Imperial College London

Module Outline

Foundations of Quantum Mechanics

Module Code	PT3.1	FHEQ Level	Level 6
Pre-requisites	None	Co-requisites	None
Primary Department	Physics		
Module Leader	Prof. Andrew J. Tolley		
Additional Teaching Departments	None		
Teaching Staff	Prof. Andrew J. Tolley + Associate		

Programmes on which the Module is delivered	Core/Elective
All UG Physics programmes (F300, F303, F309, F325, F390, F3W3, F3XC, F3XD)	Elective

Learning Outcomes	On completing the Foundations of Quantum Mechanics course, students will have acquired the mathematical techniques and conceptual background required to understand the foundations of quantum mechanics and its most significant and challenging experimental implications.
Description of Content	1. Introduction Classical probability theory of indeterministic systems, classical probability composition laws. Quantum Probability theory, quantum probability composition laws. Copenhagen Interpretation. Quantum to Classical Transition. 2. Hilbert Spaces Complex vector spaces as the arena of quantum mechanics. Inner products, bases, linear operators. Dirac notation. Hermitian operators, unitary operators, projection operators, the spectral theorem. The Cauchy-Schwarz inequality. 3. Quantum Mechanics in Hilbert Space Classical dynamics. The quantization procedure. Formal statement of the postulates of quantum mechanics. States, observables, the Born rule for probabilities, time evolution. The tensor product between vectors. The EPR state. 4. Recovery of Wave Mechanics Position and momentum operators and representations. Projections onto position. The uncertainty relations. Minimum uncertainty states. Position and momentum displacement operators. 5. Time Evolution Solving the Schrodinger equation with the unitary time evolution operator. Schrodinger and Heisenberg pictures of quantum mechanics. Conservation laws and symmetries. The evolution of wave packets. The propagator. The quantum Zeno effect. 6. The Harmonic Oscillator Spectrum of the harmonic oscillator by operator methods. Dynamics in the Heisenberg picture. Coherent states of the harmonic oscillator. 7. Angular Momentum Rotation operator. Rotational invariance. Spectrum of angular momentum by operator methods. Integral and half-integral spins. Addition of angular momentum. 8. Hydrogen Spectrum and wavefunctions of Hydrogen using operator methods.

	9. Properties of Entangled States The EPR and EPRB state. Bell inequalities. The GHZ state. 10. Density Matrices Mixed states and density matrices. Reduced density matrices. The Wigner function. Evolution of pure states to mixed states. Emergent classicality from quantum mechanics. 11. Dirac Equation and relativistic quantum mechanics. 12. Feynman `sum over histories' formulation of quantum mechanics (path integrals).		
Assessment		Assessment Type	Weighting
Written exam		Exam	100%
Learning & Teaching Hours	Independent Study Hours	Placement Hours	Total Hours
57	93	0	150
ECTS Credit	6	CATS Credit	12
Date of introduction	October 2016	Date of Last Revision	May 2020