ANX-PR/CL/001-01
GUÍA DE APRENDIZAJE

ASIGNATURA

615001052 - Quantum Information

PLAN DE ESTUDIOS

61IW - Grado En Ingenieria Del Software

CURSO ACADÉMICO Y SEMESTRE

2023/24 - Semester 1

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1. Description

1.1. Subject details

Name of the subject	615001052 - Quantum Information
No of credits	6 ECTS
Type	Optional
Academic year ot the programme	Third year
Semester of tuition	Semester 5
Tuition period	September-January
Tuition languages	English
Degree programme	61IW - Grado en Ingenieria del Software
Centre	61 - Escuela Tecnica Superior De Ingenieria De Sistemas Informaticos
Academic year	2023-24

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Luis Miguel Pozo Coronado (Coordinador/a)	2004	lm.pozo@upm.es	Sin horario. Schedule not defined yet. Mentoring schedule will be published at the beginning of the semester according to the needs.

* Tutoring hours are approximate and may be subject to change. Tutoring times should be confirmed with the teaching staff.

2.3. Profesorado externo

Name and surname	Office/Room	Centre of origin
Giannicola Scarpa	g.scarpa@upm.es	UPM

3. Skills and learning outcomes

3.1. Skills to be learned

CB2 - Ability to understand and master the physical and technological fundamentals of computer science: electromagnetism, waves, circuit theory, electronics and photonics and their application to engineering problem solving.

CB4 - Knowledge of the fundamentals of the use and programming of computers, operating systems, databases and, in general, computer programmes with applications in engineering.

CC14 - Knowledge and application of the fundamental principles and basic techniques of parallel, concurrent, distributed and real-time programming.

CC6 - Knowledge and application of the basic algorithmic procedures of computer technologies to design solutions to problems, analysing the suitability and complexity of the proposed algorithms.

CE4 - Ability to identify and analyse problems and design, develop, implement, verify and document software solutions based on an adequate knowledge of current theories, models and techniques.

CT12 - Use of information and communication technologies : Use information and communication technologies in the field of engineering.

3.2. Learning outcomes

RA438 - Knows and handles the fundamentals of quantum computing and quantum information (cubirs, superposition, entanglement, quantum gates, measurement and fundamental theorems).

RA439 - Knows and handles the fundamentals of quantum cryptography.

RA440 - Knows and operates some basic quantum algorithms.

RA441 - It uses quantum physics computer programming tools and simulators.

4. Brief description of the subject and syllabus

4.1. Brief description of the subject

The subject proposes a hands-on approach to Quantum computing, taking advantage of 1) the possibility granted by Computer Algebra Systems (such as the SymPy Python library) to simulate the behaviour of quantum circuits; 2) the open access to IBM Quantum Experience simulators and physical quantum devices.

The practical work with simulators can help to integrate and visualize the concepts of quantum information and thus build an alternative driveway to this field, requiring less abstract mathematical and physical formalism in comparison to the classical approach.

4.2. Syllabus

1. Quantum Computation and Quantum Information. Fundamentals.
   1.1. Quantum Mechanics: Superposition, measurement.
   1.2. Qubits, entanglement.
   1.3. Elementary Gates, Quantum Circuits, Universality results.
   1.4. Fundamental properties of quantum information (no-cloning theorem, Von Neumann?s Entropy?).
2. Quantum cryptography
   2.1. Quantum nonlocality: Entanglement and its properties
   2.2. Reminder of classical cryptography.
   2.3. Quantum Key Distribution

2.4. Device-Independent cryptography

3. Quantum algorithms

3.1. Deutsch-Jozsa

3.2. Shor?s factoring algorithm

3.3. Grover?s Search algorithm

3.4. HHL algorithm

5. Schedule

5.1. Subject schedule *

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	**Master class** Duración: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		
2	**Master class** Duración: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		
3	**Master class** Duración: 02:00 Lecture	**Lab class** Duration 02:00 Laboratory assignments		
4	**Master class** Duración: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		**Moodle questionnaire** Online test Continuous assessment No presential Duration: 30:00
5	**Master class** Duración: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		
6	**Master class** Duración: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		
7	**Master class** Duración: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		
8	**Master class** Duración: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		
9	**Master class** Duración: 02:00LectureLM: Actividad del tipo Lección Magistral	**Lab class** Duration: 02:00 Laboratory assignments		**Moodle questionnaire** Online test Continuous assessment No presential Duration: 30:00 **Theory test** Written test Continuous assessment Presential Duration: 01:30

10	**Master class** Duration: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		
11	**Master class** Duration: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		
12	**Master class** Duration: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		
13	**Master class** Duration: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		
14	**Master class** Duration: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		
15	**Master class** Duration: 02:00 Lecture	**Lab class** Duration: 02:00 Laboratory assignments		**Moodle questionnaire** Online test Continuous assessment No presential Duration: 30:00
16				
17				**Theory test** Written test Continuous assessment Presential Duration: 01:30 **Lab project** Group presentation Continuous assessment and final test only Presential Duration: 00:00 **Global theory test** Written Test Assessment final test only Presential Duration: 02:30

For the calculation of the total values, it is estimated that for each ECTS credit the student will spend, depending on the study plan, between 26 and 27 hours of face-to-face and non-face-to-face work.

6. Activities and assessment criteria

6.1. Assessment activities

6.1.1. Assessment (progressive)

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
4	Moodle questionnaire	Online test	No Presential	30:00	2%	/ 10	
9	Moodle questionnaire	Online test	No Presential	30:00	2%	/ 10	
9	Theory test	Written test	Presential	01:30	24%	/ 10	CC14 CB2 CE4 CB4 CC6
15	Moodle questionnaire	Online test	No Presential	30:00	2%	/ 10	CC14 CB2 CB4 CC6
17	Theory test	Written test	Presential	01:30	30%	/ 10	
17	Lab project	Group work	Presential	00:00	40%	/ 10	CB4 CC6 CT12 CC14 CB2 CE4

6.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Lab project	Group work	Presential	00:00	40%	/ 10	CB4 CC6 CT12 CC14 CB2 CE4

17	Global theory test	Written test	Presential	02:30	60%	/ 10	CB4 CC6 CC14 CB2 CE4

6.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Global theory test	EX: Técnica del tipo Examen Escrito	Presencial	02:30	60%	/ 10	CT12 CC14 CB2 CE4 CB4 CC6
Lab project	TI: Técnica del tipo Trabajo Individual	Presencial	00:00	40%	/ 10	CT12 CC14 CB2 CE4 CB4 CC6

6.2. Assessment criteria

Asessment will consist of theory (60 %) and lab (40 %) tasks.

Theory will be evaluated through three multiple choice questionnaires available in Moodle (2 % each) and two written tests (24 % and 30 % respectively). Students can recover from the questionnaires and the first witten test by taking a global theory test in week 17, with a total value of 60 %.

Practical lab work will be evaluated by a lab project than can be made in pairs. The project will weigh a 40 % of the total grade.

Students can ask for to be graded by a final evaluation only. This evaluation will consist of a theory test (60%) and a lab project (40 %).

Extraordinary evaluation will also consist of a theory test (60%) and a lab project (40 %).

7. Teaching resources

7.1. Teaching resources for the subject

Name	Type	Notes
DE WOLF, R: Quantum Computing Lecture Notes, 2022.	Bibliography	Textbook. Available in https://arxiv.org/abs/1907.09415
JOHNSTON, E; HARRIGAN, N; GIMENO-SEGOVIA, M: Programming Quantum Computers . O'Reilly, 2019.	Bibliography	Textbook.
NIELSEN, M. A.; CHUANG, I. L.: Quantum Computation and Quantum Information. Cambridge University Press, 2000.	Bibliography	Supplementary textbook.
WATROUS, J: The Theory of Quantum Information. Cambridge University Press, 2018.	Bibliography	Supplementary textbook. https://cs.uwaterloo.ca/~watrous/TQI/
SCARANI, V.: Bell Nonlocality. Oxford University Press, 2019.	Bibliography	Supplementary textbook. https://global.oup.com/academic/product/bell-nonlocality-9780198788416
WILDE, M.: From Classical to Quantum Shannon Theory, 2019.	Bibliography	Supplementary textbook. https://arxiv.org/abs/1106.1445
O'Reilly online material	Web resource	https://oreilly-qc.github.io
IBM Quantum Experience	Web resource	https://quantum-computing.ibm.com/

8. Other information

8.1. Other information about the subject

This subject will be taught in English.

The lecturers will be Giannicola Scarpa (SI) and Luis Pozo (MATIC).