UAB
Universitat Autònoma de Barcelona

Quantum Mechanics

Code: 100171
ECTS Credits: 6

2025/2026

Degree	Type	Year
Physics	OT	4

Contact

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Teachers

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Teaching groups languages

You can view this information at the end of this document.

Prerequisites

Prior knowledge of quantum physics, Hilbert spaces, operators, and group theory is required, so it is advisable to have studied Quantum Physics I, Quantum Physics II and Advanced Mathematical Methods.

Objectives and Contextualisation

The objective of this subject is for students to master various methods and formal aspects of Quantum Mechanics that allow them to deepen their knowledge and that have a wide range of applications in various areas of modern physics such as atomic, nuclear, particle, condensed matter, solid state, photonics, etc. The use of Hilbert spaces will be explored in depth, the different time evolution images will be introduced as well as the unitary operators of time evolution and those of symmetries realizations, continuous and discrete. The most important applications to assimilate are the continuous spectrum operators, the quantum-mechanical addition of angular momenta, identical particles and the theory of time-dependent perturbations, as well as the notable examples of time-dependent potentials.

Competences

- Apply fundamental principles to the qualitative and quantitative study of various specific areas in physics
- Be familiar with the bases of certain advanced topics, including current developments on the parameters of physics that one could subsequently develop more fully

- Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, and before both specialist and general publics
- Develop the capacity for analysis and synthesis that allows the acquisition of knowledge and skills in different fields of physics, and apply to these fields the skills inherent within the degree of physics, contributing innovative and competitive proposals.
- Formulate and address physical problems identifying the most relevant principles and using approximations, if necessary, to reach a solution that must be presented, specifying assumptions and approximations
- Know the fundamentals of the main areas of physics and understand them
- Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
- Use mathematics to describe the physical world, selecting appropriate tools, building appropriate models, interpreting and comparing results critically with experimentation and observation
- Work independently, have personal initiative and self-organisational skills in achieving results, in planning and in executing a project
- Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.

Learning Outcomes

1. Analyse new and old quantum experiments from different points of view to consolidate the foundations of quantum formalism and to consider unconventional views.
2. Analyse the implications of new approaches with specific proposals and test their validity in the context of quantum mechanics.
3. Apply different equivalent ways of solving the same problem, using for example, distinct images or equivalent descriptions related to unitary operators.
4. Calculate Clebsch-Gordan coefficients and be able to use the tables.
5. Calculate the evolution of a system to which we apply a time-dependent potential.
6. Calculate the probability of measuring an observable within a quantum system.
7. Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, in front of both specialist and general publics.
8. Correctly carry out the composition of angular momenta.
9. Correctly consider the evolution of a quantum system.
10. Correctly predict the result of applying discrete transformations as parity or temporary investment on a system.
11. Correctly use continuous bases and Dirac's notation.
12. Correctly use translation and rotation operators on a given quantum system.
13. Describe discrete transformations in addition to the concept of identical particles and particle exchange, and their consequences.
14. Describe Ehrenfest's theorem.
15. Describe interaction in quantum mechanics, the image of interaction and the development of perturbation theory.
16. Describe the composition of angular momenta.
17. Describe the differences between pure and mixed states and their formalism.
18. Describe the dynamics of a system and its evolution on the basis of the time evolution operator and distinct image equivalents.
19. Describe the generator concept for a continuous transformation and the associated symmetry.
20. Develop the capacity to relate the mathematical formalism of quantum mechanics experiments with the physical world.
21. Distinguish between the assumptions implicit in a given problem and the consequences of eliminating these and, therefore, learning to generalize solutions.
22. Identify the essential features of the quantum problem by translating these into operator terms and quantum states to describe the system and relevant observables.
23. List and describe the principles of quantum mechanics.
24. Relate recent research results to certain fundamental aspects of quantum mechanics.
25. Relate some of the applications of quantum mechanics with current technological developments.
26. Rigorously manipulate the properties of Hilbert's spaces and of the direct product and sum of spaces.

27. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
28. Use the spectral and matrix representation of Hermitian and unitary operators.
29. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.
30. Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.

Content

1) Theory of Angular Momentum: Addition of Angular Momenta

2) Symmetry in Quantum Mechanics: Symmetries and Conservation Laws; Discrete Symmetries (Parity, Time Reversal)

3) Approximation Methods: Time-Dependent Potentials; Time-Dependent Perturbation Theory

4) Scattering Theory: The Scattering Amplitude; The Born Approximation; Phase Shifts and Partial Waves

5) Identical Particles: Quantum Fields; Second Quantization

6) Relativistic Quantum Mechanics: The Klein-Gordon Equation; The Dirac Equation

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Exercises	16	0.64	2, 1, 3, 4, 5, 7, 19, 16, 18, 15, 13, 20, 21, 8, 22, 26, 9, 10, 27, 25, 24, 29, 30, 12, 28
Theory Lessons	33	1.32	2, 3, 4, 5, 7, 19, 16, 18, 15, 13, 20, 21, 8, 22, 26, 9, 10, 27, 25, 24, 29, 12, 11, 28
Type: Autonomous			
Discussion, Work Groups, Group Exercises	24	0.96	2, 1, 3, 4, 6, 5, 7, 19, 14, 16, 18, 15, 17, 13, 20, 21, 8, 23, 22, 26, 9, 10, 27, 25, 24, 29, 30, 12, 11, 28
Study of Theoretical Foundations	48	1.92	2, 1, 3, 4, 6, 5, 7, 19, 14, 16, 18, 15, 17, 13, 20, 21, 8, 23, 22, 26, 9, 10, 27, 25, 24, 29, 30, 12, 11, 28

Theory Lessons and Exercises.

Classwork and Homework.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continous Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Assignments: first part topics	10%	10	0.4	2, 1, 3, 4, 6, 5, 7, 19, 14, 16, 18, 15, 17, 13, 20, 21, 8, 23, 22, 26, 9, 10, 27, 25, 24, 29, 30, 12, 11, 28
Assignments: second part topics	10%	10	0.4	2, 1, 3, 4, 6, 5, 7, 19, 14, 16, 18, 15, 17, 13, 20, 21, 8, 23, 22, 26, 9, 10, 27, 25, 24, 29, 30, 12, 11, 28
Exam: first part topics	40%	3	0.12	2, 1, 3, 4, 6, 5, 7, 19, 14, 16, 18, 15, 17, 13, 20, 21, 8, 23, 22, 26, 9, 10, 27, 25, 24, 29, 30, 12, 11, 28
Exam: second part topics	40%	3	0.12	2, 1, 3, 4, 6, 5, 7, 19, 14, 16, 18, 15, 17, 13, 20, 21, 8, 23, 22, 26, 9, 10, 27, 25, 24, 29, 30, 12, 11, 28
Make-up Exam: all topics	80%	3	0.12	2, 1, 3, 4, 6, 5, 7, 19, 14, 16, 18, 15, 17, 13, 20, 21, 8, 23, 22, 26, 9, 10, 27, 25, 24, 29, 30, 12, 11, 28

Exam and submission of exercises for the topics in the first partial;

Exam and submission of exercises for the topics in the second partial;

Make-up exam: all topics;

To participate in the make-up exam, you must have been assessed in both partial exams without requiring a minimum grade;

The make-up exam covers the entire subject;

You may attend the make-up exam to improve your grade. If so, your final grade for the exam portion will be the one obtained in the make-up exam.

Single assessment: The students that opted for single assessment evaluation will have to perform a final evaluation that will first consist of a test of the whole syllabus. This test will take place on the same date, time, and place as the test of the continuous assessment modality. Besides, before the exam, the student will deliver 2 deliveries consisting in resolved exercises of a selected set of exercises proposed at an earlier date. For the mark, 80% of the final mark will come from the exam and each of the deliveries will count 10%. The students that opted for single assessment evaluation will have the chance of passing the module or improving their mark at the same re-evaluation test as the students that had opted for the continuous assessment option (both exams will be identical and will take place on the same day, time, and in the same place). However, it is mandatory to at least have taken the previous final test. At this test, it is only possible to improve the mark of the exam. The part of the deliveries can not be improved in the re-evaluation.

Bibliography

- "Modern Quantum Mechanics", J. J. Sakurai and J. Napolitano, Cambridge University Press, 2021
- "Quantum Mechanics", D. Tong, Cambridge University Press, 2025
- "Introduction to Quantum Mechanics", D. J. Griffiths and D. F. Schroeter, Cambridge University Press, 2018

Software

Software is not required.

Groups and Languages

Please note that this information is provisional until 30 November 2025. You can check it through this link. To consult the language you will need to enter the CODE of the subject.

Name	Group	Language	Semester	Turn
(PAUL) Classroom practices	1	English	first semester	morning-mixed
(TE) Theory	1	English	first semester	morning-mixed