Imperial College London

Module Specification (Curriculum Review)

Basic details

UID		Cohorts covered	Earliest cohort: 2021-22	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 operators methods, density matrices and how classical physics arises from quantum. Students will be introduced to more advanced topics such as quantum entanglement, Bell inequalities, Wigner quasi-probabilities, the Berry phase, and Feynman Path Integrals.

409 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 departments: None

Delivery campus: South Kensington

Collaborative delivery

Collaborative delivery?	N

External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module Leader		Andrew	Tolley

Learning and teaching

Module description

Learning outcomes	On completing the Foundations of Quantum Mechanics course, students will: (1) Have acquired the modern 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 in a range of situations (3) Understand the equivalence and use of a different quantum formalism for dynamical evolution (Heisenberg/Schrodinger/interacting/Feynman) (4) Be familiar with solutions for standard problems such as the harmonic oscillator/hydrogen/angular momentum as well as approximation methods such as WKB.
Module content	•Copenhagen Interpretation: Distinction between Classical and Quantum Probabilities rules. Conditional/relative probabilities. Postulates. Rules for computing probabilities of selective measurements and histories. Decoherence. •Hilbert Space Formalism: Linear operators, States, Hilbert Spaces, Probability Amplitudes, Tensor products. •Density Matrices: Entangled States. Mixed states and density matrices. Reduced density matrices. Wigner quasi-probability distribution. Uncertainty Principles. •Quantum Dynamics: Stone’s theorem. Heisenberg/Schrodinger/Interacting representations. Time-dependent Perturbation Theory. •Symmetries in Quantum Mechanics: Translations symmetries, Position and momentum representations and recovery of wave mechanics. Angular momentum, Addition of angular momentum. •Quantum mechanics in electric and magnetic fields •Path Integrals: Derivation of Path Integral for Free Particle, Propagators, Coupling to Electromagnetic Fields. •Semi-classical Methods: WKB approximation, Path Integral Saddle points, Quantum tunnelling. •Harmonic Oscillator: Operator approach, Wavefunction approach, Path Integral Approach. •Hydrogen: Operator solution for Hydrogenic Ions. •Quantum Entanglement: Bells theorem, Density Matrices, EPR, EPRB, GHZ state. •Adiabatic approximation: Berry Phase, Aharanhov-Bohm effect.
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 4 questions that will evaluate competences in the following topics: (1) Hilbert space/Operator methods in Quantum Mechanics (2) Density Matrix and Wigner quasi-probabilities (3) Angular momentum and Hydrogen in Operator formalism (3) Time evolution in Heisenberg/Schrödinger and Interacting Representations (4) Bells inequalities and quantum entanglement (5) Semi-classical (WKB) methods (6) Propagators and Feynman path integral (7) Adiabatic methods, Berry phase, Aharanov-Bohm effect.
Feedback	Problem sheets are provided most weeks (7 in total) with questions and examples students can practise with. Out of these questions part are marked as rapid feedback questions: answers to these questions will be reviewed and annotated (no formal mark) for formative feedback. Rapid Feedback questions are then reviewed during a Rapid Feedback session with a teaching assistant.

Reading list	Lecture notes are provided to students. The notes are designed to be self-contained. The main two suggested textbooks are Shankar, Principles of Quantum Mechanics (2nd edition) for the physics content and Chris J. Isham, Lectures on Quantum Theory: Mathematical and Structural Foundations for the

Quality assurance

Date of first approval	
Date of last revision	
Date of this approval	
Module leader	Andrew Tolley
Notes/ comments	

Office use only

QA Lead	
Department staff	
Date of collection	
Date exported	
Date imported	

Template version 16/06/2017

Programme structure
Associated modules

UID	Legacy code	Module title	Requisite type

Programme structure
Associated programmes

UID	Legacy code	Programme title	Core?

Assessment details

		Pass mark
Grading method	Numeric	40%

Assessments

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