



## Teaching Guide

Identifying Data					2023/24
Subject (*)	Quantum Computing Architectures	Code	614551022		
Study programme	Máster Universitario en Ciencia e Tecnoloxías de Información Cuántica				
Descriptors					
Cycle	Period	Year	Type	Credits	
Official Master's Degree	1st four-month period	First	Optional	3	
Language	SpanishGalician				
Teaching method	Face-to-face				
Prerequisites					
Department	Ciencias da Computación e Tecnoloxías da Información				
Coordinador	Moret Bonillo, Vicente	E-mail	vicente.moret@udc.es		
Lecturers	Alvarez Estevez, Diego Moret Bonillo, Vicente	E-mail	diego.alvareze@udc.es vicente.moret@udc.es		
Web	n9.cl/27996				
General description	<p>Aínda non se resolveu o problema de que hardware sería ideal para a computación cuántica. Neste sentido, definíronse unha serie de condicións que deben cumprir as arquitecturas cuánticas, e que se poden atopar na coñecida lista de Di Vincenzo. Non obstante, en toda arquitectura cuántica débense manter unha serie de restricións, como son as seguintes: o sistema debe poder ser inicializado, é dicir, debe levarse a un estado de arranque coñecido e controlado; tamén debe ser posible manipular os qubits de forma controlada, cun conxunto de operacións que forman un conxunto universal de portas lóxicas (co fin de reproducir calquera outra porta lóxica posible). Do mesmo xeito, o sistema debe manter a súa coherencia cuántica, ademais de poder ler o estado final do sistema, despois do cálculo. Finalmente, o sistema ten que ser escalable: ten que haber unha forma definida de aumentar o número de qubits, para facer fronte a problemas de maior custo computacional.</p>				

## Study programme competences

Code	Study programme competences
A4	CON_04 Have knowledge of quantum computing, algorithms, circuits, their programming in different languages and accessible platforms.
A16	CON_16 Have knowledge of quantum computer architectures, different platforms and "full stack";.
B1	HD01 Analyze and break down a complex concept, examine each part and see how they fit together
B3	HD03 Compare and contrast and point out similarities and differences between two or more topics or concepts
B6	HD11 Prepare accurately the relevant questions for a specific problem.
B8	HD13 Improvise solutions in an innovative way to solve a problem.
B12	HD23 Communicate using the expected norms for the chosen medium.
B13	HD24 Actively participate in face-to-face activities in the classroom.
B14	HD31 Assign resources and responsibilities so that all members of a team can work optimally
B16	HD33 Set goals for the group to analyze the situation, decide what outcome is desired and clearly set an achievable goal.
C1	C1. Adequate oral and written expression in the official languages.
C2	C2. Mastering oral and written expression in a foreign language.
C3	C3. Using ICT in working contexts and lifelong learning.
C4	C4. Acting as a respectful citizen according to democratic cultures and human rights and with a gender perspective.
C7	C7. Developing the ability to work in interdisciplinary or transdisciplinary teams in order to offer proposals that can contribute to a sustainable environmental, economic, political and social development.
C8	C8. Valuing the importance of research, innovation and technological development for the socioeconomic and cultural progress of society.

## Learning outcomes

Learning outcomes	Study programme competences



Adquirir conocimientos de computación cuántica, algoritmia y circuitos cuánticos.	AJ4 AJ16	BJ1 BJ3 BJ6 BJ8 BJ12 BJ13 BJ16	CJ1 CJ2 CJ3 CJ4 CJ7 CJ8
Programación en diferentes lenguajes y plataformas accesibles.	AJ4 AJ16	BJ1 BJ3 BJ6 BJ8 BJ12 BJ13 BJ14 BJ16	CJ1 CJ2 CJ3 CJ4 CJ7 CJ8
Adquirir conocimientos sobre aspectos de alto nivel en computación cuántica: diseño de máquinas cuánticas, simuladores cuánticos y arquitecturas.	AJ4 AJ16	BJ1 BJ3 BJ6 BJ8 BJ12 BJ13 BJ14 BJ16	CJ1 CJ2 CJ3 CJ4 CJ7 CJ8

Contents	
Topic	Sub-topic
1. INTRODUCCIÓN	Antecedentes Contexto
2. REQUISITOS DEL COMPUTADOR CUÁNTICO	Requisitos funcionales Requisitos no funcionales Integración de requisitos
3. COMPONENTES Y MÉTODOS	Registros de cómputo Puertas unitarias Transiciones de estados
4. ARQUITECTURAS CLÁSICAS	Arquitectura de Benioff Arquitectura de Kane Arquitectura de Deutsch
5. EL ORDENADOR CUÁNTICO DE FEYNMAN	Operadores de aniquilación Operadores de creación El Hamiltoniano de la computación cuántica Diseño y desempeño del ordenador cuántico
6. CONSIDERACIONES FINALES	Análisis crítico Discusión de aproximaciones Conclusiones

Planning				
Methodologies / tests	Competencies	Ordinary class hours	Student?s personal work hours	Total hours



Guest lecture / keynote speech	A4 A16 B1 B3 B6 B8 B12 B13 B14 B16 C1 C2 C3 C4 C7 C8	10	50	60
ICT practicals	A4 A16 B1 B3 B6 B8 B12 B13 B14 B16 C1 C2 C3 C4 C7 C8	15	0	15
Personalized attention		0	0	0

(\*)The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.

### Methodologies

Methodologies	Description
Guest lecture / keynote speech	Explicación en el aula de los contenidos de la materia. Resolución de problemas y supuestos prácticos. Realización de seminarios interactivos.
ICT practicals	Resolución de problemas prácticos en entornos TIC. Realización en equipo de prácticas de laboratorio con simuladores cuánticos.

### Personalized attention

Methodologies	Description
	Incluye clases teóricas (expositivas e interactivas), debates, resolución de problemas, seminarios, y prácticas de laboratorio en entornos TIC.

### Assessment

Methodologies	Competencies	Description	Qualification
Guest lecture / keynote speech	A4 A16 B1 B3 B6 B8	Evaluación continua de actividades realizadas individualmente.	50
	B12 B13 B14 B16 C1	Evaluación continua de actividades realizadas en equipo.	
	C2 C3 C4 C7 C8	Prueba final de desarrollo de cinco preguntas cortas de la materia.	
ICT practicals	A4 A16 B1 B3 B6 B8	Evaluación de prácticas individuales.	50
	B12 B13 B14 B16 C1	Evaluación de prácticas realizadas en equipo.	
	C2 C3 C4 C7 C8		

### Assessment comments

No se establece ninguna nota de corte, ni en Teoría ni en Prácticas. La nota final se obtendrá a partir de la siguiente ecuación:  $Nota\_Final = 0.5 \times (Nota\_Teoría + Nota\_Prácticas)$  Para aprobar la asignatura, se tiene que cumplir que  $Nota\_Final$  sea mayor o igual a 5.00 puntos.

### Sources of information



<b>Basic</b>	<p>- Noson S. Yanofsky, Mirco A. Mannucci (2009). Quantum Computing for Computer Scientists. Cambridge University Press</p> <p>- Richard P. Feynman (2001). Feynman Lectures On Computation. CRC Press</p> <p>After presenting the necessary prerequisites, the material is organized to look at different aspects of quantum computing from the specific standpoint of computer science. There are chapters on computer architecture, algorithms, programming languages, theoretical computer science, cryptography, information theory, and hardware. The text has step-by-step examples, more than two hundred exercises with solutions, and programming drills that bring the ideas of quantum computing alive for today's computer science students and researchers. After presenting the necessary prerequisites, the material is organized to look at different aspects of quantum computing from the specific standpoint of computer science. There are chapters on computer architecture, algorithms, programming languages, theoretical computer science, cryptography, information theory, and hardware. The text has step-by-step examples, more than two hundred exercises with solutions, and programming drills that bring the ideas of quantum computing alive for today's computer science students and researchers.</p>
<b>Complementary</b>	<p>- Vicente Moret Bonillo (2017). Adventures in Computer Science . Springer</p> <p>The main focus of this textbook is the basic unit of information and the way in which our understanding of this has evolved over time. In particular the author covers concepts related to information, classical computing, logic, reversible computing, quantum mechanics, quantum computing, thermodynamics and some artificial intelligence and biology, all approached from the viewpoint of computer sciences. The main focus of this textbook is the basic unit of information and the way in which our understanding of this has evolved over time. In particular the author covers concepts related to information, classical computing, logic, reversible computing, quantum mechanics, quantum computing, thermodynamics and some artificial intelligence and biology, all approached from the viewpoint of computer sciences.</p>

## Recommendations

### Subjects that it is recommended to have taken before

Quantum Mechanics I/614551001  
Quantum Mechanics II/614551002  
Fundamentals of Quantum Information/614551003  
Fundamentals of Quantum Communications/614551005  
Introduction to Quantum Computing/614551004

### Subjects that are recommended to be taken simultaneously

Quantum Computing Tools/614551006  
Quantum Computing and Machine Learning/614551008  
Programming and Implementation of Quantum Algorithms/614551007

### Subjects that continue the syllabus

Practical Applications of Quantum Computing/614551010  
Numerical Methods in Quantum Computing/614551025  
Quantum Computing and High Performance Computing/614551009  
Error Correction Codes/614551013  
Rule-Based Quantum Systems/614551029

### Other comments

(\*)The teaching guide is the document in which the URV publishes the information about all its courses. It is a public document and cannot be modified. Only in exceptional cases can it be revised by the competent agent or duly revised so that it is in line with current legislation.