Course guide
230800 - FQ - Quantum Physics

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Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: **Academic year:** 2022 **ECTS Credits:** 6.0
Languages: Spanish

LECTURER

Coordinating lecturer:

Others:

PRIOR SKILLS

Basic Physics, Mathematics and Electromagnetism, at first degree level.

REQUIREMENTS

Nothing

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Generical:
08 CRPE N1. ABILITY TO IDENTIFY, FORMULATE AND SOLVE ENGINEERING PROBLEMS Level 1.To identify the complexity of the problems presented in the subjects. To set out correctly the problem correctly from the statements suggested. To identify the possible options for its resolution. To choose an option, apply it and to identify the need to change it in case of fail. To provide tools and methods to test whether the solution is correct or at least consistent. To identify the role of creativity in science and technology
08 CRPE. ABILITY TO IDENTIFY, FORMULATE AND SOLVE ENGINEERING PROBLEMS. To plan and solve engineering problems in the ICT with initiative, making decisions and with creativity. To develop a method of analysis and problem solving in a systematic and creative way.
12 CPE N3. They will be able to identify, formulate and solve engineering problems in the ICC field and will know how to develop a method for analysing and solving problems that is systematic, critical and creative.

Transversal:
07 AAT N3. SELF-DIRECTED LEARNING - Level 3. Applying the knowledge gained in completing a task according to its relevance and importance. Deciding how to carry out a task, the amount of time to be devoted to it and the most suitable information sources.
05 TEQ N3. TEAMWORK - Level 3. Managing and making work groups effective. Resolving possible conflicts, valuing working with others, assessing the effectiveness of a team and presenting the final results.

TEACHING METHODOLOGY

Classroom version: (i) Face-to-face classes of theory supported by digital documents that facilitate the study of the subject. (ii) Face-to-face classes of problems where the studied theory is exercised. (iii) Applications of quantum physics on a daily basis. Different gadgets that make use of quantum phenomena will be presented in the classroom.
Online version: (i) Theory classes through videoconferences. (ii) Classes of problems through videoconferences where theory is practiced.
In both cases, online simulators of quantum phenomena will be used to facilitate the study of the subject to be taught.

LEARNING OBJECTIVES OF THE SUBJECT

Achieve the essential concepts of Quantum Physics, mainly those in which the operating principles of electronic devices based on quantum phenomena are established. Study the functional properties of materials from the characterization of their electronic, magnetic and optical properties. Spectroscopies.
Acquire the mathematical knowledge necessary for the study of quantum physics. During the course, we will work with wave functions, the Schrödinger equation, and perturbation theory.
Understand the fundamental principles of quantum physics: quantization, indeterminacy, superposition, tunnel effect, wave-particle duality, quantum entanglement, and energy bands in solids.
Study current and future applications based on quantum phenomena such as systems used in quantum computing, photonics, etc.
Some basic contents of the course are the why, when, and how of Quantum Theory. Understand the world on a microscopic and nanoscopic scale. Experimental techniques for characterizing materials. Spectroscopies.

STUDY LOAD

Type	Hours	Percentage
Hours large group	52,0	34.67
Self study	98,0	65.33

Total learning time: 150 h

CONTENTS

1. The origins of Quantum Theory. The photoelectric effect, Compton scattering, the diffraction of electrons.

Description:
1. Origin of Quantum Theory. Ultraviolet catastrophe and energy quantization, photoelectric effect, Compton effect, and electron diffraction. Fundamental principles of quantum physics: quantization, uncertainty, superposition, and wave-particle duality.
We follow the historical development of the main facts that founded quantum physics; from the quantization of energy to explain the ultraviolet catastrophe to the decisive experiments of the early 20th century. The fundamental principles of quantum physics, the experiments on which they were based, and the consequences derived from them are described. Emphasis is placed on the differences with classical physics.

Specific objectives:
Study the experiments which led to the quantum physics development in the first decades of the 20th century. Expose the historical context and the need for a new physics.

Related activities:
Solving exercises based on each of the phenomena studied. Determine the Planck constant from the simulation of an experiment.

Full-or-part-time: 10h
Theory classes: 8h
Guided activities: 2h

2.Schrödinger's equation in one dimension: potential wells, potential barrier and the tunnel effect. Harmonic oscillator Electronic band structure: semiconductors, conductors and insulators.

Description:
2.Schrödinger's equation in one dimension: potential wells, potential barrier and the tunnel effect. Harmonic oscillator Electronic band structure: semiconductors, conductors, and insulators.
It is the central theme of the subject. Wave functions and probability amplitudes are introduced. Several one-dimensional systems are solved. The simple harmonic oscillator, the steady states; as well as transmission, reflection, and tunneling in potential barriers are studied.

Specific objectives:
Master the necessary mathematical tools for solving exercises. Solve the Schrödinger equation individually for different one-dimensional systems.

Related activities:
Solving exercises and proposed problems using analytical techniques and different approaches. Perturbation theory.

Full-or-part-time: 10h
Theory classes: 8h
Guided activities: 2h

3. The Schrödinger equation in three dimensions. The atom. Solving exercises for potentials produced by central fields. Confinement and degeneration. Angular momentum, magnetic moment and spin.

Description:
3. The Schrödinger equation in three dimensions. The atom. Solving exercises for potentials produced by central fields. Confinement and degeneration. Angular momentum, magnetic moment, and spin. Hydrogen atom. Zeeman effect. Nuclear magnetic resonance spectroscopy.
Degenerate energy levels and their relationship to the symmetry of the system are studied. The electronic structure of the atom. The concept of orbital and its relationship with energy levels is introduced.

Specific objectives:
They have to be abble to solve the problems related to the Schrödinger equation and its applications. Analyze the different atomic models, from Democritus to Schrödinger.

Related activities:
Solving exercises and proposed problems using the mathematical tools acquired during the course.

Full-or-part-time: 10h
Theory classes: 8h
Guided activities: 2h

4. Molecules. Energy levels and spectra. Band theory in solid state physics. Semiconductors and superconductors.

Description:
4. Molecules. Energy levels and spectra. Band theory in solid-state physics. Semiconductors and superconductors.
The crystalline structure of matter and its correlation with the functional properties of materials are studied. The electrical and magnetic properties of the materials are studied, as well as their practical application.

Specific objectives:
Quantum phenomena and practical applications, from high-tech systems to consumer electronics.

Related activities:
Study of a practical application of quantum physics in some established commercial systems.

Full-or-part-time: 10h
Theory classes: 8h
Guided activities: 2h

5. The Schrödinger equation in two dimensions. Two-dimensional systems and their applications. Quantum computing: qubits and quantum entanglement.

Description:
5. The Schrödinger equation in two dimensions. Two-dimensional systems and their applications. Quantum computing: qubits and quantum entanglement.
An introduction to quantum computing, its advantages, and limitations. The concept of the qubit is introduced as the fundamental basis of quantum computing. The phenomenon of quantum entanglement and the possibilities it offers for the realization of quantum communication are studied.

Specific objectives:
Acquire a general idea of the principles on which quantum computing is based. Study the candidate's physical systems to be used as the hardware of quantum computing. Compare classical and quantum computing.

Related activities:
Solve two-dimensional system problems that can be used in quantum computing. Study any of the promising physical systems to be used as quantum computing hardware.

Full-or-part-time: 8h
Theory classes: 6h
Guided activities: 2h

GRADING SYSTEM

- Continuous evaluation consisting of exercises to be carried out during self-learning hours. Partial exam (in the online version of the course it is modified by the exposition of a topic to be chosen by the student).
- A final exam to take the last day of the course. Final Note = 50% Ev. Continued + 50% Final Exam.
- Optional work: The student who wants to improve the grade can present the final work. It can represent an increase of 10% on the final grade (as long as it is not higher than 10). In all cases, the student can use books or class notes.

EXAMINATION RULES.

Two individual examinations of problems, where they can use books

BIBLIOGRAPHY

Basic:
- Brandt, S.; Dahmen, H.D. The picture book of quantum mechanics. 4th ed. New York [etc.]: Springer, 2012. ISBN 9781461439509.
- Feynman, R.P.; Leighton, R.B.; Sands, M. Física. México: Pearson Educación, 1998. ISBN 9684443501.
- French, A.P.; Taylor, E.F. Introducción a la física cuántica. Barcelona [etc.]: Reverté, 1982. ISBN 8429141677.
- Lüth, H. Quantum Physics in the Nanoworld. Springer, 2013. ISBN 3642448402.

Complementary:
- Eisberg, R.M. Fundamentos de física moderna. México: Limusa-Wiley, 1973. ISBN 968180418X.
- Cohen-Tannoudji, C.; Diu, B.; Laloë, F. Mécanique quantique. Ed. rev., corr. et aug. Paris: Hermann, 1977. ISBN 2705657339 (V.1); 2705657673 (V.2).

RESOURCES

Other resources:

CPET notes "Quantum Mechanics"
CPET notes, "Introducció a la Física Quàntica. problemes".