

Degree programme	Type	Course
Nanoscience and Nanotechnology	OB	3

Contact lecturer

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Teaching staff

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Group languages

You can consult this information at the [end](#) of the document.

Prerequisites

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

Objectives

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

- CM16 (Use knowledge of physics to solve problems on the nanoscale.) Use knowledge of physics to solve problems on the nanoscale.
- KM29 (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.) 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.
- SM27 (Apply the tools used in quantum physics and computational calculus to simple systems.) Apply the tools used in quantum physics and computational calculus to simple systems.
- SM28 (Gather, summarise and present results and conclusions of scientific publications.) Gather, summarise and present results and conclusions of scientific publications.

Contents

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.

Learning activities and methodology

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

Theory classes

The teacher will explain the content of the program using the blackboard and 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.

Group activities

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

Use of AI

For this subject, the use of Artificial Intelligence (AI) technologies is allowed exclusively in support tasks, The student will have to clearly identify which parts have been generated with this technology, specify the tools used and include a critical reflection on how they have influenced the process and the final result of the activity. The non-transparency of the use of AI in this assessable activity will be considered a lack of academic honesty and may lead to a partial or total penalty in the grade of the activity, or greater sanctions in cases of severity.

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

Continuous assessment activities

Title	Weight	Hours	ECTS	Learning outcomes
Side activities	15%	6	0.24	CM16, KM29, SM27, SM28
Written exams (mid-term and final)	70%	8	0.32	CM16, KM29, SM27
Solved problems	15%	2	0.08	CM16, 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 not participate 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, exercises 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.

Any irregularity committed during an assessment activity (academic fraud, plagiarism, or the improper use of AI-unless such use is expressly authorized in the course syllabus) that could lead to a significant change in the grade will result in that activity being graded as a 0. If the course syllabus stipulates that passing the subject requires a minimum grade in that specific assessment activity, or if multiple irregularities occur across assessment activities for the same subject, the final grade for the subject will be 0. Furthermore, disciplinary proceedings may be initiated against any student who commits such irregularities.

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

Course groups and languages

The information provided is provisional until November 30. After this date, you will be able to consult the language of each group through this [link](#). To access the information, you will need to enter the course CODE

Type of teaching	Group	Language	Semester	Shift
(TE) Theory	1	Catalan/Spanish	first semester	afternoon
(PAUL) Classroom practices	1	Catalan/Spanish	first semester	afternoon
(SEM) Seminars	1	Catalan/Spanish	first semester	afternoon