Course guide
230491 - QTECH - Quantum Technologies

Last modified: 24/05/2026

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

Degree: BACHELOR'S DEGREE IN ENGINEERING PHYSICS (Syllabus 2011). (Optional subject).

Academic year: 2026 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: JAVIER ARGÜELLO LUENGO

Others: Primer quadrimestre:
JAVIER ARGÜELLO LUENGO - 10
IACOPO TORRE - 10

PRIOR SKILLS

Basic concepts of quantum mechanics and its postulates, including the definition of states and operators in a discrete basis and the temporal evolution of quantum states and density matrices.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
4. Knowledge and understanding of the interaction between radiation and matter in photonic systems. Knowledge of photonic devices and ability for using them. Knowledge of applications in nanotechnology, materials science, communications and biophysics.
5. Knowledge of the structure of matter and its properties at molecular and atomic level. Ability to analyze the behavior of materials, electronics and biophysical systems, and the interaction between radiation and matter.

Generical:
3. ABILITY TO IDENTIFY, FORMULATE, AND SOLVE PHYSICAL ENGINEERING PROBLEMS. Planning and solving physical engineering problems with initiative, making decisions and with creativity. Developing methods of analysis and problem solving in a systematic and creative way.

Transversal:
1. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
2. 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.

TEACHING METHODOLOGY

This course starts by introducing the fundamental aspects of quantum information and quantum optics. Using these tools, the second part of the program explores quantum algorithms, and their possible implementation in state-of-the-art quantum computers. Each topic will balance theoretical and problem-oriented sessions, that will be guided by the instructors of the course.

LEARNING OBJECTIVES OF THE SUBJECT

1) Understanding the historical development of quantum theory and emerging technologies.
2) Understanding basic concepts of quantum theory, its role and importance in the development of quantum technologies, and how to use them.
3) Understanding the current development of quantum technologies, and their applications: quantum cryptography, entanglement, quantum computing.

STUDY LOAD

Type	Hours	Percentage
Hours large group	65,0	43.33
Self study	85,0	56.67

Total learning time: 150 h

CONTENTS

1. Quantum information

Description:
-Definition of qubit, superpositions, and their representation in the Bloch sphere.
-Pure and mixed states. Density matrix
-Orthogonal and generalized measurements. POVMs. Quantum tomography
-Entanglement. Schmidt decomposition. Bell states
-How different are two quantum states? Fidelity.
-Evolution of quantum states in open systems - quantum operations.

Full-or-part-time: 34h 30m
Theory classes: 15h
Self study : 19h 30m

2. Quantum computation

Description:
Operators and quantum gates.
- Universal Basis. Pauli matrices, and their effect on the Bloch sphere.
- 2-qubit gates: quantum CNOT, swap, CU gates.
- 3-qubit gates: CSWAP, CCNOT, etc.
Algorithms:
- An academic example: The Deutsch algorithm.
- Quantum Fourier Transform. Shor’s algorithm and its impact on RSA
- Stabilizers and Grover’s algorithm

Full-or-part-time: 34h 30m
Theory classes: 15h
Self study : 19h 30m

3. Quantum hardware

Description:
What is a universal quantum computer? DiVincenzo's criteria.
Computing architectures
- Superconducting circuits: flux qubits, cryostats
- Atoms: laser, light-matter interactions, Rabi oscillation, optical traps, Rydberg blockade
- Ion traps: Paul trap, sideband addressing
- Photonic circuits: qubit codification, optical elements, quantization of the optical field, Hong-Ou-Mandel experiments

The role of imperfections, decoherence, and their effect on the Bloch sphere
Introduction to quantum error correction

Related activities:
Practical implementation of quantum algorithms using real quantum devices

Full-or-part-time: 46h
Theory classes: 20h
Self study : 26h

4. Quantum communication

Description:
- No-cloning theorem
- Bell states and superdense coding.

Quantum teleportation
Classical vs. quantum cryptography
Key distribution protocols: BB84, B89, E91
Locality and Bell inequalities

Full-or-part-time: 34h 30m
Theory classes: 15h
Self study : 19h 30m

GRADING SYSTEM

The evaluation consists of three parts:
1) Two written exams. Overall, they represent 65% of the final mark.
2) There will be assigned problems during the course, to be done at home and delivered to the professor (20% of the final mark).
3) A practical implementation of quantum algorithms using real quantum devices (15% of the final mark).

BIBLIOGRAPHY

Basic:
- Nielsen, M.A.; Chuang, I.L. Quantum computation and quantum information. 10th ed. Cambridge, UK: Cambridge University Press, 2010. ISBN 9781107002173.
- Mermin, N. D. Quantum computer science: an Introduction. Cambridge: Cambridge University Press, 2007. ISBN 9780521876582.
- Preskill, John. Lecture Notes for Physics 229: Quantun information and computation [on line]. California: California Institute of Yechnology, 1998 [Consultation: 10/07/2025]. Available on: https://www.lorentz.leidenuniv.nl/quantumcomputers/literature/preskill_1_to_6.pdf.

Complementary:
- Argüello Luengo, Javier; González Tudela, Alejandro; Cirac Sasturáin, Juan Ignacio. Simuladores cuánticos : construyendo las maquetas del mundo microscópico. Madrid: Catarata, 2025. ISBN 9788410674233.