DEPARTMENT OF PHYSICS				*CLASS: I M.Sc. Physics*				
Sem	**Course Type**	**Course Code**	**Course Title**	**Credits**	**Contact Hours/week**	**CIA**	**Ext**	**Total**
II	Major Core −5	21P2PMC5	Quantum Mechanics-I	5	4	25	75	100

Nature of Course				
Knowledge and skill	✓		Employability oriented	
Skill oriented			Entrepreneurship oriented	

Objectives:

- To recognize basic terms in Quantum physics.
- To instruct about Schroedinger wave equation and its applications to quantum mechanical problems.
- To impart knowledge on the matrix formulation of quantum mechanics and its usefulness in the equation of motion.

Unit	Description	Hour	K-level	CLO
I	**The Schroedinger wave equation:** Need for wave equation – The one dimensional wave equation – Extension to three dimensions – Interpretation of the wave function – Statistical interpretation – Normalization of the wave function – Probability – Current density – Expectation values – Ehrenfest theorem. Eigen energy function: Significance of separation constant E – Boundary conditions at large distances – Continuity conditions – One dimensional square well potential – Perfectly rigid walls – Finite potential step – Energy level parity. **Self study:** Separation of wave equation. **Audit:** Tunneling through a rectangular potential barrier	15	Up to K3	1
II	**Eigen function and Eigen values:** Postulates – Dynamical variables as operators – Expansion in Eigen function – Ortho normality of energy Eigen functions – Reality of energy eigen values - Momentum Eigen functions – Box normalization – Dirac normalization – Minimal uncertainty product – Form of the minimum wave packet – Schroedinger equation in momentum representation. **Self study:** Schwartz inequality **Audit:** Probability function and expectation value	15	Up to K2	2
III	**Discrete Eigenvalues : Bound States:** One dimensional linear harmonic oscillator – Energy levels – Degeneracy – Zero-point energy – Wave functions – Correspondence with classical theory – Rigid rotor – Eigen values and Eigen functions – Spherically symmetric potential –	15	Up to K4	3

	Spherical harmonics – Three- dimensional square well potential – Solutions for l=0 and arbitrary l values – Interior and exterior solutions – Schroedinger equation for the hydrogen atom – Solution for s-state only. **Self study:** Three-dimensional linear harmonic oscillator. **Audit:** The ground state wave function of the H atom.			
IV	**Matrix formulation of quantum mechanics:** Matrix algebra – Types of matrices – Hermitian and unitary matrices – Hilbert space – Dirac bra-ket notation –Projection operator – Physical meaning of matrix elements – Equation of motion in Schroedinger, Heisenberg and Interaction pictures – Evaluation of commutator brackets — Matrix theory of harmonic oscillator. **Self study:** Virial theorem **Audit:** Motion of a charged particle in an EM field.	15	Up to K4	4
V	**Identical particles and spin, Angular momentum:** Physical meaning of identity – Symmetric and antisymmetric wave functions –Exchange degeneracy – Pauli's exclusion principle – Spin and statistics – Pauli's spin matrices. Orbital angular momentum – Spin angular momentum – Commutation relations of J^2, J_z, J_+ and J_- – Eigen values and matrix representation of J_+ and J_- – Angular momentum matrices – Addition of angular momenta: CG coefficients – Construction of resultant wave function (j1=1/2 and j2=1/2 only) **Self study:** Construction of resultant wave function (j1=1 and j2=1/2) **Audit:** Eigen values and matrix representation of J^2, J_z.	15	Up to K4	5

Books for study:

1) L. I. Schiff, Quantum mechanics Third edition, 1968, Tata McGraw Hill Publishing Company.

Unit I : Chap. 2: 6,7, 8**,9**
Unit II : Chap. 3: 10, 11, 12
Unit III : Chap. 4: 13,14, 15, 16
Unit IV : Chap. 6: 22, 23, 24, 25

2) Satya Prakash, Advanced Quantum Mechanics, Fifth edition, 2016, Kedar Nath Ram Nath and Co. Publications.

Unit I: Chap. 2: 2.4
Unit III:Chap. 2: 2.10; Chap. 3: 3.3
Unit V: Chap.6: 6.2, 6.3, 6.4, 6.7, 6.10; Chap. 7: 7.1, 7.3, 7.4, 7.5, 7.6, 7.7, 7.9,7.11, 7.12, 7.13

Books for Reference :

1) P.M. Mathews & K. Venkatesan, A Text book of Quantum Mechanics, Second edition, 2010, McGraw Hill Publishing Company.
2) G.Aruldas, Quantum Mechanics, Second edition, 2009, PHI Learning private limited.
3) V. K. Thankappan, Quantum Mechanics, Second Edition, 2003, New Age International (P) Ltd.
4) A. K. Ghatak and Lokanathan, Quantum Mechanics – Theory and Applications, Fifth Edition, 2015, Macmillan India Ltd.

Web Resources:

1. Quantum Mechanics− An Introduction
   (Link:http://www.digimat.in/nptel/courses/video/115106066/L01.html)
2. The wave function
   Link: https://www.youtube.com/watch?v=Ei8CFin00PY
3. Wave-particle duality
   Link: https://en.wikipedia.org/wiki/ Wave–particle_duality
4. Uncertainty principle
   (Link: https://www.britannica.com/science/uncertainty-principle)
5. Schroedinger Wave Equation
   (Link: https://youtu.be/2ejyr-E7q2M)
6. Dirac delta function and & Fourier transforms, Linear harmonic oscillator, Simple applications of Schroedinger wave equation, Hydrogen atom and other two body problem, Dirac bra and ket algebra, Angular momentum
   (Link: https://nptel.ac.in/courses/115/102/115102023/)
7. Bound states in one dimension
   (Link: https://courses.physics.illinois.edu/phys485/fa2015/web/bound.pdf)
8. Mathematical formulation of quantum mechanics
   (Link:https://en.wikipedia.org/wiki/Mathematical_formulation_of_quantum_mechanics)
9. Angular momentum
   (Link: https://ocw.mit.edu/courses/physics/8-05-quantum-physics-ii-fall-2013/lecture-notes/MIT8_05F13_Chap_09.pdf)
10. Applications of quantum mechanics
    (Link: https://www.britannica.com/science/quantum-mechanics-physics/Applications-of-quantum-mechanics
    Link:https://www.forbes.com/sites/chadorzel/2018/12/04/three-ways-quantum-physics-affects-your-daily-life/?sh=17053b6844b7)

Note: 1. A maximum of Up to 10% (7.5 marks) of the questions may be asked from self – study part of the syllabus in the summative examination.

2. The questions in the Audit part of the syllabus shall not be asked in the summative examination.

Rationale for Nature of the course

This course will help to learn quantum mechanics and build problem solving skill and quantitative reasoning skill using quantum mechanical principles/concepts.

Activities having direct bearing on Skill development / Employability / Entrepreneurship

One dimensional and three dimensional wave equation for quantum mechanical systems will be solved to explain the behaviour of atoms and sub-atomic particles.

Pedagogy : Chalk and talk, PPT, Quiz, Assignment, Seminar, Problem solving, Group discussion and interaction.

Course Designer(s):

1. Prof. G.Gowri

Lecture Schedule

Unit	Topics	Hrs	Mode
Unit I	Introduction – Need for wave equation – The one dimensional wave equation – Extension to three dimension.	3	Chalk and talk, Quiz and assignment
	Interpretation of the wave function – Statistical interpretation – Normalization of the wave function – Probability – Current density	2	
	Expectation values – Ehrenfest theorem.	2	
	Eigen energy function: Significance of separation constant E – Boundary conditions at large distances – Continuity conditions	2	
	One dimensional square well potential – Perfectly rigid walls – Finite potential step – Energy level parity.	4	
	Problems discussion	2	
Unit II	Postulates – Dynamical variables as operators – Expansion in Eigen function.	3	PPT, Chalk and talk, Quiz and Group discussion
	Ortho normality of energy Eigen functions – Reality of energy eigen values.	2	
	Momentum Eigen functions – Box normalization – Dirac normalization.	4	
	Minimal uncertainty product – Form of the minimum wave packet – Schroedinger equation in momentum representation.	4	
	Problems discussion.	2	
Unit III	One dimensional linear harmonic oscillator – Energy levels – Degeneracy – Zero-point energy – Wave functions –Correspondence with classical theory	4	Chalk and talk, Quiz, assignment and seminar
	Rigid rotor – Eigen values and and Eigen functions	2	
	Spherically symmetric potential – Spherical harmonics	2	
	Three- dimensional square well potential – Solutions for l=0 and arbitrary l values – Interior and exterior solutions	3	
	Schroedinger equation for the hydrogen atom – Solution for s-state only – Problems discussion	4	
Unit IV	Matrix algebra – Types of matrices – Hermitian and unitary matrices – Hilbert space – Dirac bra-ket notation	3	PPT Chalk and talk, quiz, Group discussion
	Projection operator and its properties – Physical meaning of matrix elements	2	
	Equation of motion in Schroedinger and Heisenberg and Interaction pictures	4	
	Evaluation of commutator brackets	2	
	Matrix theory of harmonic oscillator –Problems discussion.	4	
Unit V	Physical meaning of identity – Symmetric and antisymmetric wave functions – Exchange degeneracy.	2	PPT, Chalk and talk, Quiz and Interaction
	Pauli's exclusion principle – Spin and statistics – Pauli's spin matrices – problems discussion.	4	
	Orbital angular momentum – Spin angular momentum.	1	
	Commutation relations of J^2, J_z, J_+ and J_- – Eigen values and matrix representation of J_+ and J_-.	3	
	Angular momentum matrices.	2	
	Addition of angular momenta: CG coefficients – Construction of resultant wave function (j1=1/2 and j2=1/2 only).	3	

Course Learning Outcomes:

On the successful completion of the course, students will be able to

CLOs	Course Learning Outcomes	Knowledge Level
CLO 1	Recognize the basic terms in Quantum mechanics and apply the Schroedinger wave equation to simple quantum mechanical problems.	Up to K3
CLO 2	Outline postulates of quantum mechanics and use them to a discussion of the total energy and momentum of a particle and to an illustrative problem.	Up to K2
CLO 3	Set up Schroedinger wave equation to one dimensional and three dimensional problems and solve as well as analyze the results	Up to K4
CLO 4	Comprehend the important properties of matrices and then the matrix formulation in quantum mechanics and also apply it to examine the equation of motion.	Up to K4
CLO 5	Construct angular momentum matrices and evaluate CG coefficients for system with two or more angular momentum parts	Up to K4

Mapping of CLOs with PSOs

#	PSO1	PSO2	PSO3	PSO4	PSO5
CLO1	3	1	1	1	
CLO2	3		1	1	
CLO3	3	2	2	1	1
CLO4	3	2	1	2	
CLO5	3	1	1		

Advance application –3, Intermediate level –2 , Basic level–1

Learning Outcome Based Education (LOBE) & Assessment
Summative Examination – Blue Print
Articulation Mapping-K Levels with Courses Learning Outcomes (CLOs)

Units	CLOs	K- Level	Section A		Section B		Section C (Either/or Choice)	Section D (Open Choice)
			MCQs		Short Answers			
			No. of Questions	K-Level	No. of Questions	K-Level		
1	CLO 1	Up to K3	2	K2&K3	1	K1	2(K2&K2)	1(K3)
2	CLO 2	Up to K2	2	K1&K1	1	K1	2(K1&K1)	1(K2)
3	CLO 3	Up to K4	2	K3&K4	1	K3	2(K4&K4)	1(K4)
4	CLO 4	Up to K4	2	K2&K3	1	K2	2(K3&K3)	1(K3)
5	CLO 5	Up to K4	2	K3&K4	1	K2	2(K4&K4)	1(K4)
No. of Questions to be asked			10			5	10	5
No. of Questions to be Answered			10			5	5	3
Marks for each question			1			2	5	10
Total Marks for each Section			10			10	25	30

Distribution of Section-wise Marks with K Levels

K Levels	Section A (No Choice)	Section B (No Choice)	Section C (Either/or)	Section D (Open Choice)	Total Marks	% of Marks without choice
K1	2	4	10	-	**16**	13.33
K2	2	4	10	10	**26**	21.67
K3	4	2	10	20	**36**	30.00
K4	2	-	20	20	**42**	35.00
Total Marks	10	10	50	50	**120**	100.00