COURSE DATA

DATA SUBJECT

Code: 34260
Name: Quantum physics II
Cycle: Undergraduate Studies
ECTS Credits: 6
Academic year: 2025-26

STUDY (S)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Facultat de Física	3	Second quarter
1928 - Double Degree Program Physics-Mathematics	Facultat de Ciències Matemàtiques	4	Second quarter
1929 - Double Degree Program in Physics and Chemistry	Facultat de Física	3	Second quarter

SUBJECT-MATTER

Degree	Subject-matter	Character
1105 - Degree in Physics	Quantum physics	COMPULSORY
1928 - Double Degree Program Physics-Mathematics	Cuarto Curso (Obligatorio)	COMPULSORY
1929 - Double Degree Program in Physics and Chemistry	Tercer Curso (Obligatorio)	COMPULSORY

COORDINATION

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SUMMARY

Schrödinger equation in three dimensions, orbital angular momentum and the hydrogen atom. Structure of atoms and molecules and their spectroscopy. Introduction to solids, the structure of nuclei and elementary particles. Phenomenological introduction of the spin angular momentum. Introduction to the treatment of identical particles and quantum statistics.

Objectives:

This course aims to familiarize the student with quantum phenomena and their fundamental properties, and introduce basic mathematical techniques to formalize the description of the quantum world in a logically consistent theory, completing and implementing concepts studied in Quantum Physics I.

Relationship with other previous materials:

It is imperative that the student has previously studied the subject of Quantum Physics I, which introduces the formalism and the fundamental ideas of quantum physics. It is also highly recommended that students have previously studied the following subjects in Mathematics: Algebra and Geometry, which provides the necessary background for the algebraic formal description of quantum physics as vector spaces, inner products, matrices, determinants, linear operators and diagonalization; Calculus, where differential and integral calculus are studied, and differential equations are introduced; and Mathematical Methods, which shows how to solve the differential equations that appear in many quantum problems and introduces the Fourier transforms and the method of separation variables.

The course assumes previous knowledge on the following subjects in classical physics: General Physics, which establishes the foundations of the physics to be studied more deeply in this course; Mechanics and Waves, which develops fundamental concepts for Quantum Physics such as the Lagrangian and Hamiltonian formulations, the wave equation and the description of the properties of waves; and Thermodynamics and Statistical Physics, which discuss the foundations of Boltzmann, Maxwell and Gibbs Statistical Physics, whose influence in the genesis of quantum physics was capital.

Of special relevance is the Quantum Physics Laboratory, included in subject Experimental Physics Laboratory. Here the student performs some of the most important experiences that led to the development of quantum ideas.

Relationship with other future subjects:

There are many subjects in the fourth course of the Degree in Physics, and especially the Master in Advanced Physics, which are based on the knowledge acquired in the course of Quantum Physics II. Among the most important, we can quote the subjects of Quantum Mechanics, Advanced Quantum Mechanics, Nuclear Physics and Particles, Solid State Physics, and Quantum Field Theory.

PREVIOUS KNOWLEDGE

RELATIONSHIP TO OTHER SUBJECTS OF THE SAME DEGREE

There are no specified enrollment restrictions with other subjects of the curriculum.

OTHER REQUIREMENTS

- Mathematical knowledge:

1. Vector spaces.
2. Inner products: Euclidean vector spaces.
3. Linear operators: Hermitian and unitary.
4. Matrices and determinants.

5. Diagonalization of matrices and linear operators.
6. Fourier Transforms.
7. Dirac Delta.
8. Solution of linear differential equations with constant coefficients.
9. Solution of differential equations by power series.

COMPETENCES / LEARNING OUTCOMES

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Ability to collect and interpret relevant data in order to make judgements.

Communication Skills (written and oral): Being able to communicate information, ideas, problems and solutions through argumentation and reasoning which are characteristic of the scientific activity, using basic concepts and tools of physics.

Foreign Language skills: Have improved command of English (or other foreign languages of interest) through: use of the basic literature, written and oral communication (scientific and technical English), participation in courses, study abroad via exchange programmes, and recognition of credits at foreign universities or research centres.

Knowledge and understanding of the fundamentals of physics in theoretical and experimental aspects, and the mathematical background needed for its formulation.

Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.

Modelling & Problem solving skills: be able to identify the essentials of a process / situation and to set up a working model of the same; be able to perform the required approximations so as to reduce a problem to an approachable one. Critical thinking to construct physical models.

Physics general culture: Be familiar with the most important areas of physics and with those approaches which span many areas in physics, or connections of physics with other sciences.

Problem solving: be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems .

Students must be able to apply their knowledge to their work or vocation in a professional manner and have acquired the competences required for the preparation and defence of arguments and for problem solving in their field of study.

Students must be able to communicate information, ideas, problems and solutions to both expert and lay audiences.

Students must have acquired knowledge and understanding in a specific field of study, on the basis of general secondary education and at a level that includes mainly knowledge drawn from advanced textbooks, but also some cutting-edge knowledge in their field of study.

Students must have developed the learning skills needed to undertake further study with a high degree of autonomy.

Students must have the ability to gather and interpret relevant data (usually in their field of study) to make judgements that take relevant social, scientific or ethical issues into consideration.

Theoretical understanding of physical phenomena: have a good understanding of the most important physical theories (logical and mathematical structure, experimental support, described physical phenomena).

To know how to apply the knowledge acquired to professional activity, to know how to solve problems and develop and defend arguments, relying on this knowledge.

DESCRIPTION OF CONTENTS

1. Molecule models

1.1. Double delta well potential.
1.2. The H_2^+ molecular ion.
1.3. Molecular localized states.
1.4. The Hamiltonian of a quantum two-level system.
1.5. The ammonia MASER.

2. Periodic potentials

2.1. Translational invariance.
2.2. Kronig-Penney model.
2.3. Spectrum bands.
2.4. Effective mass.
2.5. Periodic boundary conditions.
2.6. Insulators and conductors.

3. Three-dimensional problems and angular momentum

3.1. Schrödinger equation and separation of variables.
3.2. Angular momentum operator.
3.3. Angular momentum in spherical coordinates.
3.4. Eigenvalues and eigenfunctions of L^2 and L_z.
3.5. Spherical harmonics.

4. Central potentials: the hydrogen atom

4.1. The radial equation.
4.2. Two-particle system.
4.3. The hydrogen atom.

4.4. Energy spectrum.
4.5. Probability distributions.
4.6. Spectroscopic notation

5. Stationary perturbations and variational method

5.1. Stationary perturbations: development of Rayleigh-Schrödinger.
5.2. Energies and wave functions perturbed.
5.3. Wavefunction renormalization.
5.4. Treating degenerations.
5.5. The Ritz variational method.
5.6. Application of both methods to the helium atom.

6. Interaction with an electromagnetic field. The spin of the electron

6.1. Magnetic dipole moment: quantization.
6.2. Interaction with a magnetic field.
6.3. Stern-Gerlach experience.
6.4. The electron spin.
6.5. Spin operators and their eigenstates.
6.6. Spin-orbit interaction.
6.7. Total angular momentum sum of angular momenta.
6.8. Fine structure of the hydrogen atom.
6.9. Zeeman Effect.

7. Identical particles

7.1. Indistinguishability of identical particles.
7.2. Exchange degeneration.
7.3. Symmetrization Postulate: Pauli exclusion principle.
7.4. Singlet and triplet spin states.
7.5. Exchange forces: Hund's rule.
7.6. The revised helium atom.
7.7. The degenerate electron gas.
7.8. Ordinary matter "in bulk".
7.9. Gravitational systems and the Chandrasekhar limit.

WORKLOAD

PRESENCIAL ACTIVITIES

Activity	Hours
Tutorials	15,00
Theory	45,00
Total hours	**60,00**

NON PRESENCIAL ACTIVITIES

Activity	Hours
Attendance at other activities	0,00
Individual or group project	0,00
Independent study and work	0,00
Preparation of lessons	90,00
Preparation for assessment activities	0,00
Resolution of case studies	0,00
Total hours	**90,00**

TEACHING METHODOLOGY

Contact teaching 40%

Theoretical and practical classes: It addresses the conceptual and formal matter and resolution of problems or cases as the application of theoretical concepts. They are based mainly on lectures with dialogue and the use of teaching tools such as experimental demonstrations, animations or videos, graphic solutions, design presentations, etc.)..

Group tutoring sessions or work in small groups: focus on student work: Resolving doubts in dealing with theoretical concepts and problem solving, reinforcement in areas of greatest difficulty, questionnaires conceptual, experimental demonstrations relevant to the cases studied and associated with a component of continuous assessment, verification of student progress in the field.

Student's personal work 60%

- Study of the theoretical foundations.

- Troubleshooting (individually or in groups)

- Individual tutorials: querying of the teacher on student concerns and difficulties encountered in the study and resolution of problems, or discussion on topics of interest, bibliography, etc.

EVALUATION

The assessment system is as follows:

1) Written examinations: One part will assess the understanding of the theoretical-conceptual and formal nature of the subject, both through theoretical questions, conceptual questions and numerical or simple particular cases. Another part will assess the applicability of the formalism, by solving problems and critical capacity regarding the results. Proper argumentations and adequate justifications will be important in both cases.

2) Continuous assessment: assessment of exercises and problems presented by students, questions proposed and discussed in class, oral presentation of problems solved or any other method that involves an interaction with students.

COMMENTS:

The final grade will be: 1) the weighted average of the exam grade (75%) and the continuum assessment (25%) if the average is higher than the exam mark and if the exam grade is greater than 4 (over 10) 2) the exam grade otherwise.

Evaluation criteria are the same in both the first and the second call.

Subject to compliance with the compensation criteria established for this purpose, note this course can be averaged with other others belonging to the same matter, so as to pass the course.

REFERENCES

Basic

- D. J. Griffiths, *Introduction to Quantum Mechanics*, 2nd edition, Pearson- Prentice-Hall, 2004.

- S. Gasiorowicz, *Quantum Physics*, 3rd edition, John Wiley & Sons, 2002.

- R. Eisberg, R. Resnick, *Física Cuántica*, Limusa, 2002.

Additional

- Jean-Marc Lévy-Leblond y F. Balibar, *Quantics: Rudiments of Quantum Physics*, North-Holland, 1990.

- R. P. Feynman, *The Feynman Lectures on Physics III*, Addison-Wesley, 1964, 2005.

- P. A. Tipler, R. A. Llewellyn, *Modern Physics*, 5th edition, W. H. Freeman, 2007.

- R. Shankar, *Principles of Quantum Mechanics,* 2nd edition, Springer, 1994.

- W. Greiner, *Quantum Mechanics, An Introduction*, Springer-Verlag, 1997.