230557 – QINFORM – Quantum Information Theory: Communication and Computation

Coordinating unit: 230 - ETSETB Barcelona School of Telecommunications Engineering
Teaching unit: 1022 - UAB - Universitat Autònoma de Barcelona
Academic year: 2015 - 2016
Degree: Master's Degree in Photonics
Erasmus Mundus Master's Degree in Photonics Engineering, Nanophotonics and Biophotonics
ECTS credits: 3 **Teaching languages:** English

Academic staff

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Degree competences to which the subject contributes

Transversal:
1. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.
2. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.
3. ENTREPRENEURSHIP AND INNOVATION: Being aware of and understanding how companies are organised and the principles that govern their activity, and being able to understand employment regulations and the relationships between planning, industrial and commercial strategies, quality and profit.
4. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

Teaching methodology

Lectures
Activities:
- Seminars

Objectives and short description of the course

Quantum Information Theory aims at taking advantage of the quantum properties displayed by Nature at microscopic scale to outperform classical computation and communication. The course is split into 3 parts: first one introduces the basic quantum information concepts and protocols. Second one deals with cryptography and long distance communication. The course ends with a basic introduction to quantum computation and shows its capability of solving some intractable problems for classical computers. Previous knowledge of Quantum Mechanics is highly recommended but not compulsory.

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Study load

Total learning time: 75h	Hours large group:	22.5h	30%
	Hours medium group:	0h	0%
	Hours small group:	0h	0%
	Guided activity:	2.25h	3%
	Self study:	50.25h	67%

Course index

1. **Basic elements of Quantum Information Theory**

   The foundations of Quantum Mechanics and the formalism that will be adopted along the course is reviewed. Basic concepts of quantum information, such as the quantum bit (qubit), generalized measurements, and quantum channels will be presented. The concept of entanglement, locality, Bell inequalities and the class of local operations and classical communication will be discussed.

2. **Basic Protocols of Quantum Information Theory**

   This second block starts by discussing the fundamental differences between quantum information versus its classical counterpart, including an abridged account of classical Shannon theory. Quantum protocols such as dense coding, quantum teleportation and no-cloning theorem are studied.

3. **Quantum Cryptography**

   Quantum key distribution protocols are presented and an analysis of security issues is worked out.

4. **Long-Distance Quantum Communication**

   Quantum communication protocols in realistic environments need to overcome the presence of noise, especially in long-distance communications. Novel protocols such as entanglement swapping and entanglement distillation are analyzed and the crucial role quantum memories and quantum repeaters is discussed.

5. **Basic elements of Quantum Computation**

   The last part of the course is devoted to quantum computing. A short presentation of classical computer science notions, such as Turing machines and complexity classes, is followed by the quantum circuit model of quantum computing consisting on quantum gates and quantum registers. Quantum algorithms (Deutsch, Grover and Shor) demonstrating the full power of quantum computing are discussed.

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Qualification system

Exam: written or oral (90%)
Oral presentations, attending seminars, class attendance (10%)

Bibliography

- M.A. Nielsen and I.L. Chuang. Quantum Computation and Quantum Information, Cambridge Univ. Press (2000)
- JPreskil, Lectures notes of Quantum Information Course: http://www.theory.caltech.edu/people/preskill/ph229#lecture