COURSE DATA

Data Subject	
Code	34259
Name	Quantum physics I
Cycle	Grade
ECTS Credits	6.0
Academic year	2022 - 2023

Study (s)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Faculty of Physics	3	First term
1929 - D.D. in Physics-Chemistry	Double Degree Program Physics and Chemistry	3	First term

Subject-matter

Degree	Subject-matter	Character
1105 - Degree in Physics	13 - Quantum physics	Obligatory
1929 - D.D. in Physics-Chemistry	3 - Tercer Curso (Obligatorio)	Obligatory

Coordination

Name	Department
SANZ GONZALEZ, VERONICA	185 - Theoretical Physics
TORTOLA BAIXAULI, M. AMPARO	185 - Theoretical Physics

SUMMARY

The origins of quantum physics, elementary quantum physics, Schrödinger equation in one dimension, quantum observables: operators and measurement, dimensional potential field effect and penetration in areas traditionally prohibited bound states: the finite and infinite square well, the harmonic oscillator.

The objective of this course is to acquaint students with the fundamental quantum phenomena and their properties and introduce the basic mathematical tools to formalize the description of them in a logically consistent theory.

It is highly recommended that students have previously studied the subjects of Mathematics, Algebra and Geometry, which provides the necessary algebraic background for the formal description of Quantum Physics as vector spaces, inner, matrices, determinants products, linear operators and diagonalization; Calculation, in which integral and differential calculus is studied, and the differential equations are introduced; Mathematical Methods, which deepens in solving differential equations that appear in many problems and quantum Fourier transforms and the method of separation of variables are introduced; General Physics, where the fundamentals of physics to be studied more deeply in this course are established; Mechanics and Waves, in which fundamental quantum physics as the Lagrangian and Hamiltonian formulation, the wave motion and the description of the properties of waves, and thermodynamics and statistical physics, where the foundations of Statistical Physics are discussed concepts are developed Boltzmann, Maxwell and Gibbs, whose influence in the genesis of quantum physics was capital.

Special mention should be the subject of Quantum Physics Laboratory, framed in the matter of the third year, Laboratory of Experimental Physics. In it, the student performs some of the most important experiences that led to the development of quantum ideas. During the first three weeks of the Quantum Physics I course, the origins, experimental bases and fundamental concepts of the so-called Ancient Quantum Physics, prior to Schrödinger's formulation, are studied and the experiences of the Quantum Physics Laboratory are described in detail. It is therefore imperative to pursue this matter in parallel with Quantum Physics I.

The Quantum Physics II course builds on the knowledge gained in the course of Quantum Physics I. They should, therefore, be addressed in that order. Also, many are the subjects of fourth year and Master which are based on the concepts taught in the course of Quantum Physics. Among the most important subjects we find Quantum Mechanics, Nuclear and Particle Physics, Solid State Physics, Quantum Field Theory and Elementary Particles.

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

-Know and understand the limits of classical physics and experimental foundations of quantum physics.

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

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

-To acquire the concept of wave function and its probabilistic interpretation.

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

-Be able to describe quantum systems using the correct approach to the corresponding Schrödinger equation.

-Be 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.

-To determine the temporal evolution of a system from its stationary solutions.

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

DESCRIPTION OF CONTENTS

1. Introduction

Domain of Quantum Physics. Limits of applicability of classical physics: Planck's constant. The fundamental constants of nature. Natural units.

2. Energy quanta: Planck's postulate

Black body radiation. Planck Postulate: energy quanta. Specific heat of solids: Einstein and Debye models.

3. Wave-particle duality: photons

The photoelectric effect. Compton X-ray emission effect. Production and pair annihilation. Wave-particle duality: Uncertainty Principle.

4. Atomic models: the old quantum theory

Atomic spectra. The Rutherford atom. Bohr's atomic model. Correspondence Principle. Franck-Hertz experience. Rules of generalized quantization.

5. Wave-particle duality for matter

Wave-particle duality of matter: De Broglie's Postulate. Davisson-Germer experiment. Wave packets.

6. Quantum Mechanics

Introduction. The quantum mechanics of Heisenberg and Schrödinger. Schrödinger equation. Born interpretation of the wave function. Continuity equation: conservation of probability. Stationary states. Superposition of stationary states.

7. Probability distributions

Mean value. Dynamical quantities in Quantum Physics. The classical limit: Ehrenfest theorem. Observables and generalized probabilities.

8. Expected values and uncertainties

Introduction. Quantum uncertainty. Generalized uncertainty relations. Energy-time uncertainty.
Natural width of energy levels.

9. One-dimensional problems

Classical motion in one dimension. Properties of the eigenfunctions of the Hamiltonian. Solutions for a constant potential. Potential step. Temporal evolution.

10. Scattering by barriers and wells

Barrier penetration: Tunneling. Emission of alpha particles by nuclei. Thermonuclear fusion. Electron current in metals: Fowler-Nordheim formula. The scanning tunneling microscope. Transmission barriers. Drive shafts: Ramsauer-Townsend effect.

11. Bound states

Dirac's delta potential. Square well: discrete energies (bound states). Infinite square well. Parity. Poles of the transmission amplitude. Transmission resonances.

12. The harmonic oscillator

Stationary states. Hermite polynomials and allowed values of energy. Matrix mechanics: creation-destruction operators. Classical and quantum probability. Virial Theorem. Vibrational energy of diatomic molecules. Wave functions in matrix mechanics.

WORKLOAD

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

TEACHING METHODOLOGY

Face-to-face teaching 40%:

Theoretical-practical classes: the conceptual and formal aspects of the subject and the resolution of problems or cases as an application of theoretical concepts are addressed. They will combine the dialogued lectures with methodology of flipped classroom and the use of teaching tools such as experimental demonstrations, animations or videos, graphic representation of solutions, projection of presentations, etc.

Group tutoring sessions or work in small groups focused on the student's work: resolution of doubts arising when facing theoretical concepts and problem solving, reinforcement of areas of greatest difficulty, conceptual questionnaires, experimental demonstrations relevant to the cases studied and associated with a continuous assessment component, verification of the students' progress in the subject.

Student's personal work 60%:

- Study of the theoretical foundations.

- Problem solving (individually or in groups).

- Individual tutorials: specific consultations from the student to the teacher about doubts 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. To pass the subject it will be necessary to obtain at least 3 out of 10 in each of the two parts of the exam.

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.

The final grade of the course will be:

1) the weighted average of the exam mark (75%) and the continuous assessment (25%), if the average is higher than the exam mark and the exam mark is greater than 4 (out of 10),

2) the exam mark otherwise.

COMMENTS: Provided that the compensation criteria established by the CAT for this purpose are met, the grade of this subject may be averaged with Quantum Physics II in order to overcome it.

REFERENCES

Basic

- D. J. Griffiths, Introduction to Quantum Mechanics, Ed. Pearson- Prentice-Hall.
- S. Gasiorowicz, Quantum Physics, Ed. John Wiley & Sons Inc.
- R. Eisberg, R. Resnick, Física Cuántica, Ed. Limusa.
- C. Sánchez del Río (Coord.), Física Cuántica, Ediciones Pirámide.
- N. Zettili, Quantum Mechanics: Concepts and Applications, John Wiley & Sons.
- P. A. Tipler, R. A. Llewellyn, Modern Physics, Ed. W. H. Freeman.

Additional

- R. Shankar, Principles of Quantum Mechanics, Springer
- R. P. Feynman, The Feynman Lectures on Physics III, Ed. Addison-Wesley.