Approval date: 13/06/2024

COURSE GUIDE

Quantum Physics (2671132)

Grado (Bachelor's Degree)	Grado en Física	Branch	Sciences
Module	Fundamentos Cuánticos	Subject	Física Cuántica

Year of study	3º	Semester	1 y 2º	ECTS Credits	12	Course type	Compulsory course

PREREQUISITES AND RECOMMENDATIONS

It is recommended to have passed the following courses: Physics, Mathematical Methods, Linear Algebra and Geometry, Mathematics and Mechanics and Waves and desirable to have passed also the course Numerical Methods and Simulation.

BRIEF DESCRIPTION OF COURSE CONTENT (According to the programme's verification report)

- Origins of Quantum Physics. The wave function and the Copenhagen interpretation.
- The Schrödinger equation and the time-independent Schrödinger equation.
- One-dimensional problems.
- Angular momentum. Three-dimensional problems with central potentials.
- Approximate methods for stationary states.
- Experimental techniques in Quantum Physics.

SKILLS

GENERAL SKILLS

- CG01 - Skills for analysis and synthesis
- CG02 - Organisational and planification skills
- CG03 - Oral and written communication
- CG05 - Skills for dealing with information
- CG06 - Problem solving skills
- CG07 - Team work
- CG08 - Critical thinking
- CG09 - Autonomous learning skills
- CG13 - Knowlegde of a foreign language

SUBJECT-SPECIFIC SKILLS

- CE01 - Knowing and understanding the phenomena of the most important physical theories
- CE02 - Estimating the order of magnitud in order to interpret various phenomena
- CE04 - Medir, interpretar y diseñar experiencias en el laboratorio o en el entorno
- CE05 - Modelling complex phenomena, translating a physical problem into mathematical language
- CE07 - Transmitting knowledge clearly, both in academic as in non-academic contexts
- CE09 - Applying mathematical knowlegde in the general context of Physics

LEARNING OUTCOMES

The student will know and understand:

- The quantum theoretical basis of modern physics.
- The structure of quantum theory, its experimental support and its phenomenology.
- The scales and orders of magnitude of physical phenomena.

The student will be able to:

- Solve the given problems, applying the required mathematical and numerical methods.
- Learn the basics of a physical process or phenomenon and establish a model to solve it, developing the pertinent approximations in order to reduce the original problem to a treatable level.
- Initiate in new fields independently.
- Acquire a knowledge of the discipline that allows them to model and understand the essential characteristics of the dynamics of microscopic systems.
- Develop a critical thinking that allows them to build and test physical models, by incorporating new experimental data to the available models, verifying their validity and suggesting changes in order to improve the agreement between the models and the data.

PLANNED LEARNING ACTIVITIES

THEORY SYLLABUS

I. BASIC PHENOMENOLOGY: Old Quantum Physics

1. Radiation and Matter: situation in Physics at the end of the 19th century. Black body radiation: classical theory and Planck's postulate.
2. Particle nature of radiation: Photoelectric effect. Cathode rays. X-rays. Compton diffusion.
3. Old atomic models: The Rutherford model. The Bohr model. The Franck-Hertz experiment. The Bohr-Sommerfeld model: quantization rules. The Zeeman effect.
4. Wave nature of matter: matter waves: The de Broglie postulate. Experimental confirmation: The Davisson-Germer experiment.
5. Wave-particle duality.

II. THE WAVE FUNCTION AND THE SCHRÖDINGER EQUATION.

1. The wave function, its equation and its probabilistic interpretation. Wave packets. Uncertainty Principle.
2. The Schrödinger's equation and probability conservation. Position and momentum representation. Expected values. Ehrenfest's theorem.
3. The eigenvalue equation of energy or time-independent Schrödinger equation.

Quantization of energy. Time evolution of the states.

III. ONE-DIMENSIONAL CASES.

1. Diffusion processes: Step potential. Potential barrier. Reflection and transmission coefficients. Tunnel effect.
2. Bound states: Square well potentials. Harmonic oscillator.
3. Potentials with deltas. Periodic potentials.

IV. ANGULAR MOMENTUM.

1. Orbital angular momentum and spatial rotations.
2. General theory of angular momentum. Matrix representation of angular momentum operators. Eigenvalues and eigenvectors. Spherical harmonics.
3. The electron spin. The Stern-Gerlach experiment.
4. Composition of angular momentum. Clebsch-Gordan coefficients. Total angular momentum.

V. THREE-DIMENSIONAL PROBLEMS.

1. Separable variable potentials in Cartesian coordinates: free particle, three-dimensional square wells. The isotropic harmonic oscillator.
2. Two-particle systems with central force. Coordinate separation. Radial equation and degeneracy. The free particle. Square wells. The isotropic harmonic oscillator.
3. The hydrogen-like atom. Energy Spectrum. Spectroscopic notation. Spin-orbit interaction.
4. Perturbation theory. Applications. Variational method. The Helium atom.

PRACTICAL SYLLABUS

Exercise sessions:

- Detailed resolution of a selection of problems associated with each of the topics.

Laboratory sessions:
Practice 0. Introduction to the Quantum Physics laboratory.
Practice 1. The charge-to-mass ratio of the electron.
Practice 2. The photoelectric effect.
Practice 3. Electron diffraction.
Practice 4. Atomic spectra.
Practice 5. The Franck-Hertz experiment.

RECOMMENDED READING

ESSENTIAL READING

-Theory:

- B.H. Bransden and C.J. Joachain, "Quantum Mechanics"; 2nd ed., Pearson; Dorchester, 2000.
- C. Cohen-Tannoudji, B. Diu and F. Lalöe, "Quantum Mechanics"; 3 vols, Wiley-VCH, 2020.
- A. Galindo y P. Pascual, "Mecánica Cuántica"; Eudema; Madrid, 1989 (advanced text book).

- N. Zettili, "Quantum Mechanics: Concepts and Applications". 2º ed. Wiley 2009.
- R. Eisberg y R. Resnick, "Física Cuántica"; Limusa, 1979.
- L. D. Landau y E. M. Lifshitz, "Curso de Física Teórica. Vol. 3. Mecánica Cuántica (Teoría no-relativista)"; Reverté; Barcelona, 1978.
- A. Messiah, "Mecánica Cuántica"; Tecnos; Madrid, 1973 (advanced text book).
- P. Pereyra Padilla, "Fundamentos de Física Cuántica"; Reverté; 2011.
- R. W. Robinett, "Quantum Mechanics: Classical Results, Modern Systems, and Visualized Examples"; 2nd ed., Oxford Univ. Press; 2006.
- C. Sánchez del Río (coordinator), "Física Cuántica"; Eudema; Madrid, 1991.

-Problems:

- A.Z. Capri, "Problems & Solutions in Nonrelativistic Quantum Mechanics"; World Scientific; 2002.
- F. Constantinescu & E. Magyari, "Problems in Quantum Mechanics"; Pergamon Press; 1971.
- A. Galindo y P. Pascual, "Problemas de Mecánica Cuántica"; Eudema; Madrid, 1989.
- Y.K. Lim, "Problems and Solutions in Quantum Mechanics"; World Scientific.
- Y. Peleg, R. Pnini and E. Zaarur, "Schaum´s Outline of Theory and Problems of Quantum Mechanics"; McGraw-Hill; 1998.

COMPLEMENTARY READING

- D. Bohm, "Quantum Theory"; Dover; New York, 1989.
- S. Brandt y H. D. Dahmen, H.D., "The picture book of quantum mechanics"; Wiley; 1985.
- A.Z. Capri, "Nonrelativistic Quantum Mechanics"; 3º ed., World Scientific; 2002.
- P. A. M. Dirac, "The Principles of Quantum Mechanics"; Oxford Univ. Press; Oxford, 1958.
- R. Fernández Álvarez-Estrada y J. L Sánchez-Gómez, "100 problemas de Física Cuántica"; Alianza Editorial; Madrid, 1996.
- R.P. Feynman, R.B. Leighton and M. Sands, "The Feynman Lectures on Physics. Vol. III. Mecánica Cuántica" (edic. bilingüe inglés-español); Fondo Educativo Interamericano; 1971.
- S. Flügge, "Practical Quantum Mechanics"; 2nd ed., Springer; 1998.
- S. Gasiorowicz, "Quantum Physics"; 3º ed., Wiley; 2003.
- D.J. Griffiths, "Introduction to Quantum Mechanics"; 2nd ed., Pearson Prentice Hall; 2004.
- C. S. Johnson y L. G. Pedersen, "Problems and solutions in Quantum Chemistry and Physics"; Dover; New York, 1986.
- F. Mandl, "Quantum Mechanics"; Wiley; 2013.
- J. Sánchez Guillén y M. A. Braun, "Física cuántica"; Alianza Univ.; 1993.
- L. I. Schiff, "Quantum Mechanics"; 3º ed., McGraw; 1968.
- G. L. Squires, "Problems in Quantum Mechanics with solutions"; Bangalore Univ. Press; 1997.
- B. Thaller, "Visual Quantum Mechanics"; Springer; 2000
- A. I. M. Rae, "Quantum Mechanics"; 5th. ed., Taylor & Francis; 2007.
- Ta-You Wu, "Quantum Mechanics"; World Scientific; 1986.
- F. J. Yndurain Muñoz, "Mecánica Cuántica"; 2º ed., Ariel; 2003.

RECOMMENDED LEARNING RESOURCES/TOOLS

- MIT courses: http://ocw.mit.edu/courses/physics/
- Royal Spanish Physical Society: http://www.rsef.org/
- Quantum Physics Web: http://www.fisicacuantica.es
- NIST database: http://www.nist.gov/pml/data/index.cfm

- Physics degree at UGR, Physics Academic Commission: http://grados.ugr.es/fisica/

TEACHING METHODS

- MD01 - Theoretical classes

ASSESSMENT METHODS (Instruments, criteria and percentages)

ORDINARY EXAMINATION DIET

- The score of the exams corresponding to the contents of the first and second four-month periods will have a weight in the total grade of 50% and 40%, respectively. The remaining 10% of the total grade corresponds to the realization and evaluation of the laboratory practices.
- At the end of the first four-month period there will be a partial exam corresponding to the contents of that period. Students who do not pass this exam (and those who want to improve their grade) will also have the option of taking it in the corresponding final ordinary exam.
- The ordinary assessment session will consist of two exams: one for the evaluation of the each four-month period.
- In order to pass the whole course, it is necessary to have a uniform and balanced knowledge of the whole subject. In particular, it will be required to perform and pass the laboratory practices. Additionally, a minimum of 4 out of 10 must be obtained in the evaluation of the contents of each of the four-month periods.

EXTRAORDINARY EXAMINATION DIET

- The evaluation in the extraordinary assessment session will be carried out by means of three tests: one in which the contents of the first four-month period will be evaluated with a weight of 50% in the final grade, one devoted to evaluate the contents of the second four-month period, with a weight of 40%, and one to evaluate the laboratory practices, with a weight of 10%. However, those students who have passed the part of the exam associated with the laboratory practices will not have the obligation to repeat this part, maintaining in that case the grade previously obtained.

SINGLE FINAL ASSESSMENT (evaluación única final)

- The single final evaluation will be carried out by means of three tests: one in which the contents of the first four-month period will be evaluated with a weight of 50% in the final grade, one devoted to evaluate the contents of the second four-month period, with a weight of 40%, and the last one to evaluate the laboratory practices with a weight of 10%.

ADDITIONAL INFORMATION

Información de interés para estudiantado con discapacidad y/o Necesidades Específicas de Apoyo Educativo (NEAE): Gestión de servicios y apoyos (https://ve.ugr.es/servicios/atencion-social/estudiantes-con-discapacidad).