QUANTUM MECHANICS

Lecturer: Prof Andrew Jaffe, 30 lectures in Term 1 of Year 2

Aims: To introduce students to the fundamental postulates of quantum mechanics and its mathematical formulation in terms of wavefunctions, operators and eigenvalues. To give students an understanding of and familiarity with the Schrödinger equation and its applications to simple potential structures.

Objectives: On completion of the course, students will

- be aware of the critical features of basic quantum phenomena that are not explained by classical mechanics
- be able to calculate and relate wave-like and particle-like properties of particles or radiation.
- understand the motivation of the Schrödinger equation and its relationship to the classical energy equation through the replacement of energy and momentum with differential operators
- be able to separate the Schrödinger equation into time and space components
- be able to solve the time-independent Schrödinger equation using appropriate boundary conditions for simple one-dimensional short-range potentials to obtain wavefunctions and energy levels
- know the postulates that make up quantum mechanics and be able to expand on the ideas contained within these postulates to give a more detailed interpretation of the theory
- understand what is meant by an operator and the relationship between an operator and a measurable quantity
- know what is meant by compatible observables, and understand the connection between uncertainty relations and non-commuting operators
- know the importance of superposition and interference in quantum systems
- be able to evaluate expectation values and uncertainties
- appreciate that the Schrödinger wave function is a position representation of the quantum state and know how to transform to the momentum representation
- understand how to calculate the time development of quantum states and the relationship between commutation with the Hamiltonian and conserved quantities
- be able to find the solutions of a quantum simple harmonic oscillator using raising and lowering operators and be able to use these operators to demonstrate the properties of energy eigenvalues and eigenfunctions of this system
- understand the fundamentals of the quantum theory of angular momentum
- be able to separate the three-dimensional Schrödinger equation for a particle in a central potential into radial and angular parts and solve the angular part in terms of spherical harmonics
- be able to classify the energy levels of central potential systems (neglecting spin) and understand the origin of the quantum numbers assigned to each state
- understand the semi-classical treatment of the effect of magnetic fields on atoms and how it leads to level splitting and the concept of electron spin
- understand the Stern-Gerlach experiment and its importance for spin and the quantisation of angular momentum
- understand, with application to simple examples, how Pauli matrices can be used in the treatment of spin