COURSE DATA

DATA SUBJECT

Code: 34271
Name: Advanced quantum mechanics
Cycle: Undergraduate Studies
ECTS Credits: 6
Academic year: 2026-27

STUDY (S)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Facultat de Física	4	Second quarter

SUBJECT-MATTER

Degree	Subject-matter	Character
1105 - Degree in Physics	Complements of Physics	ELECTIVES

COORDINATION

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SUMMARY

This optional subject serves as a complement to Quantum Mechanics, a compulsory fourth-year subject in the Bachelor's degree in Physics at the University of Valencia. Regarding its specific content, it begins with a brief review of Hilbert spaces before the introduction of the concept of symmetry in quantum mechanics. Continuous (translations, rotations) and discrete (parity, time reversal) symmetries are considered. Next, the theory of scattering is developed, introducing the concept of effective section in quantum mechanics; Born's approximation is studied. The behavior of non-relativistic charged particles in external electromagnetic fields is analyzed, and finally an introduction to quantum computing is provided.

Relationship with previous subjects: The subject is proposed as a continuation of the 4th year Quantum Mechanics subject which, in turn, complements the 3rd year Quantum Physics I and II courses. Apart from this relationship, it is worth mentioning its formal relationship with the subject of Classical Mechanics. Also of great importance is the mathematical background acquired in Mathematical Methods on vector spaces, matrix algebra and diagonalization.

Relationship with subsequent subjects: There are many Physics subjects that use the knowledge of Quantum Mechanics and Advanced Quantum Mechanics: Solid State, Quantum Optics, Nuclear and Particle Physics and Quantum Field Theory.

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. Hibert 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.

Physics

1. Postulates of Quantum Mechanics.
2. Symmetries in Classical Mechanics.
3. Classical Scattering theory.
4. Charged classical particle in an electromagnetic field.

COMPETENCES / LEARNING OUTCOMES

1105 - Degree in Physics

Ability to collect and interpret relevant data in order to make judgements.

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 be able to apply their knowledge to their work or vocation in a professional manner and have acquired the competences required for the preparation and defence of arguments and for problem solving in their field of study.

Students must be able to communicate information, ideas, problems and solutions to both expert and lay audiences.

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.

Students must have developed the learning skills needed to undertake further study with a high degree of autonomy.

Students must have the ability to gather and interpret relevant data (usually in their field of study) to make judgements that take relevant social, scientific or ethical issues into consideration.

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. Symmetries in quantum mechanics

Simetries in Quantum Mechanics
Wigner Theorem
Symmetry Transformation Group
Continuous symmetries
Discrete symmetries

2. Translations and rotations

Spatial translations
Generators of the Spatial translations
Spatial translation of a system of particles
Velocity translation
Rotations in quantum mechanics
Rotations in 1/2 spin systems
Neutron interferometry
Helicity states
Representations of rotation operators and Euler angles
Composition of angular momentums and Clebsch-Gordan Operators
Tensor Operators
Spherical and Cartesian tensor operators
Wigner-Eckart Theorem

3. Discrete symmetries in interactions

Parity transformation
Eigenstates of parity
Transformation of the wave function
Parity of a system of particles
Intrinsec parity
Parity violation
Selection rules
Time reversal symmetry
C-Parity
CPT theorem
Baryon and lepton number
Isospin (Continuous)
G-Parity
Two nucleon systems
Isospin multiplets
Pions
Introduction to the Quark model

4. Symmetries of identical particles

Identical particles
Fermions and bosons
Pauli Principle
Separable hamiltonian
System of two identical particles. The Helium atom

5. Scattering theory

Scattering amplitude
Cross section
Optical theorem
Born Approximation
Central potential
Asymptotic behaviour of the wave function
Phase shifts
Partial wave expansion of the scattering amplitude and the cross section
Argand diagram
Bound states and Resonances

6. Introduction to quantum computing

Introduction
Bits and Qubits
Entanglement
Bell inequalities
Entropy
One qubit gates
Multiple qubit gates
No clonation theorem
Quantum Algorithm
Grover Algorithm
Teleportation
Quantum eraser
Quantum cryptography

WORKLOAD

PRESENCIAL ACTIVITIES

Activity	Hours
Theory	60,00
Total hours	**60,00**

NON PRESENCIAL ACTIVITIES

Activity	Hours
Attendance at other activities	0,00
Individual or group project	20,00
Independent study and work	0,00
Preparation of lessons	50,00
Preparation for assessment activities	20,00
Resolution of case studies	0,00
Total hours	**90,00**

TEACHING METHODOLOGY

Theoretical classes: Three hours per week during the school period. The theoretical classes will be, in general, of a magisterial nature and in them the contents of the subject will be exposed. Special emphasis will be placed on the application of theoretical knowledge to the solution of issues and problems. Simple physical systems will be solved as an example of the general theoretical methods studied and the results will be compared with the experimental data.

Practical classes: One hour per week during the school period. In the practical classes, problems of each topic of the subject will be solved. The teacher will previously give the students a collection of problems for each topic and they will expose the work carried out on these problems during the practical class.

EVALUATION

1. Written exams: the understanding of the conceptual aspects of the subject, the ability to apply the formalism developed as well as the critical analysis of the results obtained. The exam will consist of questions and problems.

2. The mark of the exams will be weighted with the mark of the continuous evaluation that will consist of the resolution of problems. The final grade will be the maximum grade between the exam grade and the weighted average = 0.75*Exam grade + 0.25*Continuous evaluation.

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

REFERENCES

- Mecánica Cuántica. A. Galindo, P. Pascual. Alhambra o Eudema Universidad.
- Lectures on Quantum Mechanics. S. Weinberg. Cambridge University Press.
- Quantum Mechanics, Vol. I, II. C. Cohen-Tannoudji, B. Diu, F. Laloë. Wiley.
- Problems in Quantum Mechanics: With Solutions. G. L. Squires. Cambridge University Press.
- Modern Quantum Mechanics. J. J. Sakurai. Addison-Wesley.
- Problems in Quantum Mechanics. F. Constantinescu, E. Magyani. Pergamon
- Quantum Computation and Quantum Information. M.A. Nielsen y I.L. Chuang. Cambridge University Press.