UAB
Universitat Autònoma de Barcelona

Quantum Phenomena II

Code: 103498
ECTS Credits: 6

2024/2025

Degree	Type	Year
2501922 Nanoscience and Nanotechnology	OB	3

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

It is recommended to have passed the subject "Quatum Phenomena I"

Objectives and Contextualisation

Acquisition of basic knowledge of Quantum Mechanics complementary to that taught in the subject of Quantum F

Quantum Phenomena I are emphasized and expanded. The second one deals with atomic electronic states and

The fourth unit addresses the study of wells and square potential barriers, and applications to nanoscience. The

student to have a solid knowledge of the fundamentals of quantum mechanics and examples are given of the int

Competences

- Apply the concepts, principles, theories and fundamental facts of nanoscience and nanotechnology to solve problems of a quantitative or qualitative nature in the field of nanoscience and nanotechnology.
- Communicate orally and in writing in one's own language.
- Demonstrate knowledge of the concepts, principles, theories and fundamental facts related with nanoscience and nanotechnology.
- Interpret the data obtained by means of experimental measures, including the use of computer tools, identify and understand their meanings in relation to appropriate chemical, physical or biological theories.
- Learn autonomously.
- Manage the organisation and planning of tasks.
- Obtain, manage, analyse, synthesise and present information, including the use of digital and computerised media.
- Propose creative ideas and solutions.
- Reason in a critical manner
- Recognise and analyse physical, chemical and biological problems in the field of nanoscience and nanotechnology and propose answers or suitable studies for their resolution, including when necessary the use of bibliographic sources.
- Resolve problems and make decisions.
- Work correctly with the formulas, chemical equations and magnitudes used in chemistry.

Learning Outcomes

1. Adequately define Bose-Einstein and Fermi-Dirac's quantum statistics.
2. Analyse situations and problems in the field of physics and propose answers or studies of an experimental nature using bibliographic sources.
3. Apply Schroedinger's equation to one-dimensional quantum systems like potential wells and/or oscillators and to three-dimensional ones like molecules.
4. Apply the acquired theoretical contents to the explanation of experimental phenomena.
5. Communicate orally and in writing in one's own language.
6. Critically evaluate experimental results and deduce their meaning.
7. Descriure el moment magnètic, orbital i d'espín.
8. Employ information and communication technology in the documentation of cases and problems.
9. Indicate the physical bases of quantum mechanics and relate them with experimental facts.
10. Learn autonomously.
11. Manage the organisation and planning of tasks.
12. Obtain, manage, analyse, synthesise and present information, including the use of digital and computerised media.
13. Perform bibliographic searches for scientific documents.
14. Propose creative ideas and solutions.
15. Reason in a critical manner
16. Recognise the quantum nature of atomic and molecular physics.
17. Recognise wave-particle duality.
18. Resolve Schrödinger's equation for one-dimensional problems and be able to calculate the tunnel effect in different physical systems.
19. Resolve problems and make decisions.
20. Resolve problems with the help of the provided complementary bibliography.
21. Use Schrödinger's equation to resolve problems with central forces.
22. Use Schrödinger's equation to resolve three-dimensional problems with spherical symmetry (hydrogen atom, harmonic oscillator).
23. Use data processors to produce reports.
24. Work correctly with the formulas, chemical equations and magnitudes used in chemistry.

Content

- Emphasis and applications of some subjects issues addressed in FQI.

Schrödinger equation in 1D and 3D. The angular moment beyond the spherical harmonics: the spin. The Hydrogen atom revisited. Fine and hyperfine structures. Solution of the Hamiltonian: matrix notation. Stationary perturbation theory (synthesis).

- Magnetic Moment. Multielectronic atoms.

Magnetic moment in classical physics. Relationship between the orbital magnetic moment and the orbital angular momentum: Diamagnetism. Permanent magnetic moment: Paramagnetism. General theorem of precession. Multielectronic states: angular momentum. Brief summary of the solution of the Schrödinger equation for to the Hydrogen atom. Russell-Saunders coupling. Hund's rules. Exchange interaction. Spin-orbit coupling. Permanent magnetic properties. Magnetic moment associated with the electronic orbital momentum. Electronic spin: associated magnetic moment. Spin-orbit coupling: associated magnetic moment. Zeeman effect.

- Density of states and occupation.

Characteristic lengths in nanoscopic systems. Quantum wells, quantum wires and quantum dots. Dimensionality and energy levels. Sommerfeld's model of free electrons. Travelling waves: Born-von Kárman's boundary conditions. Density of states (DOS); Fermi level. DOS in 3D in the Sommerfeld's model.Fermi level. DOS in 3D for traveling waves. DOS in 2D and 1D. Statistical distributions. Maxwell-Boltzmann's distribution. Bose-Einstein's distribution. Fermi-Dirac distribution; some considerations. Occupation of the energy levels. Fermi-Dirac function and physical properties.

- Square potential wells and square potential barriers: applications to Nanoscience.

Finite and symmetric square well potential in 1D. Square potential barrier in 1D; tunnel effect. Square potential step in 1D. Physical nanostructures and dimensionality. Fundamental structures of electronic devices. Energy bands in 3D semiconductors. Energy bands dispersions in 3D semiconductors. Potential wells in semiconductors; the MODFET. Double potential well barrier; the resonant tunnel diode. Multiple quantum wells; IR photodetectors. Superlattices.

- Triangular and parabolic wells: applications to Nanoscience.

Triangular quantum well in 1D. 2DEG systems; the MOSFET. Square well potential in an applied electric field; modulators. Parabolic quantum well in 1D; the harmonic oscillator. Atomic vibrations of diatomic molecules. Effect of a magnetic field on an electron gas. Magnetic field in a 2D system: Landau levels and density of states. Extension to 3D systems. Applications. Hyperbolic quantum barrier: alpha disintegration. Parabolic quantum barrier. Applications: chemical and biochemical reactions.

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Problems class	16	0.64	4, 3, 10, 6, 5, 7, 8, 9, 14, 15, 17, 18, 20, 19
Theoretical classes	30	1.2	4, 3, 10, 1, 7, 8, 9, 14, 15, 16, 18, 22
problem solving activities in the classroom	8	0.32	2, 4, 3, 10, 6, 15, 18, 20, 19, 21, 22
Type: Supervised			
Oral presentations	6	0.24	2, 4, 3, 6, 5, 7, 8, 13, 11, 9, 12, 18, 19, 23

Problem solving	6	0.24	3, 1, 7, 14, 15, 18, 20, 19, 24, 21, 22
Type: Autonomous			
Study	68	2.72	2, 4, 10, 6, 8, 13, 11, 12, 14, 15, 20, 24, 23

Theory classes

The teacher will explain the content of the program in audiovisual support. Support material hanged on the Campus Virtual will be available to the students.

Classes of problems

The aim of the problems classes is to consolidate and see how the knowledge acquired in the theory classes is put into practice. They will be interspersed with the theory classes to crefinlarify some aspects. Otherwise, they will be completed at the end of each of the thematic units. Some problems will be solved by the teacher. Some others will be solved y the students and exposed in a oral presentation.

Group activities

In this special sessions the students will confront specific problems with a group problem solving strategy.

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
Side activities	15%	6	0.24	2, 4, 10, 6, 5, 8, 13, 11, 9, 12, 14, 15, 24, 23
Solved problems	15%	2	0.08	2, 4, 10, 6, 5, 8, 13, 11, 12, 14, 15, 19, 24, 23
Written exams (mid-term and final)	70%	8	0.32	4, 3, 6, 5, 1, 7, 9, 14, 15, 17, 16, 18, 20, 21, 22

Written exams:

The weighting is 70% of the final score. Two partial exams will be scheduled throughout the course and a final exam if necessary. The two partial exams have the same weight (35%). If the two partial exams have been approved (above 4) it will not be necessary to go to the Final exam. If one or both partial exams have not been approved (below 4), the final exam will be required. It is mandatory to approve this part (above 4) to pass the subject.

If students do not take part in the solving problems group or do bnot particpate in the other activities, the two written exams will represent 100% of the note.

Solved problems:

Suppose 15% of the note. Students will have to give the teacher a document with the solved problems together with an oral presentation. The solution of problems, delivery of the corresponding documents and oral presentation in class are obligatory to pass the subject.

Other activities

Group learning strategies in the classroom, exercices and summary of articles. (15%).

Final Exam

Any student can go to the Final exam to increase his/her qualification. that can be done for the 1st part, for the 2nd part or for both. The qualification obtained in the Final Exam is the qualification that will be used to average with the other activities used for evaluation.

Unique assessment: Students who have accepted the single assessment modality will have to take a final test which will consist of a theory exam where they will have to answer a series of short questions. Next, you will have to take a problem test where you will have to solve a series of exercises similar to those worked on in the problem sessions. When you have finished, you will hand in the reports corresponding to problem solutions and the delivery of a work. The student's grade will be the weighted average of the three previous activities, where the theory exam will account for 35% of the grade, the problem exam 35% and the delivery of the problems and assignments will be 30%.

If the final grade does not reach 5, the student has another opportunity to pass the subject through the remedial exam that will be held on the date set by the Degree coordinator. In this test you can recover 70% of the grade corresponding to the theory and the problems. The delivery part of problems and works is not recoverable.

Bibliography

There is no basic reference text, but two relevant books for the subject. The pdf that the teacher gives to the stud

Introduction to quantum mechanics, David J. Griffiths, Cambridge University Press

The physics of low dimensional semiconductors. An introduction. John H. Davies, Cambridge University Press

Software

Windows-based programs for slide presentations to students

Language list

Name	Group	Language	Semester	Turn
(PAUL) Classroom practices	1	Catalan	second semester	afternoon
(SEM) Seminars	1	Catalan	second semester	afternoon

(TE) Theory	1	Catalan	second semester	afternoon