# PH4028 - Advanced Quantum Mechanics

| | | | |
|---|---|---|---|
| **Credits:** | 15.0 | **Semester:** | 2 |
| **Number of Lectures:** | 18 | | |
| **Available:** | All | **Lecturer:** | Dr Brendon Lovett |

## Overview

This module builds on the material of PH3061 and PH3062 to present some of the important current and advanced topics in quantum mechanics. Matrix mechanics is introduced as it is a convenient formalism in the applications of operator methods. These ideas are then used to cover the density matrix formalism as the most general state description. Quantum information concepts will be covered, including concepts such as quantum entanglement, qubits, quantum teleportation, and quantum key distribution. Quantum gases such as Bose-Einstein condensates and degenerate Fermi gases are discussed as well.

## 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:-

- Matrix mechanics is introduced as a powerful mathematical tool
- Quantum statistics are covered with the use of density matrix formalism - Entanglement and quantum information
- Quantum scattering and cold atom physics

## 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:

- use scattering theory to solve quantum mechanical problems.
- perform advanced calculations using matrix representation of the quantum-mechanical operators using the toolbox of linear algebra.
- 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.
- use Heisenberg, Schroedinger and interaction pictures to describe time evolution of quantum states.
- understand the notion of quantum entanglement.
- understand sample problems in quantum information, for example, be able to demonstrate via simple calculations in Dirac notation how quantum teleportation works.
- use and interpret a simple master equation that describe the time evolution of the density matrix of an open quantum system.
- understand basic physics behind a special type of matter, i.e. quantum degenerate gases. - have a basic knowledge of the Dirac equation.

## Synopsis

- scattering theory.
- review of matrix representation of operators, application to interacting systems.
- density matrix. Purity of a state.
- time evolution in quantum mechanics: Heisenberg, Schroedinger and interaction picture. - Bose-Einstein condensation. Quantum degenerate gases with Fermi-Dirac statistics.
- Quantum information processing. Quantum bit (qubit). Quantum entanglement. Quantum teleportation. Quantum key distribution.
- Dynamics of open systems: Simple master equation.
- Dirac equation.

### Prerequisites

PH3061 Quantum Mechanics 1, PH3062
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 PH3080.

### Antirequisites

none

### Assessment

2 Hour Examination = 100%

### 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.