Course guide
230998 - QCRIP - Quantum Computing and Cryptography

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications.
Degree: MASTER'S DEGREE IN CYBERSECURITY (Syllabus 2020). (Optional subject).
Academic year: 2022 ECTS Credits: 3.0 Languages: English

LECTURER
Coordinating lecturer: Consultar aquí / See here:
https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/responsables-assignatura

Others: Consultar aquí / See here:
https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/professorat-assignat-idioma

PRIOR SKILLS
Solid knowledge of linear algebra and probability theory.

TEACHING METHODOLOGY
- Lectures.
- Problems solved individually or in groups by the student.

LEARNING OBJECTIVES OF THE SUBJECT
This subject combines two of the most important branches of science of the 20th century, the quantum theory developed in the 1920s and 1930s by scientists such as Planck, Einstein, Bohr, Heisenberg, Schrödinger, Pauli, Dirac and von Neumann, and the information theory, born after the work of Shannon in 1948. The basic postulates of quantum systems as well as their mathematical model will be presented. We then cover Quantum Key Distribution protocols, which can be used to implement a classical private key cryptosystem with guaranteed security. Quantum error correction are introduced first which are described both from a theoretical and a practical implementation perspective. The last part of the course introduces the concept of quantum computing as the algorithmic framework governed by the quantum mechanical laws which promises to break break the RSA public-key cryptosystem.

STUDY LOAD

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
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</thead>
<tbody>
<tr>
<td>Hours large group</td>
<td>24,0</td>
<td>32.00</td>
</tr>
<tr>
<td>Self study</td>
<td>51,0</td>
<td>68.00</td>
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</tbody>
</table>

Total learning time: 75 h
## CONTENTS

### Introduction to Quantum Information Theory

**Description:**
- a) Introduction to Quantum Mechanics: The EPR paper, the Big Bell Test and course outline.
- b) Quantum states: the Bloch sphere, spectral decomposition, reversible evolution, measurement and the Born rule, the Stern-Gerlach experiment and measurement based on POVM.
- c) Composite quantum systems: Kronecker product description, the no-cloning theorem, separable and entangled states, the Schmidt decomposition, partial trace, purification, entanglement as a resource and the violation of the CHSH inequality.
- d) Quantum protocols: Entanglement distribution, super-dense coding and quantum teleportation.

**Full-or-part-time:** 24h  
Theory classes: 8h  
Self study : 16h

### Quantum Cryptography

**Description:**
- a) Quantum error correction: Repetition codes and the Shor code, review of classical linear codes and CSS codes.
- b) Physical-Layer Security: The wiretap channel, secret key communication, secret key agreement by the source model, sequential key distillation and the channel model.
- c) Quantum Key distribution: The BB84, B92 and EPR protocols and secure CSS and BB84 protocols.

**Full-or-part-time:** 30h  
Theory classes: 10h  
Self study : 20h

### Quantum Computing

**Description:**
- a) Quantum Fourier Transform.
- b) Phase estimation, order finding and Shor's Algorithm for integer factorization.

**Full-or-part-time:** 18h  
Theory classes: 6h  
Self study : 12h

### GRADING SYSTEM

- Attendance is mandatory.
- Participation in class (20%).
- Problems and/or group or individual presentation (80%).

### EXAMINATION RULES.

There is no final exam.
BIBLIOGRAPHY

**Basic:**