Universitat Autònoma de Barcelona

2021/2022

Quantum Mechanics

Code: 100171
ECTS Credits: 6

Degree	Type	Year	Semester
2500097 Physics	OT	4	1

The proposed teaching and assessment methodology that appear in the guide may be subject to changes as a result of the restrictions to face-to-face class attendance imposed by the health authorities.

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, solide state, 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 are the operators of continuous spectrum, the quantum addition of angular momenta, identical particles and time-dependent perturbation theory, as well as the remarkable 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 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 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 Hilberts 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

0. Overview of the postulates.

1. Review of basic QM. Angular momentum and spin. Solutions to Schroedinger equation. Pertubation theory.

2. Two-state systems.

3. Classical limit. Heisenberg picture.

4. Symmetry in QM (1). Space and time displacements. Space and time inversions. Particles in periodic potentials.

5. Symmetry in QM (2). Rotations. Formal theory of angular momentum. Addition of angular momentum.

6 .Symmetry in QM (3). Identical particles.

7. Time-dependent perturbation theory.

8. TBA (depends on available time).

Methodology

This course will be given entirely in English. All the course material (problems, homework and exams) will be distributed in English and students will be encouraged to do all the exercises/exams in English, although in Catalan or Spanish will also be accepted and assesed with the same criteria.

This course will consist of theory and problem classes. There will be an equilibrium among work at class and at home.

Problem lists will be given to be solved individually or in groups. The solutions to the problelms will be discussed in the problem classes.

The students will solve individually and hand in after a limited time a selection of 'homework' problems that will count for the final course mark.

The students will have to prepare 2 written exams: a mid-term exam and a final exam, the latter of which can be re-taken once.

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.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Hours of attendance (exercises)	16	0.64	3, 4, 5, 7, 21, 22, 26, 9, 27, 11, 28
Hours of attendance (theory)	33	1.32	3, 19, 13, 16, 18, 15, 17, 14, 23, 26, 10, 25, 24
Type: Autonomous			
Discussion and work in group	46	1.84	3, 4, 7, 19, 16, 18, 17, 14, 20, 21, 8, 23, 27, 29, 30, 12

Study of theoretical concepts	47	1.88	4, 5, 6, 7, 19, 13, 16, 18, 15, 17, 14, 8, 23, 9, 10, 27, 29, 12

Assessment

There will be a resit exam for students that: a) have done Exam 1 and Exam 2 and b) have failed the course with a mark of at least 3.5 (over 10).

Details on this exam will be announced in due course.

Students not attending Exam 2 will have the mark "Not presented - no avaluable"

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Exam 1	30%	2	0.08	2, 1, 3, 4, 5, 6, 7, 19, 13, 16, 18, 15, 17, 14, 20, 21, 8, 23, 22, 26, 9, 10, 27, 25, 24, 29, 30, 12, 11, 28
Exam 2 (Final)	50%	2	0.08	2, 1, 3, 4, 5, 6, 7, 19, 13, 16, 18, 15, 17, 14, 20, 21, 8, 23, 22, 26, 9, 10, 27, 25, 24, 29, 30, 12, 11, 28
Homework	20%	2	0.08	2, 1, 3, 4, 5, 6, 7, 19, 13, 16, 18, 15, 17, 14, 20, 21, 8, 23, 22, 26, 9, 10, 27, 25, 24, 29, 30, 12, 11, 28
Resit Exam	85%	2	0.08	2, 1, 3, 4, 5, 6, 7, 19, 13, 16, 18, 15, 17, 14, 20, 21, 8, 23, 22, 26, 9, 10, 27, 25, 24, 29, 30, 12, 11, 28

Bibliography

J.J. Sakurai and J. Napolitano, "Modern Quantum Mechanics", Pearson Education

Others:

D.J. Griffiths and D.F. Schroeter, "Introduction to Quantum Mechanics" 3rd edition, Cambridge University Press

L. I. Schiff, "Quantum Mechanics", Ed. McGraw-Hill.
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.

Software

No "programari"