Imperial College London

# Module Specification (Curriculum Review)

## Basic details

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|---|---|---|---|---|
| UID | | Cohorts covered | Earliest cohort: 2024-25 | Latest cohort: |

Long title: Foundations of Quantum Mechanics

New code: PHYS60011

New short title: Foundations of Quantum Mechs

Brief description of module *(approx. 600 chars.)*: This course will introduce the conceptual and mathematical foundations of quantum mechanics. Emphasis will be on Hilbert Space (bra-ket) methods, formal operator methods and density matrices. Students will also be introduced to topics such as syymmetry, angular momentum, quantum entanglement, coherent states, and Feynman path integrals.

338 characters

Available as a standalone module/ short course? N

## Statutory details

| | ECTS | CATS | Non-credit |
|---|---|---|---|
| Credit value | 7.5 | 15 | N |

HECOS codes:

FHEQ level: Level 6

## Allocation of study hours

| | Hours | |
|---|---|---|
| Lectures | 26 | |
| Group teaching | 10 | *Incl. seminars, tutorials, problem classes.* |
| Lab/ practical | 0 | |
| Other scheduled | 12 | *Incl. project supervision, fieldwork, external visits.* |
| Independent study | 139.5 | *Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.* |
| Placement | 0 | *Incl. work-based learning and study that occurs overseas.* |
| Total hours | 187.5 | |
| ECTS ratio | 25.00 | |

## Project/placement activity

Is placement activity allowed? No

## Module delivery

| | | | |
|---|---|---|---|
| Delivery mode | Taught/ Campus | Other | |
| Delivery term | | Other | Term 2, exam in term 3 |

## Ownership

Primary department: Physics

Additional teaching: None

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| departments | |
| | |
| Delivery campus | South Kensington |

## Collaborative delivery

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|---|---|
| Collaborative delivery? | N |

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|---|---|
| External institution | N/A |
| External department | N/A |
| External campus | N/A |

## Associated staff

| Role | CID | Given name | Surname |
|---|---|---|---|
| Module Leader | | Jerome | Gauntlett |
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# Learning and teaching

## Module description

**Learning outcomes**

On completing the Foundations of Quantum Mechanics course, students will:
(1) Have acquired mathematical techniques (Hilbert spaces) to understand and solve quantum problems
(2) Have the conceptual background required to understand the foundations of quantum mechanics and how it is used to compute probabilities.
(3) Understand the equivalence and use of different quantum formalisms for dynamical evolution (Heisenberg/Schrodinger/interacting pictures)
(4) Have a general understanding of symmetry in quantum mechanics, including rotations, translations, parity. In addition have an understanding of the role of generators of symmetries and, in particular, an understanding of representation theory of angular momentum.
5) Be familiar with solutions for standard problems such as the harmonic oscillator.

**Module content**

•Hilbert Space Formalism: States, linear operators, bra and ket notation, Hilbert spaces, tensor products, general uncertainty principle
•Postulates of quantum mechanics, including the Born rule for computing probabilities of measurements and the Copenhagen interpretation.
•Position and momentum representations and the recovery of wave mechanics. Momentum operator as the generator of translations.
•Quantum Dynamics: The propagator and the Hamiltonian as the generator of time translations. Schrodinger and Heisenberg pictures. The interacting picture.
•The simple harmonic oscillator and coherent states.
•Angular momentum. Rotations and representation of angular momentum algebra. Spin and spinors. Addition of angular momentum. Parity in quantum mechanics.
•Density Matrices: Mixed and pure states and density matrices. Reduced density matrices and entanglement. von Neumann entropy. Thermal density matrices.
•Path Integrals: Derivation of the path integral for free particles. Propagator. Aharonv Bohm effect. Canonical quantisation and path integral quantisation.
•Quantum mechanics in the presence of electromagnetic fields. Gauge invariance. Landau levels.

| | |
|---|---|
| Learning and Teaching Approach | Students will be taught over one term using a combination of lectures, office hours and directed exercises on theoretical work. |
| Assessment Strategy | 100% summative assessment based on final exam of 2h or more with 3 questions that will evaluate competency in the topics covered in the lectures and in the problem sheets. |
| Feedback | Problem sheets are provided each week (10 in total) with questions and examples students can practise with. Students will have the opportunity to solve problems real time in interactive Rapid Feedback sessions with assistance and advice provided by several teaching assistants. Solutions will be provided after the rapid feedbacks. |
| Reading list | Lecture notes are provided to students. The notes (and problem sheets) are designed to be self-contained and there is no designated textbook required for this module.<br>There are however also some excellent textbooks, that are suggested as supplementary or complementary reading for those of wishing to explore further some aspects of the module.<br>J. J. Sakurai and J. Napolitano, Modern Quantum Mechanics<br>R. Shankar,  Principles of Quantum Mechanics<br>Other books include<br>Chris Isham, Lectures On Quantum Theory: Mathematical And Structural Foundations<br>P.A.M. Dirac, Principles of Quantum Mechanics<br>Landau-Lifshitz, Quantum Mechanics (Nonrelativistic theory) |

## Quality assurance

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|---|---|
| Date of first approval | |
| Date of last revision | |
| Date of this approval | |
| Module leader | Jerome Gauntlett |
| Notes/ comments | |

## Office use only

| | |
|---|---|
| QA Lead | |
| Department staff | |
| Date of collection | |
| Date exported | |
| Date imported | |

## Programme structure
### Associated modules

| UID | Legacy code | Module title | Requisite type |
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## Assessment details

| | | | Pass mark |
|---|---|---|---|
| Grading method | Numeric | | 40% |

### Assessments

| Assessment type | Assessment description | Weighting | Pass mark | Must pass? |
|---|---|---|---|---|
| | | | 40% | |
| final exam | Written exam over 2 hours | 100% | 40% | N |
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