Universitat Autònoma de Barcelona

2019/2020

Quantum Phenomena II

Code: 103498
ECTS Credits: 6

Degree	Type	Year	Semester
2501922 Nanoscience and Nanotechnology	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

Prerequisites

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

Objectives and Contextualisation

Basic knowledge of quantum mechanics phenomena complementary to subjects learned in Quantum Phenomena I with specific focus on the behaviour of matter and the applications at the nanoscale. The course is organized in six units:
In the first unit, the emphasis is placed on some of the topics covered in Quantum Phenomena I that are developed in more detail. The second unit deals with the electronic atomic states and the magnetic moment of the electrons. In the third unit the Zeeman effect, the nuclear magnetic moment and the magnetic resonance are studied in deepness. The fourth unit offers a brief introduction to the classical and quantum statistics complemented with the study of the density and occupation of electronic states. The fifth unit deals with the study of square potential wells and barriers, with some applications to the nanoscience world. The subject is closed with a sixth unit where the attention is focused on the study of triangular and parabolic potential wells, and a brief introduction to parabolic and hyperbolic potential barriers, with some examples at the nanoscale.
The subject Quantum Phenomena II helps the student to have a solid knowledge of some specific topics of quantum mechanics and how they can be used as essential tools for the understanding of the behaviour of matter at the nanoscale.

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 ones 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-Diracs 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 Schroedingers 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 ones 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. Effect of the crystalline field on molecules and solids. Permanent magnetic properties. Magnetic moment associated with the electronic orbital momentum. Electronic spin: associated magnetic moment. Spin-orbit coupling: associated magnetic moment. Atomic paramagnetism.

- Atoms / ions in an external magnetic field.

Zeeman effect. Selection rules of electronic transitions. Nuclear spin; associated magnetic moment. Hyperfine interaction. Electrical quadrupole interaction. Hyperfine structure in an applied magnetic field. Magnetic resonance. Electronic paramagnetic resonance. Nuclear magnetic resonance.

- 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.

Methodology

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.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			

Problems class	20	0.8	4, 3, 10, 6, 5, 7, 8, 9, 14, 15, 17, 18, 20, 19
Theoretical classes	36	1.44	4, 3, 10, 1, 7, 8, 9, 14, 15, 16, 18, 22
Type: Supervised			
Oral presentations	8	0.32	2, 4, 3, 6, 5, 7, 8, 13, 11, 9, 12, 18, 19, 23
Type: Autonomous			
Study	68	2.72	2, 4, 10, 6, 8, 13, 11, 12, 14, 15, 20, 24, 23

Assessment

Written exams:

The weighting is 90% 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 (45%). If the two partial exams have been approved, it will not be necessary a resist exam. If one or both partial exams have not been approved, the final exam will be required. It is mandatory to approve this part to pass the subject.

If students do not take part in the solving problems groupo, the two written exams will represent 100% of the note.

Solved problems:

Suppose 10% 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.

Recovery test:

To participate in the resist exam, the student must have submitted to the two partial exams of the continuous assessment of the subject.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Solved problems	10%	10	0.4	2, 4, 10, 6, 5, 8, 13, 11, 12, 14, 15, 19, 24, 23
Written exams (mid-term and final)	90%	8	0.32	4, 3, 6, 5, 1, 7, 9, 14, 15, 17, 16, 18, 20, 21, 22

Bibliography

There is no a basic reference book. The teacher delivers to students (in the Campus Virtual) six pdf units with all the students need: lectures and solved problem.