [H,Q] = 0 and ∂Q/∂t ≠ 0.
d. [H,Q] > 0 and ∂Q/∂t > 0.
e. [H,Q] < 0 and ∂Q/∂t < 0.

(vii) The completeness relation is
a) $\langle\varphi_m|\varphi_n\rangle = \delta_{mn}$ b) $|\varphi_m\rangle\langle\varphi_n| = \delta_{mn}$ (c) $|\varphi_m\rangle\langle\varphi_n| = 0$ d) $\langle\varphi_m|\varphi_n\rangle$

(viii) For the adjoint of the product of two operators A and B, (AB)† = ______________
(a) A†B† (b) B†A† (c) B†A (d) AB

(ix) If there exist more than one eigen function corresponding to a given eigen value, then the eigen value is called
(a) degenerate (b) Non- degenerate (c) continuum (d) discrete

(x) The walls of a particle in a box are supposed to be ______________:
(a) Small but infinitely hard (b) Infinitely large but soft (c) Soft and Small (d) Infinitely hard and infinitely large

(xi) According to the wave function and it first partial derivative should be ________ functions
(a) Zero (b) continuous (c) identity (d) discontinued

(xii) Particle in a box can never be at rest.
(a) 100%True (b) 100%False (c) Couldn't be (d) Could be

(xiii) For the wave functions Ψ and Φ and operator A, the shorter notation of the integral ∫Ψ*A Φdx=____________
(a) (Φ , Ψ) (b) (Φ , AΨ) (c) (Ψ* AΦ) (d) (AΨ* Φ)

(xiv) If there exist more than one eigen function corresponding to a given eigen value, then the eigen value is called
(a) degenerate (b) Non- degenerate (c) continuum (d) discrete

(xv) The walls of a particle in a box are supposed to be ______________:
(a) Small but infinitely hard (b) Infinitely large but soft (c) Soft and Small (d) Infinitely hard and infinitely large

(xvi) The relation $\langle\varphi_m|A_{mn}|\varphi_n\rangle$ will give
a) number b) Square matrix c) identity matrix d) identity matrix

(xvii) The zero-point energy for simple harmonic oscillator is:
(a) 0.5ħω (b) 1.5ħω (c) 0 (d) ħω

(xviii) The intensity of the diffraction pattern is proportional to ________ of the wave function:
(a) forth power (b) Cube (c) Squre (d) Fifth power

(xix) Symmetric wave function has ----------------
(a) Even parity (b) Odd parity (c) Mixed parity (d) None of these

(xx) Any two eigen functions belonging to unequal eigen values of a self adjoint operator are ____________
(a) Non orthogonal (b) parallel (c) orthogonal (d) imaginary

Course Code: PHY-504 | Maximum Marks: 100
Course Title: Quantum Mechanics-I | Cr. Hr.: 3(3-0)
Subjective Marks: 80 | Time Allowed: 02:30 hours

ROLL No.:------------------------- Signature:-----------------------------

Q-2. (a) Define Hermitian operator and write three conditions for any operator to be Hermitian operator. Also, show that if any operator commutes with the generator of the infinitesimal unitary transformation, remains unchanged
(b) Show that the eigen value of any Hermitian operator is real. (10+10=20)

Q # 3:- a) If the position operator is $\hat{X} = \sqrt{\frac{\hbar}{2m\omega}}\begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & \sqrt{2} & 0 & 0 \\ 0 & \sqrt{2} & 0 & \sqrt{3} & 0 \\ 0 & 0 & \sqrt{3} & 0 & \sqrt{4} \\ 0 & 0 & 0 & \sqrt{4} & 0 \end{bmatrix}$. Then prove, by using virial theorem that energy of the 3rd state of the quantum harmonic oscillator is $\frac{5}{2}\hbar\omega$

b) Consider a particle of mass m moving freely between inside an infinite square potential well of width a. Show that $\langle\psi_n|P^2|\psi_n\rangle = 2mE_n$ (10+10=20)

Q.4. (a) Define expectation values. Give classical and quantum descriptions and show that expectation values of an observable can be obtained by adding all permissible eigenvalues multiplied by the corresponding probability.

(b) Consider two state vectors $|\psi\rangle = 3i|\varphi_1\rangle - 7i|\varphi_2\rangle$ and $|\chi\rangle = -|\varphi_1\rangle + 2i|\varphi_2\rangle$, where $|\varphi_1\rangle$ and $|\varphi_2\rangle$ are orthonormal sets

i. Show that $\langle\psi|\chi\rangle$ is equal to the complex conjugate of $(\langle\chi|\psi\rangle)^{*}$.
ii. Show that $|\psi\rangle$ and $|\chi\rangle$ obey Schwarz inequality. (10+10=20)

Q.5. (a) Obtain the energy expression of a particle in a potential region.
(b) Analytically and graphically show how a particle with energy less than barrier will transmit through barrier ____________________________________ (10+10=20)

Roll No. ________

Course Code: PHY-504 Course Title: Quantum Mechanics – I Semester: 6th
Time Allowed: 1h:45min Marks: 24
Session: 2019-23

Part 2: Subjective

Q. No. 2 Write the short answers to following questions **Marks: 2 x 6**

1. How do you justify the quantum tunneling?
2. State Ehrenfest theorem.
3. Find the eigen value of J^2 for a state $|2,-2\rangle$.
4. In quantum mechanics what is Spin?
5. Show that $a^{\dagger}|1\rangle = \sqrt{2}|2\rangle$.
6. Explain Heisenberg uncertainty principle for position and momentum.

Q. No. 3 Show that $J_-|j,m\rangle = \hbar\sqrt{j(j+1) - m(m-1)}|j,m-1\rangle$. **(Marks:04)**

Q. No. 4. A particle of mass m is confined to a deep potential (defined below). Show that the energy is quantized and the wavefunction is oscillating function.

$$V(x) = \begin{cases} +\infty, & x < 0 \\ 0, & 0 \le x \le a \\ -\infty, & x > a \end{cases}$$

(Marks:04)

Q. No. 5. The Harmonic oscillator is in its third excited state. Find $\langle q^2 \rangle$ and $\langle p^2 \rangle$. **(Marks: 04)**

UNIVERSITY OF THE PUNJAB

B.S. 4 Years Program / Third Semester – Fall 2022

R

Paper: Quantum Physics Course Code: PHYS-2001 Time: 3 Hrs. Ma

THE ANSWERS MUST BE ATTEMPTED ON THE ANSWER SHEET PROVID

Q.1. Answer the following short questions: (15x2=

1. Express the Planck radiation formula in terms of wavelength.
2. Find the energy of a 700 nm photon.
3. What volatage must be applied to an X-ray tube for it to emit X-rays with a minimum wavelength of 30pm.
4. The distance between adjacent atomic planes in calcite ($CaCO_3$) is 0.300nm. Find the smallest angle of Bragg scattering for 0.030nm X-rays.
5. What is the frequency of an X-ray photon whose momentum is 1.1×10^{-23}kg-m/s?
6. A positron collides head on with an electron and both are annihilated. Each particle had a kinetic energy of 1.00MeV. Find the wavelength of resulting photons.
7. Find the de Broglie wavelength of a 1.0mg grain of sand blown by the wind at a speed of 20m/s.
8. What effect on the scattering angle in the Davisson-Germer experiment does increasing the electron energy have?
9. A proton in a one dimensional box has an energy of 400KeV in its first excited state. What is the width of the box?
10. What is the shortest wavelength present in the Brackett series of spectral lines?
11. In the Bohr model, the electron is in constant motion. How can such an electron have a negative amount of energy?
12. A beam of 13.0eV electrons is used to bombard gaseous hydrogen. What series of wavelength will be emitted?
13. Under what circumstances, if any L_z is equal to L?
14. The azimuthal wave function of hydrogen atom is

$$F(\phi) = Ae^{im\phi}$$

Integrate $|F|^2$ over all values from $0 - 2\pi$ and obtain the value of normalization constant A.

15. Why is the ground state of the hydrogen atom not split into two sublevels by spin-orbit coupling?

Q.2. Answer the following questions. (3x10=30)

1. Electrons with energies of 1.0eV and 2.0eV are incident on a barrier 10.0eV high and 0.50nm wide. Find their respective transmission probabilities. How are the transmission probabilities be effected if we double the width of the barrier?
2. State and explain Uncertainty principle. In a harmonic oscillator, the particle varies in position from $-A$ to $+A$ and in momentum from $-p_0$ to $+p_0$. In such an oscillator, $\Delta x = A/\sqrt{2}$ and $\Delta p = p_0/\sqrt{2}$. Use these results to show that minimum energy of a harmonic oscillator is $\frac{1}{2}h\nu$.
3. Define and explain all Four quantum numbers. What are possible values of the magnetic quantum number m_l of an atomic electron whose orbital quantum number is 4?Also Compare the angular momentum of a ground state electron in the Bohr model of hydrogen atom with its value in Quantum theory.

DEPARTMENT Of PHYSIC

[M]Sc-III (M & E) & BS-VII (M & E) Quantum Mechanics-II (PHYS 6102) Session: 2014-16 & 2012-201
[F]inal Exam Time: 2.5 hour Total Marks: 50

3+5

NOTE: Attempt all the questions.

Q. 1: Solve the hydrogen atom by considering the spherically symmetric potential V(r) and find out the ground state energy of the hydrogen atom

$$E_1 = -m_e e^4/2\hbar^2 \quad (15)$$

Q. 2: (a) By applying the Degenerate perturbation theory, prove that the energy eigenstates are degenerate. (8)

(b) Define and explain the variational method and apply it to estimate the ground state energy of the one-dimensional Harmonic Oscillator. (7)

Q. 3: In the light of Time-Dependent Perturbation theory, find the transition probability for a constant perturbation and transition into a continuum of final state. (10)

Q. 4: (a) Describe the exchange degeneracy in detail for identical particles and wave-functions of 2 identical particles. (7)

(b) From the non-degenerate perturbation theory, find the first order correction in energy. (3)

UNIVERSITY OF THE PUNJAB

Sixth Semester - 2018

Examination: B.S. 4 Years Programme

Roll No. ....

PAPER: Quantum Mechanics-II TIME ALLOWED: 15 Mints.
Course Code: PHY-309 Part – I (Compulsory) MAX. MARKS: 10

Attempt this Paper on this Question Sheet only.

Please encircle the correct option. Each MCQ carries 1 Mark. This Paper will be collected back after expiry of time limit mentioned above.

Q1: Choose (encircle) the best possible answer from the given. (1x10=10)

1 The operators which connect the Hilbert space :

a) Creation operator
b) Annihilation operator
c) Momentum operator
d) Both a & b

2 Identify, which is an approximation method?

a) Time dependent perturbation theory
b) Time independent perturbation theory
c) Variational technique
d) All above

3 The diagonal matrix of operator $\hat{S}_y$ is obtained after diagonaliztion is

a) $\frac{\hbar}{2}\begin{pmatrix}0 & 1\\ 1 & 0\end{pmatrix}$
b) $\frac{\hbar}{2}\begin{pmatrix}0 & -i\\ i & 0\end{pmatrix}$
c) $\frac{\hbar}{2}\begin{pmatrix}1 & 0\\ 0 & -1\end{pmatrix}$
d) $\frac{\hbar}{2}\begin{pmatrix}1 & 0\\ -1 & 0\end{pmatrix}$

4 Spin angular momentum is quantized by ____ quantum numbers?

a) 3
b) 2
c) 4
d) 6

5 Identify fermion particle:

a) Photon
b) graviton
c) pi meson
d) Neutron

6 The particles composed of two or more identical elementary particles are:

a) Quarks
b) Composite particles
c) Photons
d) Gravitons

7 For anti-symmetric wave function the value of permutation operator is:

a) -1
b) +1
c) a or b
d) Zero

8 Condition for the validity of WKB approximation is:

a) $d\lambda \ll dx$
b) $\frac{d\lambda}{dx} \ll 1$
c) None of above
d) Both a & b

9 The total no of collisions over the duration of scattering experiment is proportional to

a) No of particles in incident beam
b) No of target particles per unit area
c) Both a & b
d) All of above

10 The 'Frame' in which both colliding particles has equal and opposite velocity is called

a) Centre of mass Frame
b) Inertial Frame
c) Lab Frame
d) Non-inertial Frame

UNIVERSITY OF THE PUNJAB

Sixth Semester - 2018

Examination: B.S. 4 Years Programme

Roll No. ....

PAPER: Quantum Mechanics-II TIME ALLOWED: 2 Hrs. & 45 Mints

Course Code: PHY-309 Part – II MAX. MARKS: 50

Attempt this Paper on Separate Answer Sheet provided.

SUBJECTIVE TYPE

Q.2 Give short answers to the following questions. (4x5=20)

i. Prove that $[\hat{H}, \hat{P}_{ij}]=0$, interpret your results.
ii. Defines later determinant? Write it for N-particle system.
iii. Define 'Exchange Symmetry' and 'Exchange Degeneracy'.
iv. What is the Solid angle? Write its physical interpretation in scattering reference.
v. What is boson-Einstein-condensation? Give one example.

Q.3 Write Detail Description of Time-independent perturbation theory up to first order Correction. (10)

Q.4 Explain the theory of scattering? write a note on potential scattering. (10)

Q.5 Briefly describe (5+5)

a) Born Approximation

b) Check validity of WKB method.

EMERSON UNIVERSITY MULTAN

Midterm examination

B.S. Physics 6^{th} semester

Paper. Quantum Mechanics-IIP *Paper code. PHYS-304*

Time. 1 hour & 30 min. *Total marks: 30*

Question.1

(a) Show that $\hat{H} \mid \Psi = E \mid \Psi >$ is equivalent to Schrodinger wave equation $\delta\ (\Psi) = 0$

(b) Write the extracted results obtained due to degenerate time independent pertu
theory.

Question.2

(a) Use WKB approximation to calculate energy levels of states of an electron that are bounded to Ze nucleus.

(b) Use WKB method to estimate energy levels of one dimensional harmonic oscillator.

Question.3

(a) Using variational method to estimate the ground state energy of hydrogen atom.

(b) Suppose we are looking for ground state energy of electric potential

$$\frac{-\hbar^2}{2m}\frac{d^2}{dx^2} - \alpha\delta(x)$$

Using variational principle where state vectors is $\Psi = Ae^{-bx^2}$

Question .4

(a) Find the ground state energy of one dimensional harmonic oscillator by using variational principle whose state vector is given as $\Psi = Ae^{-bx^2}$

(b) Write the total energy and total wave function up to second order due to time independent non degenerate perturbation theory.

Question.5

(a) Explain the time dependent perturbation theory in detailed.

(b) Explain the inspiration's with detailed behind WKB approximation.

GOVERNMENT COLLEGE UNIVERSITY FAISALABAD
Government Affiliated Colleges
Final-Term Examination Fall 2019 (Subjective)

FULL NAME		Roll No	
Subject	PHY-601 Quantum Mechanics-II 3(3-0)	Class	BS(Physics) 7^{th} Semester
Total Marks	26	Time	1 Hour and 45 Minutes

Question:2 (6+3)

(a) Define and elaborate many particles system? Describe how symmetric and anti-symmetric wave functions are determind.

(b) Express operator N for harmonic oscillator in matrix form.

Question:3 (6+2+1)

(a) Discuss determinantal wave function of many electrons system.

(b) Define kinetic energy operator?

(c) Differentiate between Symmetric and Antisymmetric spin eigen function?

Question:4 (6+2)

(a) Explain time-dependent perturbation theory and calculate first order transition probability.

(b) Evaluate $[S_y, S_z]$ using matrices.

GOVERNMENT COLLEGE UNIVERSITY, FAISALABAD
External Semester Examination Fall, 2021-22
B.S. Physics 7th

Course Code: PHY-601
Course Title: Quantum Mechanics-II
Objective Objective Marks: 20
Maximum Marks: 100
Cr. Hr.: 3(3-0)
Time Allowed: 00:30 hours

ROLL No.:------------------------ Signature:------------------------

Saleem

Q1. Tick the correct answer. (20×1=20)

i. The wave function of Fermions is not
a) Single Valued b) Differentiable c) Symmetric d) Continuous

ii. Bose Einstein statistics is for the ---------------
a) Particle with integral spin b) Distinguishable particles
c) Particle with half integral spin d) All type of particles

iii. Fermi Dirac statistics is for the ---------------
a) Particle with integral spin b) Distinguishable particles
c) Particle with half integral spind) All type of particles

iv. The eigen values of permutation operator are ---------------
a) ±1 b) ±2 c) 0 and 1 d) None of these

v. Permutation operator is also called ---------------
a) Null operator b) Hermitian operator
c) Exchange operator d) Independent operator

vi. If $\Psi(r_1,r_2)=\frac{r_1-r_2}{(r_1-r_2)^2}$, then $\hat{P}_{12}\Psi(r_1,r_2)$ will be
a) $-\Psi(r_1,r_2)$ b) $\Psi(r_1,r_2)$ c) $-\Psi(r_2,r_1)$ d) None of these

vii. The Alpha particle which comprise 4 fermionic particles, is a ---------------
a) Boson b) Fermions c) Could be a and b d) None of these

viii. Half integral spin particles are called
a) Boson b) Fermions c) Mesons d) Kaons

ix. Integral spin particles are called
a) Boson b) Fermions c) Mesons d) Kaons

x. Alpha particle obeys
a) Bose Einstein statistics b) Fermi Dirac statistics
c) Maxwell-Boltzmann statistics d) None of these

xi. Alpha particle is an example of
a) Particle with half integral spin b) Fermionic particles
c) Mixed state particles d) Composite particles

xii. Slater determinant vanishes only for
a) Particle with half integral spin b) Particle with integral spin
c) Both a and b d) None of these

xiii. The Bosons tends to lie in same state, then the ground state of bosons is known as
a) Boson condensation b) Fermion condensation
c) Both a and b d) None of these

xiv. The WKB approximation is a
a) Classical Approach b) Semi-classical Approach
c) Quantum Approach d) None of these

xv. The Variational method is useful for
a) Ground state b) Excited state
c) Both a and b d) None of these

xvi. $\Psi(r_1,r_2)=(r_1-r_2)^2$ represent a --------------- state
a) Anti-Symmetric b) Symmetric c) Mixed d) None of these

xvii. The wave function describing the N-particle system will be
a) $\Psi(t)$ b) $\sqrt{\Psi(r_1,r_2,r_3 \ldots\ldots r_N,t)}$
c) $|\Psi(r_1,r_2,r_3 \ldots\ldots r_N,t)|^2$ d) $\Psi(r_1,r_2,r_3 \ldots\ldots r_N,t)$

xviii. The similarity transformation yields a
a) Square matrix b) Identity matrix
c) Diagonal matrix d) Row matrix

xix. Degeneracy can be removed by using
a) Time independent perturbation theory b) WKB approximation
c) Variational method d) None of these

xx. Operation of square of permutation operator will leave the function

GC UNIVERSITY, FAISALABAD

Final Semester Examination MSc 3rd Total Marks = 80 Name:..............

Course: Quantum Mechanics-II Physics Fall, 2021-22

Time: $2\frac{1}{2}$ hrs Code: PHY- 501 Roll No:............

Subjective

Note: Solve all questions, and each question carries equal marks.

Q-2: Describe the time Independent Nondegenerate Perturbation Theory and prove that

The exact Eigen function $|\psi_n\rangle$ of $\hat{H}$ with its first order correction is

$$|\psi_n\rangle = |\Psi_n^0\rangle + \sum_{m\neq n} \frac{\langle\Psi_m^0|\hat{H}_p|\Psi_n^0\rangle}{E_n^0 - E_m^0}|\Psi_m^0\rangle$$

Note: Where, E_n^0 is the energy eigenvalue of the equilibrium Hamiltonian, $|\Psi_n^0\rangle$ is the state vector corresponding to equilibrium state and $\hat{H}_p$ is the perturbed part of the exact Hamiltonian $\hat{H}$ of the system. (16)

Q-3: (a) Describe the validity of WKB approximation

(b) Describe the quantization rule for the potential wells with two rigid walls by using WKB method

(c) Use the WKB approximation to calculate the energy levels of a spineless particle of mass m moving in a one-dimensional box with walls at $x = 0$ and $x = L$. (5+6+5)

Q-4: Describe in detail

(i) the First Born Approximation

(ii) Validity of the First Born Approximation (8+8)

Q-5: (a) Find the eigenvalues and eigenvectors of the spin operator $\vec{S}$ of an electron in the direction of a unit vector $\vec{n}$ lying in the xz Plane.

(b) Find the probability of measuring $S_z = \frac{\hbar}{2}$

Whereas the spin operators in matrix form are given as

$$\hat{S}_x = \frac{\hbar}{2}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \quad \hat{S}_y = \frac{\hbar}{2}\begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, \quad \hat{S}_z = \frac{\hbar}{2}\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$ (12+4)

Q 6: (a) Describe the reason that why the total enegy of a system of identical noninteracting particle is given by a sum of the single particle energies $\left(E_{n_1,n_2,\ldots,n_N} = \sum_{i=1}^{N} \varepsilon_{n_i}\right)$ like a system of non-interactin distinguishable particles. Whereas the wave functions can no longer be given by simple product of orbitals.

(b) Show that the trace of an operator does not depend on the basis in which it is expressed.

(c) Define the quantum Tunneling Phenonenon (4+8+4)

Govt. College UNIVERSITY, FAISALABAD

External Semester Examinations Fall-2022-2023

Roll No.: ______

Programme: BS Physics

Semester: 7th | Part: Objective | Credit Hrs.: 3(3-0)

Course Code: PHY-601 | Course Title: Quantum Mechanics-II | Marks: 20

Time allowed: 30 Minutes

Q-1:- Tick the correct answer from the given choices:

i) Orthonormality condition of the discrete, complete and orthonormal basis$\{|\phi_n\rangle\}$ is given as
(a) $\sum_{n=1}^{\infty}|\phi_n\rangle\langle\phi_n| = I$ (b) $|\phi_n\rangle\langle\phi_n| = 0$ (c) $\langle\phi_n|\phi_n\rangle = 1$ (d) $\langle\phi_n|\phi_m\rangle = \delta_{nm}$

ii) According to matrix representation $|\Psi\rangle$ and $\langle\Psi|$ are ———— of each other
(a) Opposite (b) Complex conjugate (c) Hermitian Adjoint (d) Always transpose

iii) If a state vector $|\chi\rangle$ is not normalized then it can be normalized by multiplying it with.....
(a) $\frac{1}{\sqrt{\langle\Psi|\Psi\rangle}}$ (b) $\frac{1}{\sqrt{\langle\chi|\chi\rangle}}$ (c) $\sqrt{\langle\Psi|\Psi\rangle}$ (d) $\sqrt{\langle\chi|\chi\rangle}$

iv) The diagonal elements of a Hermitian Matrix are..........
(a) Complex (b) Pure imaginary (c) Both real and imaginary (d) Real

v) Which of the approximation methods is called Semi-classical?
(a) Perturbation (b) WKB (c) Variational Method (d) both b and c

vi) Which of the given particles is Fermion?
(a) Alfa particle (b) Photon (c) Neutron (d) Pion

vii) Degenerate time independent Perturbation theory may ..... the degeneracy.
(a) increase (b) confirm (c) apply (d) reduce

viii) Operators corresponding to different particles.....
(a) Are degenerate (b) are not degenerate (c) Commute (d) do not commute

ix) By the permutation of a pair of particles, the probability density of identical particles is....
(a) Changed (b) Confirmed (c) Normalized (d) Not changed

x) The wave-function associated with a particle having spin $\hbar/2$ is ......
(a) Anti-symmetric (b) Symmetric (c) Asymmetric (d) Anti-asymmetric

xi) The wave function associated with photon is...
(a) Asymmetric (b) Symmetric (c) anti-symmetric (d) anti-asymmetric

xii) Operators corresponding to different particles.....
(a) Commute (b) Are degenerate (c) are not degenerate (d) do not commute

xiii) Which of the given products is physically nonsense
(a) $\langle\Psi|\hat{A}$ (b) $|\Psi\rangle|\phi\rangle$ (c) $\hat{A}|\Psi\rangle$ (d) $|\phi\rangle\langle\Psi|$

xiv) The uncertainty principle is applicable only on ....
(a) Bosons (b) identical particles (c) Quantum particles (d) fermions

xv) According to Pauli Exclusion Principle, every-quantum state can be occupied by at most....
(a) Two fermions (b) two bosons (c) one fermion (d) one boson

xvi) The WKB method is applicable on the quantum-mechanical problems involving.....potential.
(a) Fastly varying (b) constant (c) time-dependent (d) slowly varying

xvii) The particles having spin as $S = 0, 1\hbar, 2\hbar, 3\hbar$ .... are called....
(a) Fermions (b) bosons (c) gravitons (d) quantum particles

xviii) An Operator matrix written in its own discrete, complete and orthonormal eigen-state basis is...
(a) Square matrix (b) Diagonal matrix (c) Adjoint of square Matrix (d) Identity Matrix

xix) Energy of nth Eigen state of a quantum particle of mass m moving in a one dimensional infinite potential well of width d is
(a) $\left(n+\frac{1}{2}\right)\hbar\omega$ (b) $\frac{\pi^2\hbar^2 n}{2md^2}$ (c) $\frac{\pi^2\hbar^2 n^2}{2md^2}$ (d) $\frac{\pi^2\hbar^2 n^2}{2m^2 d}$

xx) The total wave function of the system of distinguishable non-interacting particles is.........
(a) Product of orbitals (b) Sum of the orbitals
(c) Difference of orbitals (d) $\frac{1}{\sqrt{n!}}$ (Sum of the orbitals)

Govt. College UNIVERSITY, FAISALABAD

External Semester Examinations Fall-2022-2023

Roll No.: 992034

Programme: BS Physics

Semester: 7th
Part: Subjective
Credit Hrs.: 3(3-0)
Course Code: PHY-601
Course Title: Quantum Mechanics-II
Marks: 80
Time allowed: 2:30 Hours

Note: Attempt all questions. All the questions carry equal marks.

Q-2:

(a) Describe the conditions of applicability of the following approximation methods

i) Perturbation theory

ii) The WKB approximation

iii) The Variation Method

(b) Consider a matrix

$$\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

Find its eigenvalues and the corresponding orthonormal Eigen states (6+10)

Q-3: (a) Find the matrix representing the spin momentum operator $\hat{S}_z$, for the case, when $s = \frac{1}{2}$.

(b) Describe the following terms

(i) Pauli Exclusion Principle (ii) Bose-Einstein-Condensation (iii) Symmetrisation Postulate

(7+9)

Q-4: (a) Consider a system of two identical fermions with spin 1/2 in an in finite potential well of width "d", Find the total wave function and energy of the system when it is at its

(i) Ground state (ii) First excited state

(b) Describe the characteristics of Fermions and Bosons particles (10+6)

Q-5: Define the perturbation theory, and by using time Independent Nondegenerate Perturbation Theory prove that

Total energy eigenvalue up to the first order correction is

$$E_n = E_n^0 + \langle \Psi_n^0 | \hat{H}_p | \Psi_n^0 \rangle$$

Note: Where, E_n^0 is the energy eigenvalue of the equilibrium Hamiltonian, $|\Psi_n^0\rangle$ is the state vector corresponding to equilibrium state and $\hat{H}_p$ is the perturbed part of the exact Hamiltonian $\hat{H}$ of the system. 16

Q-6: (a) Describe the quantization rule for potential wells with two rigid walls by using the WKB Approximation method

(b) Use the WKB approximation to calculate the energy levels of a spinless particle of mass m moving in a one-dimensional box with rigid walls at $x = 0$ and $x = L$

(8+8)