Universitat Autònoma de Barcelona

2018/2019

Quantum Mechanics

Code: 100171
ECTS Credits: 6

Degree	Type	Year	Semester
2500097 Physics	OT	4	0

Contact

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Use of languages

Principal working language: english (eng)

Some groups entirely in English: Yes

Some groups entirely in Catalan: No

Some groups entirely in Spanish: No

Prerequisites

It is advisable to have studied
- Quantum Physics I
- Quantum Physics II

It is also recommended to take or have completed:
- Advanced Mathematical Methods

Objectives and Contextualisation

The goal of this course is that the student master several methods and formal aspects of Quantum Mechanics that allow them to deepen their knowledge and have a wide range of applications in various fields of modern physics such as atomic physics, nuclear, particles, condensed matter, photonics, etc. Hilbert Spaces and its formalism will be extensively used, the different images of temporary evolution will be introduced as well as the unitary operators of temporary evolution and those of symmetries, both continuous and discrete. The most important applications to be consolidated in the student's background are the operators of continuous spectrum, the mechanical-quantum addition of angular momenta, identical particles and time-dependent perturbation theory, as well as the remarkable examples of time-dependent potentials

Skills

- 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 critical thinking and reasoning and know how to communicate effectively both in the first language(s) and others
- Develop independent learning strategies
- 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
- Generate innovative and competitive proposals for research and professional activities.
- Know the fundamentals of the main areas of physics and understand them
- Respect the diversity and plurality of ideas, people and situations
- 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 Diracs notation.
12. Correctly use translation and rotation operators on a given quantum system.
13. Describe Ehrenfests theorem.
14. Describe discrete transformations in addition to the concept of identical particles and particle exchange, and their consequences.
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 critical thinking and reasoning and communicate ideas effectively, both in the mother tongue and in other languages.
21. Develop independent learning strategies.
22. Develop the capacity to relate the mathematical formalism of quantum mechanics experiments with the physical world.
23. Distinguish between the assumptions implicit in a given problem and the consequences of eliminating these and, therefore, learning to generalize solutions.
24. Generate innovative and competitive proposals for research and professional activities.
25. Identify the essential features of the quantum problem by translating these into operator terms and quantum states to describe the system and relevant observables.
26. List and describe the principles of quantum mechanics.
27. Relate recent research results to certain fundamental aspects of quantum mechanics.
28. Relate some of the applications of quantum mechanics with current technological developments.
29. Respect diversity in ideas, people and situations.

30. Rigorously manipulate the properties of Hilberts spaces and of the direct product and sum of spaces.
31. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
32. Use the spectral and matrix representation of Hermitian and unitary operators.
33. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.
34. Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.

Content

Formalism of Quantum Mechanics

Hilbert Spaces, Linear Operators and Dirac Notation
Observable and Representations
The Postulates

Quantum Dynamics

Operator of Time Evolution
Schrödinger and Heisenberg Pictures
The Ehrenfest theorem

Simetries

Translations
Rotations Angular momentum. Adding Angular Momenta
Discrete symmetries. Parity and Time reversal
Identical Particles

Time-Dependent Potentials

Interaction image
Time evolution in systems of two states. Rabi's formula.
Time-dependent perturbation theory.

Methodology

The course's structure will be: sessions of theory and problems.
Lists of problems will be provided in each chapter to be solved individually or in groups with the aim that the student consolidate the knowledge that is explained in the theory part.
Solutions to problems will be discussed jointly with the professor in the exercise's class.
The students will have to solve individually in a limited time and deliver a selection of problems that will count towards the final note and that will constitute the note of the continuous evaluation.
Finally, students will have to prepare for a written exam at the end of the course.

Activities

Title	Hours	ECTS	Learning outcomes
Type: Directed			
Hours of attendance (exercises)	15	0.6	3, 4, 5, 7, 20, 23, 25, 30, 9, 31, 11, 32
Hours of attendance (theory)	30	1.2	3, 19, 13, 16, 18, 15, 17, 14, 26, 30, 10, 28, 27
Type: Autonomous			

Delivery of Solved Problems	24	0.96	3, 7, 22, 20, 23, 31, 33, 34
Problem Solving	45	1.8	2, 3, 4, 5, 6, 21, 30, 9, 31, 33, 12, 32
Study of theoretical concepts	30	1.2	4, 5, 6, 19, 13, 16, 18, 15, 17, 14, 8, 26, 9, 10, 12

Evaluation

The evaluation of the course will consist of two blocks:

- A written exam (of theory and problems) that will count 65% of the note, and with the right to a recovery exam (for 70%).
- TWO deliveries of problems will be proposed that will count the remaining 30% of the note.
- Attendance and active participation in class will count 5% of the mark and will be recovered in the recovery exam, which will be 70% and not 65%.

To qualify for the recovery exam the student must have tried to pass a minimum of 2/3 of the final mark.
A student must be considered submitted for evaluation if it is presented in more than 35% of the final mark of the evaluation.
The minimum mark to make an average that must be taken to the exam is 4.

Evaluation activities

Title	Weighting	Hours	ECTS	Learning outcomes
Active participation in class	5%	1	0.04	7, 22, 20, 31
Delivery of Solved Problems	30%	0	0	2, 7, 21, 22, 20, 24, 25, 31, 28, 27, 29, 33, 34
Final Exam	65%	2.5	0.1	1, 3, 4, 5, 6, 19, 13, 16, 18, 15, 17, 14, 23, 8, 26, 30, 9, 10, 12, 11, 32
Recovery Exam	70%	2.5	0.1	1, 3, 4, 5, 6, 19, 13, 16, 18, 15, 17, 14, 23, 8, 26, 30, 9, 10, 12, 11, 32

Bibliography

J. J. Sakurai, "Modern Quantum Mechanics", Ed. Addison-Wesley.
C. Cohen-Tannoudji, B. Diu and F. Laloe "Quantum Mechanics", Vols 1&2, Ed. Hermann and Wiley & Sons.
W. Greiner, "Quantum Mechanics: An Introduction", Ed. Springer.
W. Greiner and B. M\"uller, "Quantum Mechanics. Symmetries", Ed. Springer.
R. Shankar, "Principles of Quantum Mechanics", Ed. Plenum Press.
L. I. Schiff, "Quantum Mechanics", Ed. McGraw-Hill.