

## 230557 - QINFORM - Quantum Information Theory: Communication and Computation

Coordinating unit: 230 - ETSETB - Barcelona School of Telecommunications Engineering  
Teaching unit: 1022 - UAB - (ANG) pendent  
Academic year: 2015  
Degree: ERASMUS MUNDUS MASTER'S DEGREE IN PHOTONICS ENGINEERING, NANOPHOTONICS AND BIOPHOTONICS (Syllabus 2010). (Teaching unit Optional)  
MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Teaching unit Optional)  
ECTS credits: 3 Teaching languages: English

### Teaching staff

Coordinator: John Calsamiglia, UAB.  
Others: Emili Bagan, Ramon Muñoz-Tapia.

### Opening hours

Timetable: john.calsamiglia@uab.cat (coordinator)  
emili.bagan@uab.cat  
ramon.munoz@uab.cat

### 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. 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.
3. 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.
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

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### Learning objectives of the subject

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. Theory lessons will be combined with exercise sessions. Previous knowledge of Quantum Mechanics is highly recommended but not compulsory.

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### BIBLIOGRAPHY:

M.A. Nielsen and I.L. Chuang. Quantum Computation and Quantum Information, Cambridge Univ. Press (2000)

J Preskil, Lectures notes of Quantum Information Course:

<http://www.theory.caltech.edu/people/preskill/ph229#lecture>.

D. Aharonov. Quantum Computation: A review. Ann.Rev of Comp. Physics, World Scientific, vol VI ed. Dietrich Stauffer (1998).

### Study load

Total learning time: 75h	Theory classes:	22h 30m	30.00%
	Practical classes:	0h	0.00%
	Laboratory classes:	0h	0.00%
	Guided study:	2h 15m	3.00%
	Self study:	50h 15m	67.00%

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## Content

### 1. Basic elements of Quantum Information Theory

Degree competences to which the content contributes:

Description:

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 along with some paradigmatic examples of state discrimination and quantum metrology. 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

Degree competences to which the content contributes:

Description:

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

Degree competences to which the content contributes:

Description:

Unconditional security in communications using quantum resources. Quantum key distribution protocols are presented and an analysis of security issues is worked out.

### 4. Long-Distance Quantum Communication

Degree competences to which the content contributes:

Description:

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

Degree competences to which the content contributes:

Description:

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 in detail.



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### Qualification system

- Exam: written or oral (50-60%)
- Homework assessments (30%)
- Oral presentations, attending seminars, class attendance (10-20%)

### Bibliography