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300050 - TIQ - Quantum Information Technology

Coordinating unit: 300 - EETAC - Castelldefels School of Telecommunications and Aerospace Engineering

Teaching unit: 748 - FIS - Department of Physics

Academic year: 2018

Degree: BACHELOR'S DEGREE IN AEROSPACE SYSTEMS ENGINEERING/BACHELOR'S DEGREE IN TELECOMMUNICATIONS SYSTEMS ENGINEERING (Syllabus 2015). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN NETWORK ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN TELECOMMUNICATIONS SYSTEMS ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN AEROSPACE SYSTEMS ENGINEERING/BACHELOR'S DEGREE IN NETWORK ENGINEERING (Syllabus 2015). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN AEROSPACE SYSTEMS ENGINEERING (Syllabus 2015). (Teaching unit Optional)
BACHELOR'S DEGREE IN AIR NAVIGATION ENGINEERING (Syllabus 2010). (Teaching unit Optional)
BACHELOR'S DEGREE IN AIRPORT ENGINEERING (Syllabus 2010). (Teaching unit Optional)

ECTS credits: 6 Teaching languages: Catalan, Spanish, English

Teaching staff

Coordinator: SANTIAGO TORRES GIL

Others: PERE BRUNA ESCUER

Degree competences to which the subject contributes

Transversal:

1. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
2. 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.
3. TEAMWORK - Level 1. Working in a team and making positive contributions once the aims and group and individual responsibilities have been defined. Reaching joint decisions on the strategy to be followed.
4. 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.

Learning objectives of the subject

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Study load

Total learning time: 150h	Hours large group:	42h	28.00%
	Guided activities:	24h	16.00%
	Self study:	84h	56.00%

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Content

INTRODUCCIÓ A LA FISICA QUANTICA

Learning time: 22h

Theory classes: 7h
Guided activities: 3h
Self study : 12h

Description:
.- Historic introduction: electromagnetic radiation, blackbody radiation, Wien and Stefan-Boltzmann's law.
.- The blackbody, Planck's law. Wave-corpuscle duality, De Broglie's law. Electron difraction. Energy quantization. Photoelectric effect. Bohr's atom model.
.- Schrödinger equation. Probabilistic interpretation of the wave function. Quantum states and entanglement. Unidimensional potentials. The square dwell potential. Tunnel effect.
.- Heisenberg's uncertainty principle. Superposition of states. Uncertainty princple of the lineal momentum-position, uncertainty princple of the energy-time.
.- Magnetic momento and spin moment. Angular momento of atomic systems. Atomic orbital and energy levels. Pauli exclusión principle.
.- Solid state applications of the quantum mechanics: semiconductors, superconductors and lasers.

QUANTUM COMPUTING

Learning time: 45h

Theory classes: 14h
Guided activities: 6h
Self study : 25h

Description:
.- Definition of qubits. Bloch sphere.
.- Operations with qubits: Pauli matrices and Hadamard matrix. Systems of qubits: entanglement and Bell estates. Quantum gates.
.- Quantum circuits. Deterministic, probabilístic and quantum computers. The Turing machine.
.- Basic applications with quantum circuits: non-cloning theorem, quantum parallelism, Bell state generators-measuremeters, superdense coding, teleportation.
.- Algoritms and quantum emulators. Shor's algorithm. Grover's algorithm.
.- Quantum measurements. Measurement operators. Density matrix: pure and mixed states. Quantum tomography.

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QUANTUM PROCESSORS	Learning time: 38h Theory classes: 11h Guided activities: 5h Self study : 22h

Description:
.- Quantum hardware. General requeriments DiVincenzo criteria.
.- Quantum Optic computer model. Optic elements: polarizers, retarders, wave-plates, BBOs, beam-spliters and detectors. Polarized mode and espatial mode. Mach-Zehnder's interferometer. Exemple of teleportation based on the Canary Islands experiment.
.- Quantum Computer based on the ion trap model. Paul's trap. Energy states, Rabi oscillation and pulses. Phonon model. Sideband cooling method and readout. Cirac-Zoller model's. Example of the IBM Q quantum processor.
.- General characteristics of alternative models: magnetic nuclear resonance, superconductor circuits, etc.

QUANTUM COMMUNICATION	Learning time: 45h Theory classes: 10h Guided activities: 10h Self study : 25h

Description:
.- Criptografia Clàssica vs. Quàntica.
.- Sessió de Distribució Quàntica de Clau. Protocols bàsics: BB84, B89 i E91.
.- Elements clàssics de la teoria de la informació. Entropia de Shannon.
.- Informació Quàntica. Definició de l'entropia quàntica. Teorema de Holevo.
.- Compressió quàntica de dades i correció d'errors quàntics.

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Planning of activities

(ENG) (AV1): CONTROL DE PROBLEMES DELS TEMES 1 I 2	Hours: 6h 30m Theory classes: 1h 30m Self study: 5h
(ENG) (AV2): CONTROL DE PROBLEMES DELS TEMES 3 I 4	Hours: 6h 30m Theory classes: 1h 30m Self study: 5h
(ENG) (AV3): ACTIVITATS DIRIGIDES D'APLICACIONS PRÀCTIQUES	Hours: 81h Guided activities: 21h Self study: 60h
(ENG) (AV4): PROJECTE APLICACIÓ DE LES TECNOLOGIES DE LA INFORMACIÓ QUÀNTICA	Hours: 25h Theory classes: 2h Guided activities: 3h Self study: 20h
(ENG) (AV5): EXAMEN DE MIG QUADRIMESTRE	Hours: 1h 30m Guided activities: 1h 30m
(ENG) (AV6): EXAMEN DE FINAL DE QUADRIMESTRE	Hours: 1h 30m Guided activities: 1h 30m

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Bibliography

Basic:

Nielsen, M.A.; Chuang, I.L. Quantum computation and quantum information. 10th ed. Cambridge, UK: Cambridge University Press, 2010. ISBN 9781107002173.

Desurvire, Emmanuel. Classical and quantum information theory : an introduction for the telecom scientist. Cambridge ; New York: Cambridge University Press, 2009. ISBN 9780521881715.

Scarani, Valerio. Quantum Physics : a first encounter : interference, entanglement, and reality. Oxford: Oxford University Press, 2006. ISBN 9780198570479.

Complementary:

Kaye, Phillip; Laflamme, Raymond; Mosca, Michele. An Introduction to quantum computing. Oxford [etc.]: Oxford University Press, 2007. ISBN 9780198570493.

Tipler, Paul Allen; Mosca, Gene. Física para la ciencia y la tecnología. 5a ed. Barcelona [etc.]: Reverté, 2005. ISBN 8429144102.

Zeilinger, Anton; Ekert, A.; Bouwmeester, Dirk. The Physics of quantum information : quantum cryptography, quantum teleportation, quantum computation. Berlin: Springer, 2000. ISBN 3540667784.