PH4028 - Advanced Quantum Mechanics: Concepts and Methods

Credits:	15.0	**Semester:**	2
Number of Lectures:	27	**Lecturer:**	Dr Brendon Lovett
Academic Year:	2018-19		

Overview

This module builds on the material of PH3061 and PH3062 Quantum Mechanics 1 and 2 to present some of the important current and advanced topics in quantum mechanics. The mathematics of complex analysis is introduced to allow this to be used for relevant quantum mechanics problems. Scattering theory is developed using partial waves and Green's functions, leading to a discussion of quantum degenerate gases.

The density matrix formalism as the general state description in open quantum systems is presented; open system dynamics are described within the formalism of the density matrix master equation. Quantum information processing is covered, including concepts such as qubits, quantum entanglement, quantum teleportation, and measurement based quantum computing.

Aims & Objectives

The core idea of the course is to give a clear picture of the modern, 21st century quantum mechanics and to teach basic operational tools in this context. The module will include:

- Quantum statistics are covered with the use of density matrix formalism.
- Variational theory and WKB approximation.
- Entanglement and quantum information and their application.
- Quantum scattering.
- Complex analysis, importantly introducing the residue theorem which is then used in quantum scattering problems.

Learning Outcomes

By the end of the module, students will have a comprehensive knowledge of the topics covered in the lectures and will be able to:

- classify and manipulate functions of a complex variable.
- use the residue theorem to perform real integrals.
- use scattering theory to solve quantum mechanical problems.
- Use variational theory and WKB approximation to solve quantum mechanical problems.
- use the density matrix as a representation of an open quantum system. Understand and be able to characterise whether a state is pure or mixed.
- understand the notion of quantum entanglement and its relationship to Bell's inequalities.
- understand sample problems in quantum information, for example, be able to demonstrate via simple calculations in Dirac notation and tensor products how quantum teleportation works.
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Synopsis

- complex analysis; Cauchy-Reimann conditions, Cauchy's integral theorem and formula; Laurent series, residue theorem and principal value.
- scattering theory
- variational theory.
- WKB approximation.
- density matrix. Purity of a state.
- tensor product notation for multipartite states.
- Bell's inequalities and entanglement.
- quantum information processing. quantum bit (qubit). quantum teleportation. quantum key distribution.

Pre-requisites

PH3061, PH3062, (PH3081 or PH3082) or MT2003 or (MT2506 and MT2507)
This is an advanced course in quantum mechanics. We advise that this module is most appropriate for students who have obtained an understanding and competence in mathematical physics and quantum mechanics at least at the level of PH3061 and PH3062 and PH3081.

Anti-requisites
none

Assessment
2 Hour Examination = 100%

Accreditation Matters
This module may not contain material that is part of the IOP "Core of Physics", but does contribute to the wider and deeper learning expected in an accredited degree programme. The skills developed in this module, and others, contribute towards the requirements of the IOP "Graduate Skill Base".

Recommended Books
Please view University online record:
http://resourcelists.st-andrews.ac.uk/modules/ph4028.html

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