UAB
Universitat Autònoma de Barcelona

Quantum Phenomena II

Code: 106817
ECTS Credits: 6

2025/2026

Degree	Type	Year
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

Learning Outcomes

1. CM16 (Competence) Use knowledge of physics to solve problems on the nanoscale.
2. KM29 (Knowledge) Understand the principles of quantum mechanics and how they can be used to describe the structure and properties of matter on an atomic and molecular scale.
3. SM27 (Skill) Apply the tools used in quantum physics and computational calculus to simple systems.
4. SM28 (Skill) Gather, summarise and present results and conclusions of scientific publications.

Content

1. Introduction

1.1. Time-independent Schrödinger Equation (SE). Wave-particle duality. Wave function. Hamiltonian.
1.2. Linearity.
1.3. Time-dependent SE. Superposition. Current density.
1.4. Operators and observables. Measurement postulate.
1.5. Uncertainty principle.
1.6. Functions and vectors. Dirac notation.
1.7. Linear algebra. SE in matrix notation.

2. Electrons in Potential Wells

2.1. Infinite square potential well. Solution, wave functions, and orthogonality. Time evolution.
2.2. Nanostructures and low-dimensional physical heterostructures (2D, 1D, 0D).
2.3. Effective mass approximation, envelope wave function.
2.4. Finite and symmetric square potential well.
2.5. Double square potential wells with and without interaction.
2.6. Parabolic wells: The harmonic oscillator.
2.7. Triangular wells.
2.8. Spherical potentials. Semiconductor quantum dots.

3. Approximate Methods

3.1. Time-independent perturbation theory. Non-degenerate and degenerate cases.
3.2. Variational method.

4. Periodic Solids (Electrons in Crystals)

4.1. Periodicity conditions. Bloch's theorem.
4.2. Kronig-Penney model. Band formation.
4.3. Tight-binding approximation.
4.4. One-dimensional chain. Band formation.
4.5. Bands in semiconductors.

5. Density of States and Occupation

5.1. Characteristic lengths in mesoscopic systems. Quantum wells, wires, and dots.
5.2. Distribution functions. Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein.
5.3. Dimensionality and energy levels. Sommerfeld model of free electrons. Traveling waves: Born-von Karman boundary conditions.
5.4. Density of states (DOS); Fermi level. DOS in 3D in the Sommerfeld model. Fermi level. DOS in 3D for traveling waves. DOS in 2D and 1D.
5.5. Occupation of energy levels.

6. Electrons in External Fields

6.1. Effect of a magnetic field on an electron gas.
6.2. Vector potential and Aharonov-Bohm experiment.

6.3. Magnetic field in a 2D system: Landau levels and density of states.
6.4. Electric fields.

7. Angular Momentum

7.1. Orbital angular momentum. Operators and associated wave functions.
7.2. The L^2 operator. Spherical harmonics.
7.3. Experimental measurement of angular momentum.
7.4. Spin angular momentum. Pauli matrices. Stern-Gerlach experiment.

8. Hydrogen Atom

8.1. Review of the hydrogen atom. Radial and angular equation.
8.2. Fine structure: relativistic correction and spin-orbit coupling.
8.3. Hyperfine structure.
8.4. Electrons in a magnetic field. Precession.
8.5. Zeeman effect.
8.6. Multielectronic atoms.
8.7. Atoms/ions in the presence of external magnetic fields: Magnetic moment. Zeeman effect.

9. Applications in Nanoscience

9.1. One-dimensional square potential barrier; tunneling effect. One-dimensional square potential step. Delta barriers. Electronic transport.
9.2. Wells with doublepotential barrier; the resonant tunneling diode. Transmission.
9.3. Superlattices: infrared photodetectors.
9.4. Triangular quantum well: MODFET. Modulators.
9.5. Quantum Hall effect in semiconductors and 2D materials.
9.6. Spin-orbit coupling beyond the hydrogen atom.

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
problem solving activities in the classroom	8	0.32	
Problems class	16	0.64	
Theoretical classes	30	1.2	
Type: Supervised			
Oral presentations	6	0.24	
Problem solving	6	0.24	
Type: Autonomous			
Study	68	2.72	

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	CM16, KM29, SM27, SM28
Solved problems	15%	2	0.08	CM16, SM27
Written exams (mid-term and final)	70%	8	0.32	CM16, KM29, SM27

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

Groups and Languages

Please note that this information is provisional until 30 November 2025. You can check it through this link. To consult the language you will need to enter the CODE of the subject.

Name	Group	Language	Semester	Turn
(PAUL) Classroom practices	1	Catalan	first semester	afternoon
(SEM) Seminars	1	Catalan/Spanish	first semester	afternoon
(TE) Theory	1	Catalan/Spanish	first semester	afternoon