

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

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| Coordinating unit:  | 230 - ETSETB - Barcelona School of Telecommunications Engineering   |
| Teaching unit:      | 1022 - UAB - (ANG) pendent  |
| Academic year:      | 2018  |
| Degree:             | MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Teaching unit Optional)<br>ERASMUS MUNDUS MASTER'S DEGREE IN PHOTONICS ENGINEERING, NANOPHOTONICS AND BIOPHOTONICS (Syllabus 2010). (Teaching unit Optional) |
| ECTS credits:       | 3   |
| Teaching languages: | English   |

### Teaching staff

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|--------------|--|
| Coordinator: | Calsamiglia Costa, John                    |
| Others:      | Bagan Capella, Emili<br>Muñoz Tapia, Ramon |

### Degree competences to which the subject contributes

#### Basic:

- CB6. (ENG) Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación
- CB7. (ENG) Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio.
- CB8. (ENG) Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicio.
- CB10. (ENG) Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo.

#### Specific:

- CE2. (ENG) Màster en Fotònica:  
Demostrar que comprende las peculiaridades que comporta el modelo cuántico para la interacción luz-materia.
- CE9. (ENG) Màster en Fotònica:  
Capacidad para sintetizar y exponer los resultados de investigación en fotonica según los procedimientos y convenciones de las presentaciones científicas en inglés.

#### General:

- CG1. (ENG) Màster en Fotònica:  
Capacidad para proyectar, diseñar e implantar productos, procesos, servicios e instalaciones en algunos ámbitos de la fotonica como los relacionados con la ingeniería fotonica, la nanofotonica, la óptica cuántica, las telecomunicaciones y la biofotonica
- CG2. (ENG) Màster en Fotònica:  
Capacidad para la modelización, cálculo, simulación, desarrollo e implantación en centros de investigación, centros tecnológicos y empresas, particularmente en tareas de investigación, desarrollo e innovación en todos los ámbitos relacionados con la Fotónica.
- CG4. (ENG) Màster en Fotònica:  
Capacidad para entender el carácter generalista y multidisciplinario de la fotonica viendo su aplicación por ejemplo a la medicina, biología, energía, comunicaciones o la industria

#### 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

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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

- Lectures
- Activities: Seminars

### 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: the first one introduces the basic quantum information concepts and protocols. The second part 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.

### Study load

|                          |                     |         |        |
|--------------------------|---------------------|---------|--------|
| Total learning time: 75h | Hours large group:  | 22h 30m | 30.00% |
|                          | Hours medium group: | 0h      | 0.00%  |
|                          | Hours small group:  | 0h      | 0.00%  |
|                          | Guided activities:  | 2h 15m  | 3.00%  |
|                          | Self study:         | 50h 15m | 67.00% |

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

### Content

|   |   |
|---|---|
| <p>1- Basic elements of Quantum Information Theory</p>  | <p>Learning time: 8h<br/>Theory classes: 8h</p>         |
| <p>Description:<br/>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.</p> |   |
| <p>2- Basic Protocols of Quantum Information Theory</p>   | <p>Learning time: 6h<br/>Theory classes: 6h</p>         |
| <p>Description:<br/>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.</p>   |   |
| <p>3- Quantum Cryptography</p>  | <p>Learning time: 1h 30m<br/>Theory classes: 1h 30m</p> |
| <p>Description:<br/>Unconditional security in communications using quantum resources. Quantum key distribution protocols are presented and an analysis of security issues is worked out.</p>  |   |
| <p>4- Long-Distance Quantum Communication</p>   | <p>Learning time: 2h<br/>Theory classes: 2h</p>         |
| <p>Description:<br/>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.</p>  |   |

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| 5- Basic elements of Quantum Computation   | Learning time: 5h<br>Theory classes: 5h |
| Description:<br>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. |   |

### Planning of activities

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| Seminars | Hours: 2h 18m<br>Theory classes: 2h 18m |
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### Qualification system

- Exam: written or oral (70%)
- Home assessments (30%)

### Bibliography

#### Basic:

Nielsen, M.A; Chuang, I.L. Quantum Computation and Quantum Information. 10th ed. Cambridge University Press, 2010. ISBN 9781107002173.

#### Others resources:

##### Hyperlink

Lectures notes of Quantum Information Course from J. Preskil  
<http://www.theory.caltech.edu/people/preskill/ph229#lecture>