Mathematical foundation for quantum information and technologies

Academic Year: (2023 / 2024) **Review date: 21-04-2023**

Department assigned to the subject: Mathematics Department

Coordinating teacher: VICENTE MAJUA, JULIO IÑIGO DE

Type: Electives ECTS Credits : 3.0

Year : 2 Semester : 1

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Linear Algebra

OBJECTIVES

- To know and use the mathematical tools from linear algebra and matrix theory that are necessary for the formulation of quantum theory in finite dimensions and its application in quantum information theory.
- To understand the description of quantum states in its most general form as density matrices and their most relevant mathematical properties.
- To understand the description of quantum measurements in its most general form as generalized measurements, their relation to projective measurements and their most relevant mathematical properties.
- To understand the description of quantum evolution in its most general form as completely positive maps, their most relevant mathematical properties and some concrete examples that give rise to quantum channels of relevance.
- To understand entanglement as a consequence of the tensor product structure of composite systems in quantum theory. To learn some mathematical properties of entangled states that are relevant for their characterization and application, in particular in the context of quantum non-locality.

DESCRIPTION OF CONTENTS: PROGRAMME

1. Overview of linear algebra and matrix theory.
2. Quantum states: Density matrices.
3. Quantum measurements: Generalized measurements.
4. Quantum evolution and quantum channels: Completely positive trace-preserving maps.
5. Quantum composite systems: Entanglement and non-locality.

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

% end-of-term-examination:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

Solution of problems raised in class during the course individually or in group (40%). End-of-term evaluation (60%).

BASIC BIBLIOGRAPHY

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

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

ADDITIONAL BIBLIOGRAPHY

- J. A. Bergou, M. Hillery, and Mark Saffman Quantum Information Processing, Springer, 2021