UAB
Universitat Autònoma de Barcelona

Quantum Physics I

Code: 100154
ECTS Credits: 6

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Degree	Type	Year
2500097 Physics	OB	3

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Teachers

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Teaching groups languages

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

Prerequisites

It is recommended that students start Quantum Physics meeting a few reasonable prerequisites. One has to take into account that quantum physics is one of the most difficult subjects in physics, either because of its anti-intuitive and very broad content (it affects many parts of physics), or because it involves several sophisticated mathematical tools:

Physics: Knowledge of classical mechanics including, at an elementary level, Hamiltonian formulism; Knowledge of electromagnetism, waves and first-year optics

Mathematics: knowledge of algebra, including vector spaces (with metrics), linear operators and eigenvectors and eigenvalues; elementary knowledge of complex numbers, integration of functions of several variables, and differential equations.

General: it takes an open mind and an ability (training) to keep up with the course work that involves formal and conceptual difficulties.

Objectives and Contextualisation

The aim is to introduce students to the world of quantum mechanics, which is an essential part of modern physics. To expose them and to help them reach the fundamental concepts and the basic formalism of this discipline. Illustrate its usefulness, importance and meaning with applications. To provide a training to tudents that will allow them to deepen and broaden their knowledge in Quantum Physics II and in the optional subjects of Quantum Mechanics, Advanced Quantum Mechanics, Quantum Information, Quantum Optics, among others.

The (no-exhaustive) list of basic objectives is:

(i) Know the experiments that gave birth to quantum mechanics

(ii) Identify the quantum formulation and postulates in finite and infinite dimensional systems.

(iii) Make temporal evolutions in spaces of finite dimension (essentially dimension 2)

(iv) Know the wave formulation in space of coordinates and moments

(v) Solve the energy spectrum and states of simple 1D potentials (wells and harmonic oscillator) in wave mechanics

(vi) Description of collision states (scattering) in simple potential barriers and know the differences with bound states

(vii) Knowing how to make the temporal evolution of a free wave packet.

(viii) Solve simple problems in 3D (infinite well and isotropic and non-isotropic harmonic oscillator). Analyze degeneracies.

(ix) Sovle problems with radial symmetry, Laplacian expressions and orbital angular momentum.

(x) Solve the spectrum of the hydrogen atom

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 certain paradigmatic quantum systems such as the Stern-Gerlach experience, the double slit or potential barriers (tunnelling effect).
3. Describe the laws that govern the quantum world: identify the postulates of quantum mechanics and develop an intuition of its characteristic properties.
4. Describe unperturbed atomic structure and levels.
5. Transmit, orally and in written format, physical concepts of a certain complexity, making them understandable to non-specialist settings.
6. Use Hilbert's spaces and Hermitian and unitary operators.
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. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.

Content

Physical grounds of Quantum Physics. Experimental facts and basic consequences. Indeterminations and Heisenberg principle.

Basic formulism of the Quantum Physics. States and observables. Vector spaces. Operators. Dirac Notation.

Postulates of Quantum Physics. Matrix mechanics (Heisenberg) and wave mechanics (Schrödinger).

One dimensional applications of wave mechanics: simple potential wells, tunnel effect, harmonic oscillator, diatomic molecules.

Three-dimensional applications of wave mechanics: orbital angular momentum and spherical harmonics, hydrogen atom. Central potentials.

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Exercise sessions (problem solving and seminars)	22	0.88	5, 6, 7, 8, 9
Theory lectures	28	1.12	1, 2, 3, 4, 6, 7, 8, 9
Type: Autonomous			
Solve assigned problems	51	2.04	2, 3, 4, 6, 7, 8, 9
Study theory	40	1.6	1, 2, 3, 4, 6, 8, 9

Theory lectures: In the theory classes we introduce the key concepts and methods that define the contents of the subject. Before each class the students must become familiar with the subject, making us of the material (notes, videos or bibliography) that will be made available to them.

Problem sessions: The exercises illustrate the application of the concepts learned to specific problems of pedagogical or practical relevance. They should also serve the student to strengthen her or his mathematical skills.

A part of the problems are solved in class by the 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.

There are scheduled four sessions of 2 hours each where problems are done in groups of 3-4 randomly assigned students. These problems deal with some aspects in a more exhaustive way and allow to illustrate the application of concepts in more depth as well as to learn some new techniques.

Tutoring: The individual tutorials (eventually it will be possible to organize some in group) can be used to solve any issues or difficulties.

Home activities:

Study and preparation of Theory classes.

Study and resolution of problems.

Peer reviewing of projects

Additional considerations

The creation of a SLACK workspace to facilitate communication between different groups of students and teachers will be considered.

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
Assignment i and problem Sessions	10-15%	0	0	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
First evaluation	42.5-45% redeemable	3	0.12	2, 3, 5, 6, 8, 9
Make up exam	100%	3	0.12	1, 2, 3, 4, 6, 7, 8, 9
Second evaluation	42.5-45% redeemable	3	0.12	1, 3, 4, 5, 6, 7, 8, 9

All evaluations will be written. Exams will be split into a Theory and Problems part 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 of at least 3 for each of the parts. In general, it is necessary to sit in both partials in order to be able to take the make-up exam. Special circumstances may be considered. 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.

With respect to students approved for partials who present themselves to upload a grade (of the partials or overall), if the grade is higher than the previous one, the latter will be considered, and if it is lower, an average will be made at 75% previous grade 25% recovery grade.

Singleassessment

Students who have requested the single assessment modality will have to take a final test which will consist of: (i) a theory exam with theoretical questions of the whole course (ii) solve a series of exercises similar to those worked on in the Classroom Practice sessions, and (iii) once finished, will have to answer some oral questions about concepts developed in the seminar sessions. These tests will take place on the same day, time and place as the tests of the second part of the continuous assessment modality. The student's grade will be the weighted average of the three previous activities, where the theory exam will account for 40% of the grade, the problem exam 40% and the oral questions 20%. If the final grade does not reach 5, the student has another opportunity to pass the subject through the recovery exam that in general will coincide with the date of the retake exam, or on a date set by the degree coordinator. In this test 70% of the grade corresponding to the theory and the problems can be compensated. The oral part is not redeemable."

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 Universidad, Madrid 1989. (there is also an English edition)

Other

Eisberg, Resnick. Fisica Cuantica. Atomos, Moleculas, Solidos, Nucleos y Particulas. 2002 (original edition in english)

Alonso, Marcelo, and Edward J. Finn. "Fisica" Vol III: Fundamentos cuanticos y estadisticos". Ed. Rev. Addison Wesley Longman, 2000.(original edition in english)

Software

No specific programs are necessary for the course, but access to the programs Mapple or Mathematica may be convenient to check and extend some results. The LaTeX word processor is very useful for the presentation of the deliverables.

Language list

Name	Group	Language	Semester	Turn

(PAUL) Classroom practices	1	Catalan	first semester	morning-mixed
(PAUL) Classroom practices	2	Catalan	first semester	morning-mixed
(TE) Theory	1	Catalan	first semester	morning-mixed
(TE) Theory	2	Catalan	first semester	morning-mixed