**COM-611 Quantum Information Theory and Computation**

**Macris Nicolas**

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<th>Cursus</th>
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<td>Photonics</td>
<td>Opt.</td>
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**Language of teaching**: English  
**Credits**: 4  
**Session**: Oral  
**Exam**: Oral  
**Workload**: 120h  
**Hours**: 56  
**Lecture**: 28  
**Exercises**: 28  
**Number of positions**:

**Remark**
Not offered this year

**Summary**
Today one is able to manipulate matter at the nanoscale were quantum behavior becomes important and possibly information processing will have to take into account laws of quantum physics. We introduce concepts developed in the last 25 years to take advantage of quantum resources.

**Content**

**Part I. A primer on Quantum Mechanics and Qubits.**
Quantum bits.  
Interference experiments with photon polarisation, spin; Superposition principle; Measurement postulate;  
Basic principles of quantum mechanics in finite Hilbert spaces.  
Many Qubit states.  
Entanglement; Bell inequalities and EPR paradox; No cloning; Quantum key distribution; Quantum teleportation.

**Part II. Quantum Information Theory.**
Von Neumann Entropy and Mutual Information.  
Density matrix and mixed states; Von Neumann entropy; Subadditivity; Araki-Lieb lower bound; Mutual information.  
Quantum data compression.  
Schumacher compression; Compression of mixed states and Holevo bound.  
Noisy Quantum Channels.  
Channel models; Capacity results.

**Part III. Quantum Computation.**
Basic ideas behind the Quantum Computer.  
Feynman and Deutsch point of view; Unitary evolution and quantum parallelism; Quantum circuits;  
Universal elementary gates; Quantum Fourier transform and its circuit.  
Quantum Algorithms.  
Deutsch-Josza problem; Grover search algorithm; Shor algorithm for the period of a function;  
Application to factoring and cryptography.  
Quantum Error Correcting Codes (if time permits)

**Learning Prerequisites**

**Required courses**
Linear algebra.

**Recommended courses**
Linear Algebra and Basic Information Theory. No prerequisite in quantum mechanics will be needed.

**Important concepts to start the course**
Matrix and vector calculus, inner product, complex numbers.

Learning Outcomes
By the end of the course, the student must be able to:
• Master the basic principles of quantum computation and information theory.
• Be able to state the main differences between classical and quantum concepts related to computation, information and correlations.

Teaching methods
Ex-Cathedra. Homeworks.

Expected student activities
Participation in class and homeworks.

Assessment methods
Homeworks + oral exam

Resources
Bibliography
Nielsen and Chuang: Quantum Information and Computation. CUP.

Ressources en bibliothèque
• Quantum information and computation / Nielsen

Notes/Handbook
Class notes.

Websites
• http://ipg.epfl.ch/doku.php?id=en:courses