Teaching Guide					
Identifying Data					2024/25
Subject (*)	Numerical Methods in Quantum Computing			Code	614551025
Study programme	Máster Universitario en Ciencia e Tecnoloxías de Información Cuántica				
Descriptors					
Cycle	Period	Year		Type	Credits
Official Master's Degree	2nd four-month period	First		Optional	3
Language	Spanish				
Teaching method	Face-to-face				
Prerequisites					
Department	Matemáticas				
Coordinador	Vazquez Cendon, Carlos		E-mail	carlos.vazquez.cendon@udc.es	
Lecturers	Vazquez Cendon, Carlos		E-mail	carlos.vazquez.cendon@udc.es	
Web	n9.cl/ikre8				
General description	The application of Quantum Computing to numerical simulation problems of processes and products is very promising, although the advancement of quantum computer technology is currently required to address the complexity of the problems that arise in real applications in different disciplines. . On the other hand, the benefits of Quantum Computing often require a redesign of the classical numerical methods, or the construction of new methods, so that they are efficient. In this subject there will be an introduction to quantum algorithms related to different problems that numerical methods solve, such as those related to functions of one variable, approximations in matrix numerical calculus, numerical optimization and simulation. In addition to explaining the problems addressed by numerical methods and some algorithms that are used in Quantum Computing to solve them, the practical implementation of these algorithms will be carried out.					

Study programme competences / results	
Code	Study programme competences / results
A4	CON_04 Have knowledge of quantum computing, algorithms, circuits, their programming in different languages and accessible platforms.
A14	CON_14 Be aware of problem sets where quantum computing at its current stage of development can offer an advantage over classical computing: chemistry, biology, optimization, logistics, finance, etc.
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 / results

Know the state of the art of the use of quantum computing to develop numerical methods	AJ4 AJ14	BJ1 BJ3 BJ6 BJ8 BJ12 BJ13 BJ14 BJ16	CJ1 CJ2 CJ3 CJ4 CJ7 CJ8
Know the quantum algorithms related to functions of a variable, matrix numerical calculation, numerical methods of optimization and numerical and stochastic simulation	AJ4 AJ14	BJ1 BJ3 BJ6 BJ8 BJ12 BJ13 BJ14 BJ16	CJ1 CJ2 CJ3 CJ4 CJ7 CJ8
Know how to implement numerical methods in quantum computer simulators	AJ4 AJ14	BJ1 BJ3 BJ6 BJ8 BJ12 BJ13 BJ14 BJ16	CJ1 CJ2 CJ3 CJ4 CJ7 CJ8

Contents	
Topic	**Sub-topic**
1. Introduction to Numerical Methods	
2. Quantum numerical methods on functions of one variable	- Quantum algorithms for arithmetic operations - Quantum algorithms for some basic functions
3. Quantum algorithms for matrix numerical computation	
4. Quantum algorithms for numerical and stochastic simulation	
5. Quentum algorithms for optimization	

Planning				
Methodologies / tests	**Competencies / Results**	**Teaching hours (in-person & virtual)**	**Student?s personal work hours**	**Total hours**
Guest lecture / keynote speech	A4 A14 B1 B3 B6 B8 B12 B13 B14 B16 C1 C2 C3 C4 C7 C8	11	0	11
ICT practicals	A4 A14 B1 B3 B6 B8 B12 B13 B14 B16 C1 C2 C3 C4 C7 C8	4	10	14
Case study	A4 A14 B1 B3 B6 B8 B12 B13 B14 B16 C1 C2 C3 C4 C7 C8	2	8	10
Problem solving	A4 A14 B1 B3 B6 B8 B12 B14 B16 C1 C2 C3 C4 C7 C8	4	10	14

Supervised projects	A4 A14 B1 B3 B6 B8 B12 B14 B16 C1 C2 C3 C4 C7 C8	0	20	20
Personalized attention		6	0	6
(*)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	Presentation in the classroom of the contents of the subject
ICT practicals	Programming and use of simulators to solve examples
Case study	Presentation of use cases that propose quantum algorithms for different numerical methods
Problem solving	The student is given problems to solve individually or in a group
Supervised projects	Students are given assignments to prepare individually or in groups, which are monitored with personalized attention when necessary

Personalized attention	
Methodologies	**Description**
Supervised projects	Supervised work is monitored, giving guidance and recommendations for its development

Assessment			
Methodologies	**Competencies / Results**	**Description**	**Qualification**
Problem solving	A4 A14 B1 B3 B6 B8 B12 B14 B16 C1 C2 C3 C4 C7 C8	Problems of greater or lesser complexity are posed to be carried out individually or in groups, which may involve handling simulators. The student will deliver a document with his resolution	50
Supervised projects	A4 A14 B1 B3 B6 B8 B12 B14 B16 C1 C2 C3 C4 C7 C8	Supervised work is proposed to be carried out individually or in a group, depending on the complexity. The student must deliver a brief report on the work done and make a brief oral presentation about it, answering the teacher's questions	50

Assessment comments

Sources of information	
Basic	- Bansal, K. et al. (2020). A novel approach to basic arithmetic operations in quantum computing. Preprint - Cao, Y., Papageorgiou, A., Petras, I., Traub, J., Kai, S. (2012). Quantum algorithm and circuit design solving the Poisson equation. Preprint - Cui, X., Shi, Y. (2020). QBLAS: A quantum basic algebra and simulation library. preprint - García-Ripoll, J.J. (2021). Quantum-inspired algorithms for multivariate analysis: from interpolation to partial differential equations. Quantum 5, 431 - Gómez, A., Leitao Rodriguez, A., Manzano, A., Nogueiras, M., Ordoñez, G., Vázquez, C. (2022). A survey on quantum computational finance for derivatives pricing and VaR. Archives of Computational Methods in Engineering, 29, 4137?4163. - Hadfield, S.A. (2018). Quantum algorithms for scientific computing and approximmate optimization. PhD Thesis, Columbia University - Harrow, A.W., Hadssidim, A. Lloyd, S. (2009). Quantum algorithm for linear systems of equations. Physical Review Letters, 15(103):150502.
Complementary	

Recommendations
Subjects that it is recommended to have taken before
Quantum Computing Tools/614551006 Quantum Computing Architectures/614551022 Programming and Implementation of Quantum Algorithms/614551007 Quantum Computing and High Performance Computing/614551009 Introduction to Quantum Computing/614551004
Subjects that are recommended to be taken simultaneously
Quantum Computing and Machine Learning/614551008 Rule-Based Quantum Systems/614551029
Subjects that continue the syllabus
Master`s Dissertation/614551033 Practical Applications of Quantum Computing/614551010
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.