Mathematical foundations of quantum mechanics

Academic Year: (2023 / 2024) **Review date: 12/02/2024 13:25:58**

Department assigned to the subject: Mathematics Department

Coordinating teacher: IBORT LATRE, LUIS ALBERTO

Type: Electives ECTS Credits : 6.0

Year : 5 Semester : 2

LEARNING OUTCOMES

CB1. Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study.
CB2. Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.
CB3. Students have the ability to gather and interpret relevant data (usually within their field of study) in order to make judgements which include reflection on relevant social, scientific or ethical issues.
CB4. Students should be able to communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.
CB5. Students will have developed the learning skills necessary to undertake further study with a high degree of autonomy.
CG2. Learn new methods and technologies from basic scientific and technical knowledge, and being able to adapt to new situations.
CG3. Solve problems with initiative, decision making, creativity, and communicate and transmit knowledge, skills and abilities, understanding the ethical, social and professional responsibility of the engineering activity. Capacity for leadership, innovation and entrepreneurial spirit.
CG4. Solve mathematical, physical, chemical, biological and technological problems that may arise within the framework of the applications of quantum technologies, nanotechnology, biology, micro- and nano-electronics and photonics in various fields of engineering.
CG5. Use the theoretical and practical knowledge acquired in the definition, approach and resolution of problems in the framework of the exercise of their profession.
CG6. Develop new products and services based on the use and exploitation of new technologies related to physical engineering.
CG7. Undertake further specialized studies, both in physics and in the various branches of engineering.
CE17. Understand and handle the fundamental concepts of Quantum Physics, its relationship with Classical Physics, and its application to the understanding of the physics of atoms and molecules, as well as solving simple one- and three-dimensional quantum problems and applying approximate resolution methods.
CE20. Understand and address the general problems of the field of Energy, as well as the scientific and technological foundations of its generation, conversion, transport and storage.
CT1. Work in multidisciplinary and international teams as well as organize and plan work making the right decisions based on available information, gathering and interpreting relevant data to make judgments and critical thinking within the area of study.

RA1. To have acquired sufficient knowledge and proved a sufficiently deep comprehension of the basic principles, both theoretical and practical, and methodology of the more important fields in science and technology as to be able to work successfully in them.
RA2. To be able, using arguments, strategies and procedures developed by themselves, to apply their knowledge and abilities to the successful solution of complex technological problems that require creating and innovative thinking.
RA3. To be able to search for, collect and interpret relevant information and data to back up their conclusions including, whenever needed, the consideration of any social, scientific and ethical aspects relevant in their field of study.

RA4. To be able to successfully manage themselves in the complex situations that might arise in their academic or professional fields of study and that might require the development of novel approaches or solutions.
RA6. To be aware of their own shortcomings and formative needs in their field of specialty, and to be able to plan and organize their own training with a high degree of independence.

OBJECTIVES

Acquire a deeper understanding of the foundations of Quantum Mechanics and its axiomatic formulation.

Understand the structure of Hilbert spaces and the basic properties of linear operators.

Understand the meaning and implications of the spectral theorem for self-adjoint operators.

Learn the basic ideas behind Feynman's formulation of Quantum Mechanics.

Learn the basic ideas leading to a tomographic description of Quantum Mechanics.

DESCRIPTION OF CONTENTS: PROGRAMME

On the many pictures of Quantum Mechanics: Schrödinger, Heisenberg and Dirac. An introduction to the theory of Hilbert spaces.

Von Neumann's picture of Quantum Mechanics. The theory of operators, observables and the spectral theorem.

Perturbation theory: stationary and time-dependent perturbation theory, adiabatic theorem, semiclassical approximation, scattering theory.

Weyl's picture of Quantum Mechanics. Weyl's quantization. Coherent states and quantum optics: Wigner's transform and quantum tomography.

Feynman's picture of Quantum Mechanics. The double slit experiment. Feynman's path integral and Dirac's Lagrangian description of Quantum Mechanics.

From particles to fields.

The measurement problem in Quantum Mechanics. Measurement and reversibility. Quantum cloning. Quantum Zeno effect. The nature of quantum states.

EPR. Bell inequalities. Quantum non-locality

LEARNING ACTIVITIES AND METHODOLOGY

AF1. THEORETICAL-PRACTICAL CLASSES. Knowledge and concepts students mustacquire. Receive course notes and will have basic reference texts.Students partake in exercises to resolve practical problems
AF2. TUTORING SESSIONS. Individualized attendance (individual tutoring) or in-group (group tutoring) for students with a teacher.Subjects with 6 credits have 4 hours of tutoring/ 100% on- site attendance.
AF3. STUDENT INDIVIDUAL WORK OR GROUP WORK.Subjects with 6 credits have 98 hours/0% on-site.
AF8. WORKSHOPS AND LABORATORY SESSIONS. Subjects with 3 credits have 4 hours with 100% on-site instruction. Subjects with 6 credits have 8 hours/100% on-site instruction.
AF9. FINAL EXAM. Global assessment of knowledge, skills and capacities acquired throughout the course. It entails 4 hours/100% on-site
AF8. WORKSHOPS AND LABORATORY SESSIONS. Subjects with 3 credits have 4 hours with 100% on-site instruction. Subjects with 6 credits have 8 hours/100% on-site instruction.
MD1. THEORY CLASS. Classroom presentations by the teacher with IT and audiovisual support in which the subject`s main concepts are developed, while providing material and bibliography to complement student learning
MD2. PRACTICAL CLASS. Resolution of practical cases and problem, posed by the teacher, and carried out individually or in a group
MD3. TUTORING SESSIONS. Individualized attendance (individual tutoring sessions) or in-group (group

tutoring sessions) for students with teacher as tutor. Subjects with 6 credits have 4 hours of tutoring/100% on-site.
MD6. LABORATORY PRACTICAL SESSIONS. Applied/experimental learning/teaching in workshops and laboratories under the tutor's supervision.

ASSESSMENT SYSTEM

% end-of-term-examination/test:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

SE1. FINAL EXAM. Global assessment of knowledge, skills and capacities acquired throughout the course.The percentage of the evaluation varies for each subject between 60% and 0%.
SE2. CONTINUOUS EVALUATION. Assesses papers, projects, class presentations, debates, exercises, internships and workshops throughout the course.The percentage of the evaluation varies for each subject between 40% and 100% of the final grade.

BASIC BIBLIOGRAPHY

- A. Galindo, P. Pascual Quantum Mechanics I, Springer Verlag, 1990

- G. Auletta, M. Fortunato, G. Parisi Quantum Mechanics, Cambridge Univ. Press, 2009

- G. Esposito, G. Marmo, G. Sudarshan From Classical to Quantum Mechanics, Cambridge Univ. Press, 2004

- J. Cariñena, A. Ibort, G. Marmo, G. Morandi Geometry from dynamics: classical and quantum, Springer-Verlag, 2014

- R. Feynman, A. Hibbs Quantum Mechanics and Path Integrals, Mac-Gray Hill Publish. Co., 1965