COURSE DATA

Data Subject	
Code	34260
Name	Quantum physics II
Cycle	Grade
ECTS Credits	6.0
Academic year	2021 - 2022

Study (s)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Faculty of Physics	3	Second term

Subject-matter

Degree	Subject-matter	Character
1105 - Degree in Physics	13 - Quantum physics	Obligatory

Coordination

Name	Department
BOTELLA OLCINA, FRANCISCO JOSE	185 - Theoretical Physics
SANTAMARIA LUNA, ARCADI	185 - Theoretical Physics

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 the third-course 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 en Physics, and especially the Master, 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.

OUTCOMES

1105 - Degree in Physics

- Knowledge and understanding of the fundamentals of physics in theoretical and experimental aspects, and the mathematical background needed for its formulation.
- 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.
- Ability to collect and interpret relevant data in order to make judgements.
- 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 .
- Theoretical understanding of physical phenomena: have a good understanding of the most important physical theories (logical and mathematical structure, experimental support, described physical phenomena).
- 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.
- 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.
- Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.
- 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.
- 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 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 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.
- Students must be able to communicate information, ideas, problems and solutions to both expert and lay audiences.

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

LEARNING OUTCOMES

-Knowing and understanding the limits of classical physics and the experimental foundations of quantum physics.

-Understanding the fundamental concepts in the description of quantum phenomena: the quantization of energy, wave-particle duality, quantization rules, the measurement of quantum observables and uncertainty relations.

-Understanding the concept of wave function and its probabilistic interpretation.

-Knowing how to calculate the possible values of the measurement of a quantum observable and the relative probabilities of different outcomes and their average value.

-Being able to describe quantum systems by using the correct Schrödinger equation.

-Being able to solve the Schrödinger equation for one-dimensional problems. Specifically, knowing how to calculate the transmission and reflection coefficients in problems of dispersion, and the wave function and energy levels of bound states problems.

-Being able to determine the temporal evolution of a system from its stationary solutions.

-Use of the symmetries (parity, timing, rotations) of the problem at hand to simplify the solution and understand more deeply the results.

-Knowing how to use the method of separation of variables in two-and three-dimensional problems.

-Knowing the fundamental properties of the quantum angular momentum operator: relations, eigenvalues and eigenfunctions, possible results of measurements and calculation of the relative probabilities of the results.

-Solve three-dimensional problems of two bodies with central potentials by separation of variables (hydrogen atom and harmonic oscillator).

-Use of typical atomic scale (eV, Angstroms, ... etc) units.

-Knowing and understanding the experiments leading to the introduction of spin.

-Knowing how to calculate the eigenvalues and eigenvectors of the spin operator in an arbitrary direction, and the relative probabilities of the results of experiments with two Stern-Gerlach.

-Understanding the concept of indistinguishability and its implication on the behavior of identical quantum particles.

-Knowing how to use the symmetrization postulate and the Pauli exclusion principle, especially in atomic systems.

DESCRIPTION OF CONTENTS

1. Molecule models

1.1. Double delta well potential.
1.2. The H2+ 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

ACTIVITY	Hours	% To be attended
Theory classes	45,00	100
Tutorials	15,00	100
Preparing lectures	31,00	0
Preparation of practical classes and problem	59,00	0
TOTAL	**150,00**	

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.

- 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.

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, Ed. Pearson Education Limited.
- S. Gasiorowicz, Quantum Physics, Ed. John Wiley & Sons Inc.
- R. Eisberg y R. Resnick, Física Cuántica (átomos, moléculas, sólidos, núcleos y partículas), Ed. Limusa.

Additional

- Jean-Marc Lévy-Leblond y F. Balibar, Quantics: Rudiments of Quantum Physics, Ed. North-Holland.
- P. A. Tipler, Física Moderna, Ed. Reverté S.A.
- R. P. Feynman, The Feynman Lectures on Physics III, Ed. Addison-Wesley.
- R. Shankar, Principles of Quantum Mechanics, Springer-Verlag.
- W. Greiner, Quantum Mechanics, An Introduction, Springer-Verlag.

ADDENDUM COVID-19

This addendum will only be activated if the health situation requires so and with the prior agreement of the Governing Council

TEACHING METHODOLOGY:

In case that health situation requires blended teaching, the teaching model approved by the Academic Degree Committee on July 23, 2020 will be adopted. For lectures this model consist of 50% student attendance in the classroom, while the rest of students attend the class in streaming broadcast. Two groups will be set with alternate days attendance to the classroom in order to guarantee 50% of teaching hours attendance for all students. The rest of the teaching activities (laboratories and tutorials) will have a 100% attendance.

If a total reduction in attendance is necessary, classes will be broadcast by synchronous videoconference at their regular schedule, along the period determined by the Health Authority.