Bachelor in Physics
(Academic Year **2021-22**)

Quantum Mechanics		**Code**	800509	**Year**	3º	**Sem.**	2º
Module	Fundamental Physics	**Topic**	Obligatory in Fundamental Physics	**Character**	Optional		

	Total	**Theory**	**Exercises**
ECTS Credits	6	4	2
Semester hours	43	28.5	14.5

Learning Objectives (according to the Degree's Verification Document)

- To assimilate the concept of quantum state and to introduce the quantum information theory.
- To understand the scattering theory in quantum mechanics
- To learn the theory of symmetry in quantum mechanics
- To apply time-dependent perturbation methods in quantum mechanics.

Brief description of contents

Pure and mixed states; discrete and continuous symmetries, rotations and angular momentum; composite systems; quantum information and quantum computation; time-dependent perturbation theory; scattering theory.

Prerequisites

Linear algebra, vector calculus, the content of the subjects Quantum Physics I and II.

Coordinator	Antonio Dobado González			**Dept.**	FT
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Theory/Exercises – Schedule and Teaching Staff								
Group	**Lecture Room**	**Day**	**Time**	**Professor**	**Period/ Dates**	**Hours**	**T/E**	**Dept.**
B	8	M W	17:00-18:30 16:30-18:00	Ángel Rivas Vargas	Full term	43.0	Both	FT

T: Theory, E: Exercises

Office hours				
Group	**Professor**	**Schedule**	**E-mail**	**Location**
B	Ángel Rivas Vargas	Mo, Th 15:00-16:30 Tu: 16:30-19:30	anrivas@ucm.es	West Wing, 3rd floor, Room 15

Syllabus

Topic 1: The Foundations of Quantum Mechanics.

Mathematics and notation of Quantum Mechanics. Pure states and unit rays. Observables and physical variables. Measurement outcomes and probabilities. Uncertainty relations. Complete set of compatible observables. State operator and mixed states. Filtering measurements. Time-evolution. Canonical quantization rules. Stationary states and constants of motion. Time-energy uncertainty relation. Evolution operator. Evolution pictures.

Topic 2: Symmetries in Quantum Mechanics.

Symmetry transformations and Wigner's theorem. Space translations. Rotations and angular momentum. Spin. Wigner-Eckart theorem. Parity and time-reversal. Symmetries sand conservation laws. Identical particles and symmetrization.

Topic 3: Time-dependent perturbations,

Perturbative expansion of transition amplitudes. Transitions to a continuum: Fermi's golden rule. Adiabatic approximation.

Topic 4: Scattering theory

Scattering by a central potential and cross sections. Scattering amplitude and differential cross sections. Integral representation of the scattering amplitude. Born approximation. Partial waves expansion and phase-shifts. Optical theorem. Calculation of phase-shifts for finite range potentials. Resonances. Coulomb scattering. S and T matrices.

Topic 5: Introductory Quantum Information and Quantum Computation

Classical and quantum composite systems. Bipartite systems, qubits and pure entangled states.

Bibliography

Basic:

- G. Auletta, M. Fortunato, G. Parisi, Quantum Mechanics, Cambridge University Press.
- L.E. Ballentine, Quantum Mechanics: A Modern Development, World Scientific.
- C. Cohen-Tannoudji, B. Diu, F. Laloe, Quantum Mechanics Vol. I & II. John Wiley & Sons.
- E. d'Emilio, L.E. Picasso, Problems in Quantum Mechanics: with solutions. Springer.
- A. Galindo y P. Pascual, Mecánica Cuántica Vol. I y II. Eudema Universidad.
- L. Landau & E.M. Lifshitz, Quantum Mechanics, Buttenworth-Heinemann.
- A. Messiah, Quantum Mechanics, Dover.
- L.I. Schiff, Quantum Mechanics, McGraw-Hill.
- M. Le Bellac, Quantum Physics, Cambridge University Press.

Complementary:

- J. Audretsch, Entangled Systems, Wiley-VCH.
- J.L. Basdevant and J. Dalibard Quantum mechanics, Springer.
- D.J. Griffiths, Introduction to quantum mechanics, Prentice Hall.
- K.T. Hecht, Quantum Mechanics, Springer.
- E. Merzbacher, Quantum Mechanics, John Wiley.
- L. E. Picasso, Lectures in Quantum Mechanics: A Two-Term Course. Springer.
- J.J. Sakurai, Modern Quantum Mechanics, Addison-Wesley.
- F. Schwabl, Quantum Mechanics, Springer.
- R. Shankar, Principles of Quantum Mechanics, Plenum Press.

Online Resources

UCM's Virtual Campus, Google Drive, Dropbox, Microsoft Teams, Google Meet.

Methodology
On-campus teaching 100% (Scenario 0)
There will be lectures on the blackboard, explaining and discussing the topics of the subject. The concepts and techniques introduced in this explanation will be illustrated with examples and problems that will be solved in class. Discussion on all the concepts and techniques introduced in class will be stimulated, individually and in groups, with the students.
Semi-online teaching (Scenario 1)
The methodology will be similar in the four groups of the subject. It will be chosen an A plus B mixed modality, consisting of in-person teaching for small groups, which may have both theoretical and practical content, along with online teaching. Some of the in-person sessions will be broadcast so that they can be remotely visualized by the subgroup of students that is not in the room. Other sessions will be repeated for the different subgroups. Written and/or audiovisual reinforcement material will be produced according the circumstances that may arise, and it will be made available to the students on the UCM's Virtual Campus.

Online teaching (Scenario 2)
This scenario would arise in the event that the health authorities and/or the UCM order the suspension of all in-person teaching activities due to the circumstances derived from the COVID19 pandemic. All teaching, both theoretical and practical, will be developed online, for which the appropriate materials will be produced in written and/or audiovisual format, using the resources available at the UCM. Lessons will be taught through the UCM's Virtual Campus in a synchronous or asynchronous way using Microsoft Teams or Google Meet, and questions will be answered by email and through online tutorials.

Evaluation Criteria		
Exams	**Weight:**	70%
There will be a final exam consisting of one part of theoretical-practical questions and/or another part of problems of a similar level of difficulty to those solved in class.		
Other Activities	**Weight:**	30%
One, or more, written tests of continuous assessment carried out during the class time or outside of it.		
Final Mark		
The final mark will be given by max(0.7 (exam mark) + 0.3 (other activities mark), exam mark), on a 0-10 scale. A minimum mark will be required in the final exam in order to pass the course, which will depend on the scenarios in which the course is finally developed. The mark of the extraordinary call of June-July will be obtained following the same evaluation procedure.		