COURSE DATA

DATA SUBJECT

Code: 34268
Name: Quantum mechanics
Cycle: Undergraduate Studies
ECTS Credits: 4.5
Academic year: 2026-27

STUDY (S)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Facultat de Física	4	First quarter
1928 - Double Degree Program Physics-Mathematics	Facultat de Física	5	First quarter

SUBJECT-MATTER

Degree	Subject-matter	Character
1105 - Degree in Physics	Expansion of Physics	COMPULSORY
1928 - Double Degree Program Physics-Mathematics	Quinto Curso (Obligatorio)	COMPULSORY

COORDINATION

BARENBOIM SZUCHMAN GABRIELA ALEJANDRA

FABBRI ALESSANDRO

SUMMARY

Quantum mechanics is an essential tool for the description of physical phenomena. There are many disciplines in physics developed from the application of Quantum Mechanics to different fields: Solid State, Elementary Particle Theory, Nuclear Physics, Quantum Optics, Quantum Field Theory... Technological applications are also very relevant.

Furthermore Quantum Mechanics is still in continuum progress from the experimental and theoretical points of view: new experiments are performed in which atoms, photons, Bose-Einstein condensates or superconducting circuits are manipulated with an accuracy that only a few years ago could not be imagined; new advances in fields such as quantum computing, teleportation or quantum cryptography (already in a commercial stage) are taking place. This is giving rise to a deeper understanding of quantum reality, its limitations and its relation to the classical phenomena.

Objective

The main objective of this course is the construction of the formalism of Quantum Mechanics and its application. This provides a formal framework to the contents of the previous Quantum Physics courses and allows tackling more complex problems.
For this purpose the space of states of a system with the connection state-vector and operator-observable is introduced. The postulates of Quantum Mechanics are discussed. The role of symmetries and the time evolution of a system are analyzed. The formalism is applied to the study of time dependent Hamiltonian systems.

Related previous courses

This course on Quantum Mechanics may be considered as the natural continuation of the former Quantum Physics courses. It has also some connection with the Mechanics courses through the parallelism of the developed formalism with classical Hamiltonian mechanics. The differences between classical and quantum variables are also emphasized.

Regarding the needed mathematical tools they correspond to the contents of the previous Mathematical Methods courses.

PREVIOUS KNOWLEDGE

RELATIONSHIP TO OTHER SUBJECTS OF THE SAME DEGREE

There are no specified enrollment restrictions with other subjects of the curriculum.

OTHER REQUIREMENTS

The following prior knowledge is recommended:

Mathematics

1. Vector spaces.
2. Internal products: Euclidean vector spaces.
3. Linear operators: Hermitian and unitary operators.
4. Matrices and determinants.
5. Diagonalization of linear operators and matrices.
6. Fourier transform.
7. Dirac delta.
8. Solution of linear differential equations with constant coefficients.
9. Notions of probability and statistics.

Physics

1. Hamiltonian mechanics: construction of the Hamiltomian.
2. Oscillatory movement: the classical harmonic oscillator.

COMPETENCES / LEARNING OUTCOMES

1105 - Degree in Physics

Basic & applied Research: acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, e.g. engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results.

Communication Skills (written and oral): Being able to communicate information, ideas, problems and solutions through argumentation and reasoning which are characteristic of the scientific activity, using basic concepts and tools of physics.

Foreign Language skills: Have improved command of English (or other foreign languages of interest) through: use of the basic literature, written and oral communication (scientific and technical English), participation in courses, study abroad via exchange programmes, and recognition of credits at foreign universities or research centres.

Knowledge and understanding of the fundamentals of physics in theoretical and experimental aspects, and the mathematical background needed for its formulation.

Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.

Literature Search: be able to search for and use physical and other technical literature, as well as any other sources of information relevant to research work and technical project development.

Modelling & Problem solving skills: be able to identify the essentials of a process / situation and to set up a working model of the same; be able to perform the required approximations so as to reduce a problem to an approachable one. Critical thinking to construct physical models.

Physics general culture: Be familiar with the most important areas of physics and with those approaches which span many areas in physics, or connections of physics with other sciences.

Problem solving: be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems .

Students must have acquired knowledge and understanding in a specific field of study, on the basis of general secondary education and at a level that includes mainly knowledge drawn from advanced textbooks, but also some cutting-edge knowledge in their field of study.

Theoretical understanding of physical phenomena: have a good understanding of the most important physical theories (logical and mathematical structure, experimental support, described physical phenomena).

To know how to apply the knowledge acquired to professional activity, to know how to
solve problems and develop and defend arguments, relying on this knowledge.

DESCRIPTION OF CONTENTS

1. Fundamental concepts. Polarization of a photon and two photons. Tensor product. Entangled states. The Stern-Gerlach experiment. States, operators and observables.
2. Matrix representations. Spectral theorem. Functions of an operator. Change of base. Diagonalization of Hermitian matrices.
3. Observables and measurements. Observables and expected values. Measurement. Compatible observables. Uncertainty relations.
4. Symmetries in quantum mechanics. Symmetry transformations in quantum mechanics. Symmetries and temporal evolution.
5. Continuous spectrum. Position and moment operators. Wave functions. Diagonalization of operators. The harmonic oscillator.
6. Density operator. Pure and mixed ensembles. Polarization vector. Non-filtering measurements.
7. Evolution of systems and observables. Evolution of states and observables. Evolution of wave functions. Evolution Images. Spin 1/2 systems.
8. Introduction to quantum information. Bits and Qubits. Quantum computing. No-cloning theorem. Teleportation. Bell inequalities. Quantum cryptography.
9. Time-dependent potentials: the interaction image. Theory of time-dependent perturbations. Applications.

WORKLOAD

PRESENCIAL ACTIVITIES

Activity	Hours
Theory	45,00
Total hours	**45,00**

NON PRESENCIAL ACTIVITIES

Activity	Hours
Attendance at other activities	0,00
Individual or group project	12,50
Independent study and work	20,00
Preparation of lessons	20,00
Preparation for assessment activities	15,00
Resolution of case studies	0,00
Total hours	**67,50**

TEACHING METHODOLOGY

Lectures

Two lectures per week during the semester. The theoretical content will be applied to simple physical systems and, when possible, compared to data.

Practical classes

One hour per week dedicated to solving problems. The teacher will give in advance to students the set of problems for each chapter. Students will present in class their results.

class their results.

EVALUATION

1. Written exams to evaluate the understanding of the theoretical concepts of the course, the ability to solve problems and the critical analysis of the results. The exams will contain questions and problems.
2. Continuous assessment will count in the final grade up to 20% as long as the exams grade be greater than or equal to 4 out of 10.

These evaluation criteria are common to the first and second calls.

REFERENCES

- Modern Quantum Mechanics. J.J. Sakurai. Addison-Wesley.
- Introduction to Quantum Mechanics. D. J. Griffiths. Benjamin Cummings.
- Quantum Mechanics and Quantum Information. Moses Fayngold y Vadim Fayngold. Wiley-VCH.
- Schaum's Outline of Quantum Mechanics. Yoav Peleg y otros. McGraw-Hill.
- Problems in Quantum Mechanics: With Solutions. G. L. Squires.
- Quantum Computation and Quantum Information. M.A. Nielsen y I.L. Chuang. Cambridge University Press.
- Mecánica Cuántica, F.J. Ynduráin. Ed. Alianza Universidad Textos.
- Mecánica Cuántica. Alberto Galindo y Pedro Pascual. Alhambra.