Course guide
200249 - CQ - Quantum Computing

Last modified: 01/06/2023

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.

Degree: BACHELOR'S DEGREE IN MATHEMATICS (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN DATA SCIENCE AND ENGINEERING (Syllabus 2017). (Optional subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: SIMEON MICHAEL BALL MARKS

Others: Segon quadrimestre:
SIMEON MICHAEL BALL MARKS - M-A

PRIOR SKILLS

Basic probability, linear algebra.

REQUIREMENTS

Basic probability, linear algebra.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
GM-CE2. CE-2. Solve problems in Mathematics, through basic calculation skills, taking in account tools availability and the constraints of time and resources.
GM-CE6. Ability to solve problems from academic, technical, financial and social fields through mathematical methods.

Generical:
GM-CB4. CB-4. Have the ability to communicate their conclusions, and the knowledge and rationale underpinning these to specialist and non-specialist audiences clearly and unambiguously.
GM-CG3. CG-3. Have the ability to define new mathematical objects in terms of others already know and ability to use these objects in different contexts.
GM-CG6. CG-6 Detect deficiencies in their own knowledge and pass them through critical reflection and choice of the best action to extend this knowledge.
GM-CG4. CG-4. Translate into mathematical terms problems stated in non-mathematical language, and take advantage of this translation to solve them.
GM-CB3. CB-3. Have the ability to integrate knowledge and handle complexity, and formulate judgements with incomplete or limited information, but that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgements.

Transversal:
03 TLG. 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.
07 AAT. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.

TEACHING METHODOLOGY

Lectures and problem classes

LEARNING OBJECTIVES OF THE SUBJECT

The main objective of the course is to give the student a grounding in quantum computation. This will require the student to cover the fundamentals of quantum mechanics, computer science and develop a more advanced level of linear algebra.

STUDY LOAD

Type	Hours	Percentage
Hours small group	30,0	20.00
Hours large group	30,0	20.00
Self study	90,0	60.00

Total learning time: 150 h

CONTENTS

Introduction

Description:
The double-slit experiment, quantum bits, measurements, Bell states, quantum teleportation.

Full-or-part-time: 15h
Theory classes: 3h
Laboratory classes: 3h
Self study : 9h

Linear Algebra and the Dirac notation

Description:
Pauli matrices, spectral decomposition theorem, tensor products, polar and singular value decomposition.

Full-or-part-time: 25h
Theory classes: 5h
Laboratory classes: 5h
Self study : 15h

Quantum Mechanics

Description:
State space, evolution, measurements, superdense coding, entanglement, Bell inequality.

Full-or-part-time: 20h
Theory classes: 4h
Laboratory classes: 4h
Self study : 12h

Quantum Computation

Description:
Turing machine, quantum circuits, controlled operations, universal quantum gates.

Full-or-part-time: 20h
Theory classes: 4h
Laboratory classes: 4h
Self study : 12h

Quantum Algorithms

Description:
Quantum Fourier transform, algorithms with super-polynomial speed-up.

Full-or-part-time: 20h
Theory classes: 4h
Laboratory classes: 4h
Self study : 12h

Quantum Information

Description:
Classical and quantum noise, Shannon and Von Neumann entropy.

Full-or-part-time: 20h
Theory classes: 4h
Laboratory classes: 4h
Self study : 12h

Quantum Error-Correction

Description:
Classical error-correcting codes, quantum error-correction condition theorem, discretisation of errors, stabiliser codes.

Full-or-part-time: 30h
Theory classes: 6h
Laboratory classes: 6h
Self study : 18h

GRADING SYSTEM

- Midterm exam (contents 1, 2, 3 and 4) (P)
- Final exam (either contents 5, 6 and 7, or all the contents) (F)
- Final score: Max {(P+F) / 2, F}

BIBLIOGRAPHY

Basic:
- Nielsen, Michael A; Chuang, Isaac L. Quantum computation and quantum information. 10th anniversary ed. Cambridge, UK: Cambridge University Press, cop. 2010. ISBN 9781107002173.
- Preskill, John. Quantum Computation [on line]. [Consultation: 26/06/2023]. Available on: http://theory.caltech.edu/~preskill/ph229/.
- Kaye, Phillip; Laflamme, Raymond; Mosca, Michele. An Introduction to quantum computing [on line]. Oxford [etc.]: Oxford University Press, cop. 2007 [Consultation: 26/06/2023]. Available on: https://academic-oup-com.recursos.biblioteca.upc.edu/book/41807. ISBN 9780198570493.

Complementary:
- Diosi, Lajos. A Short course in Quantum Information Theory. Springer, 2011. ISBN 9783642161179.