UAB
Universitat Autònoma de Barcelona

2022/2023

Quantum Physics II

Code: 100155
ECTS Credits: 6

Degree	Type	Year	Semester
2500097 Physics	OB	3	2

Contact

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Use of Languages

Principal working language: catalan (cat)
Some groups entirely in English: No
Some groups entirely in Catalan: Yes
Some groups entirely in Spanish: No

Teachers

Ramón Muñoz Tapia

Arnau Riera Graells

Prerequisites

It is recommended that students have successfully completed the first two years of the Physics degree (or equivalent joint degrees) in order to guarantee that they have the necessary scientific maturity and skills necessary to assimilate the concepts in this course. A good basis of calculus of one and several variables, and linear algebra is necessary, as well as basic notions of complex numbers. These requirements should be met by any student who has passed the mathematics courses taken during the first and second years. Naturally, it is also necessary to master the formalism and concepts of quantum mechanics introduced in Quantum Physics I.

Objectives and Contextualisation

The objectives set in Quantum Physics I, where the aim is to introduce students to the world of quantum mechanics, will be completed. The student will be exposed and and assisted in reaching the fundamental concepts and formalism of this discipline. Its usefulness, importance and meaning will be illustrated with applications. Algebraic techniques and approximate methods will be developed to tackle relevant problems. Students will be prepared to deepen and broaden their knowledge in the subjects of Quantum Mechanics, Quantum Information and Quantum Optics where they can enrol in the following years.

Competences

- Develop strategies for analysis, synthesis and communication that allow the concepts of physics to be transmitted in educational and dissemination-based contexts
- 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

Learning Outcomes

1. Calculate the electronic structure of the hydrogen atom using formalism and the methods introduced in a general manner.
2. Describe perturbed atomic structure and levels. Fine structure and Zeeman's effect.
3. Describe scale operators in a harmonic oscillator and angular momentum and characterize the coherent states.
4. Transmit, orally and in written format, physical concepts of a certain complexity, making them understandable to non-specialist settings.
5. Use Hilbert's spaces and Hermitian and unitary operators.
6. Use alternative techniques (algebraic and analytical) to solve problems such as the harmonic oscillator or orbital angular momentum.
7. Use approximate methods in simple models that describe the general characteristics and behaviour of highly complex physical systems.
8. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
9. Use differential equations and orthogonal families of function.
10. Use perturbation theory for the study of fine structure and the effects of external electromagnetic fields.
11. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.

Content

1 Matrix Mechanics (Algebraic approach)
1.1 Harmonic oscillator (algebraic solution)
Coherent States
1.2 Angular moment
Orbital and intrinsic angular momentum (spin)
1.3 Wave functions of various components or spinorials

2 Composite systems
2.1 Distinguishable particles
2.2 Identical particles
2.3 Helium atom
2.4 EPR Paradox and Bell Inequalities

3 Approximate methods: variational method
3.1 General formulation
3.2 Examples

4 Approximate methods: Time-independent perturbation theory
4.1 General formulation: degenerate and non-degenerate cases
4.2 Fundamental state of the He atom and H_2^+ molecule.
4.3 H atom: fine structure. Zeeman and Paschen-Back Effects

Methodology

Theoretical lessons: In the master classes we introduce the key concepts and methods that define the contents of the subject, and that the student will have to complete and assimilate with the help of the recommended bibliography and the material that is provided in the virtual campus.

Practice lessons: Problem exercises illustrate the application of the learned concepts to specific problems of pedagogical or practical relevance and should also serve the students to strengthen their mathematical skills.

A part of the problems are solved in class by the problem teacher, so that the students -who will have previously attempted to solve the problems at home- can know the degree of success of their solutions and incorporate the pertinent corrections; other problems must be solved and delivered by the student directly to the teacher. The latter will be done in the form of home deliveries. At least, four seminar sessions, where students in small groups solve a problem that covers in depth some of the key concepts of the course, are scheduled.

Tutoring: individual tutroing sessions (it might also be possible to organize some in group) are meant for resolving any issues or doubts that arise.

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			
Exercise sessions	22	0.88	8, 4, 5, 9, 7, 6
Theory lectures	28	1.12	1, 3, 2, 8, 5, 10, 9, 7, 6
Type: Autonomous			
Solve exercises	38	1.52	2, 8, 4, 10, 9, 7, 6
Study theory	54	2.16	1, 3, 2, 8, 5, 10, 9, 6

Assessment

All evaluations will be in written form. Exams will be split into a Theory and Problems parts of the same weight. Support texts may not be used during the exams, except for a formulary that will either be attached to the exam or prepared beforehand by the student. The first evaluation (with Theory and Problems) will be done after about 7 weeks and will include approximately half of the syllabus. The second will be done about 7 weeks later and will include the other half.

Both the first and the second partial exams will be redeemable (and with the possibility to improve the grade) at the end of the semester with a final evaluation or make up exam. In other words, there will be two partial exams and for those who want it or need it, there will be a make-up exam for the relevant parts. It is necessary to have a grade above 3 for each of the parts and, in any case, it is necessary to sit in both partials in order to be able to take the make-up exam. The assignements and problem sessions will contribute up to one point (or depending on the workload, up to a point and a half) to the mark of the partial examinations (not to the one of make-up exam). The student will be considered evaluatable if any of the partial or final examinations are handed in.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
1rst partial exam	42.5-45%	2.5	0.1	3, 8, 4, 5, 6
2nd partial examn	42.5-45%	2.5	0.1	1, 2, 8, 4, 10, 9, 7, 6
Assignments and problem sessions	10- 15%	0	0	1, 3, 2, 8, 4, 11, 5, 10, 9, 7, 6
Make up exam	100%	3	0.12	1, 3, 2, 8, 5, 10, 9, 7, 6

Bibliography

Basic

F. Mandl, ``Quantum Mechanics'', John Wiley 1992. Llibre de referència que tradicionalment s'ha fet servir a Física Quàntica la UAB i del que disposeu moltes copies a la Bilbioteca de Ciències. S'hi troben molts continguts del curs, tot i així trobareu una exposició més moderna (i pel meu gust més clara) al Griffiths i Ballentine.

D. J. Griffiths, "Introduction to Quantum Mechanics", Pearson Prentice Hall; 2nd Ed. 2004.

Advanced

L. Ballentine, "Quantum Mechanics: A Modern Development", World Scientific Publishing Company, 1998.

J. J. Sakurai, "Modern Quantum Mechanics", Addison Wesley, 1993.

C. Cohen-Tannoudji, B. Diu, F. Laloe, "Quantum Mechanics", vol.1-2, Wiley-Interscience, 2006.

A. Galindo y P. Pascual, "Mecánica Cuántica", vol I,II y III, Eudema, 1989.

Software

Depending on the adopted presentiallity policy, SLACK will be used to facilitate interaction among students and between students and professors. Zoom will be used for virtual classes