# Introduction to Quantum Computing

**Academic Year: ( 2021 / 2022 )** **Review date: 01/07/2021 11:30:48**

**Department assigned to the subject: Mathematics Department**

**Coordinating teacher: VICENTE MAJUA, JULIO IÑIGO DE**

**Type: Electives ECTS Credits : 3.0**

**Year : 1 Semester : 2**

## REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Linear Algebra

## OBJECTIVES

- To understand the basic principles of the quantum formalism and their mathematical formulation in terms of linear algebra and matrix theory. To know how to apply them in the context of computation and of basic protocols of information processing.
- To understand the formulation of a quantum algorithm in the circuit model.
- To be familiar with the main quantum gates and the basic rudiments for their concatenation to give rise to universal computation.
- To understand the formulation of two basic quantum algorithms (Grover's and Shor's) and the computational advantage they provide with respect to classical models of computation for the problems of database search and factorization.

According to the master's documentation the students will obtain in this course the following basic, general and specific competences (see additional documentation in the application "Reina").

CB6, CB7, CB8, CB9, CB10
CG2, CG4, CG5, CG6, CG7
CE1, CE2, CE3, CE4, CE6, CE8, CE11, CE12, CE15

## DESCRIPTION OF CONTENTS: PROGRAMME

1. Quantum theory
1.1 Matrix theory notions and Dirac notation
1.2 The axioms of quantum mechanics
1.3 Basic protocols of quantum information theory
1.4 Some toy quantum algorithms

2. The circuit model for quantum computation
2.1 Quantum gates
2.2 Universality

3. Quantum algorithms
3.1 Database search: Grover's algorithm
3.2 Factorization: Quantum Fourier transform and Shor's algorithm

## LEARNING ACTIVITIES AND METHODOLOGY

Learning activities:
- Theoretical lessons.
- Practical lessons.
- Office hours.
- Group work.
- Individual student work.

Methodology:
- In class presentations by the teacher with computer and audiovisual support, in which the main concepts of the course are developed. Bibliography is provided to complement the students' learning.
- Critical reading of texts recommended by the course teacher to expand and consolidate knowledge of the course and to complete and deepen the understanding of those topics in which the students are more interested.
- Resolution of problems raised by the teacher individually or in a group.
- Elaboration of works individually or in group.

Office hours:
An office-hours schedule of 2 hours per week will be established so that the students can ask questions and discuss with the teacher the content of the theoretical lessons, the assigned problems and the works to be elaborated.

## ASSESSMENT SYSTEM

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| **% end-of-term-examination/test:** | 50 |
| **% of continuous assessment (assigments, laboratory, practicals…):** | 50 |

Solution of problems raised in class during the course individually or in group (50%). Elaboration and public presentation at the end of the course of a work individually or in group (50%).

## BASIC BIBLIOGRAPHY

- J. Preskill Lecture Notes on Quantum Computation, California Institute of Technology.

- J. Watrous Lecture Notes: Introduction to Quantum Computing, Institute for Quantum Computing, University of Waterloo.

- M. A. Nielsen and I. L. Chuang Quantum Computation and Quantum Information, Cambridge University Press, 2010

## ADDITIONAL BIBLIOGRAPHY

- A. Yu. Kitaev, A. H. Shen, and M. N. Vyalyi Classical and Quantum Computation, American Mathematical Society, 2002

- J. Watrous The Theory of Quantum Information, Cambridge University Press, 2018