PH3061 - Quantum Mechanics 1

Credits:	10.0	**Semester:**	1
Number of Lectures:	18	**Lecturer:**	Dr Antje Kohnle
Academic Year:	2018-19		

Overview

Quantum Mechanics is that description of physical phenomena in which the wave and particle aspects of matter and radiation are reconciled in a unified theory. As such it is one of the most fundamental topics in physics. It has widespread applicability in virtually every area of physics from the solid-state to fundamental particles, and is hence an essential item in the 'toolbox' of any practitioner in modern physics. As a theory it has never been shown to be incorrect in any of its predictions if properly employed. However, at a fundamental level it poses many challenges to our understanding, and this is an area of much current research. As well as playing a key role in describing many traditional areas of physics, deeper insights continue to emerge, leading to new applications such as quantum computing, quantum cryptography and quantum information processing. It is hence a topic of continuing fundamental interest and study in its own right as well as being essential for describing many areas of applied physics. The present course is the first in a sequence of four courses that progressively develop the topic to an advanced level.
The present course is based on the Schrödinger equation description of quantum mechanics (often referred to as wave mechanics), and is limited to non-relativistic situations. A more formal approach to describing quantum systems based on operator methods is also developed. Applications covering a range of important physical situations are considered, as well as some of the current challenges. Essential mathematical background is developed throughout the course.
Part of the continuous assessment is associated with engagement with a web-based multiple-choice question repository built by students. Students will need to author two multiple-choice questions with associated explanations (solution and feedback), answer a small number of existing questions and rate them for quality and difficulty, and take part in discussions. An introductory session will give students guidance on characteristics of good questions and give examples of high-quality questions. It is expected that meaningful interaction with this system will help students develop a deeper understanding of the material, and help clear up potential difficulties.

Aims & Objectives

To present an introductory account of quantum mechanics (wave mechanics) including important applications and recent progress, in particular:

- To develop an intuitive understanding of such basic concepts as the wave function, probability density, operators, eigenfunctions and eigenvalues.
- To introduce both the time-independent and time-dependent Schrödinger equations and to develop an understanding of their meaning and how they are utilised.
- To apply the Schrödinger equation to a range of important physical situations, develop solutions and discuss their implication.
- To introduce the operator formalism and consider a number of its applications.

Learning Outcomes

You will have acquired the ability to:

- Author and critique high-quality quantitative, conceptual and interpretive multiple choice questions focusing on application, analysis and synthesis of quantum mechanics developed in the course.
- Write down and solve the Schrödinger equation for simple 1D, 2D and 3D systems, and use the wave functions to calculate expectation values and measurement probabilities for observables such as energy, position and momentum using Cartesian and spherical polar coordinates.
- Compare and contrast classical and quantum behaviour for simple 1D, 2D and 3D systems.
- Contrast eigenfunctions of an operator with superposition states with respect to that operator.
- Explain the relevance of Hermitian and non-Hermitian operators in quantum mechanics, and determine whether or not a given operator is Hermitian.
- Qualitatively sketch and explain the shape of energy eigenfunctions for a given potential

energy.
- State the measurement problem in quantum mechanics.
- Determine degeneracies of energy levels for simple 2D and 3D systems.
- Use properties of ladder operators for the 1D harmonic oscillator to determine wave functions and expectation values.
- State properties of the spherical harmonics and their relation to angular momentum.

Synopsis
Historical/Recent Experiments, Uncertainty principle
Time-dependent Schrödinger equation, momentum operator and Hamilton operator, time-independent Schrödinger equation, probability interpretation, normalization, expectation values, probability current
Wave packets and their propagation; group velocity and spreading
The infinite potential well: Eigenfunctions and energy eigenvalues, orthonormality and completeness of eigenfunctions, superposition of states, expansion theorem, Bohr's correspondence principle
Properties of Hermitian operators, the commutator, maximal set of mutually commuting operators
The 1- and 3-dimensional quantum harmonic oscillator: solution of the Schrödinger equation, discussion of eigenfunctions and eigenenergies, superposition state and wave packet oscillations, solution via ladder operators, Dirac notation
The hydrogen atom: Schrödinger equation for the hydrogen atom, discussion of the hydrogen atom solutions, angular momentum

Pre-requisites
PH2012, MT2501 and MT2503

Co-requisites
PH3081 or PH3082 or (MT2506 and MT2507)

Assessment
Continuous Assessment (Class test mid semester 14%, successful engagement with web-based question system 6%) = 20%, 2 Hour Examination = 80%

Additional information on continuous assessment etc.
Please note that the definitive comments on continuous assessment will be communicated within the module. This section is intended to give an indication of the likely breakdown and timing of the continuous assessment.

This module is part of the core JH programme, and as such there is a summary of deadlines etc on the School's Students and Staff web pages. There is one class test, contributing 14% to the module mark, likely to be in week eight. Successful engagement with a web-based question system (Peerwise) counts for 6% of the module mark. Students have compulsory tutorials every two weeks.

Accreditation Matters
This module contains material that is or may be part of the IOP "Core of Physics". This includes
Heisenberg's uncertainty principle
Wave function and its interpretation
Standard solutions and quantum numbers, to the level of the hydrogen atom
Quantum structure and spectra of simple atoms

Recommended Books
Please view University online record:
http://resourcelists.st-andrews.ac.uk/modules/ph3061.html

General Information
Please also read the general information in the School's honours handbook.