Quantum information and computation

Lecturer
Ognyan Oreshkov (Coordinator)

Course mnemonic
INFO-H514

ECTS credits
5 credits

Language(s) of instruction
English

Course period
See programme details

Campus
Solbosch

Course content

Introduction

- Basic principles of quantum mechanics (pure and mixed states, unitary evolution)
- Quantum measurements (projective and positive operator valued measure)
- Notion of quantum bit
- Quantum no-cloning theorem

Quantum entanglement

- Separability vs entanglement of pure and mixed states
- Nonlocality (EPR paradox and Bell inequalities)
- Dense coding and teleportation

Quantum information theory

- Basic notions of classical information theory
- Quantum source coding (von Neumann entropy)

Quantum cryptography

- BB84 protocol for quantum key distribution
- Entanglement-based quantum key distribution

Quantum computing

- Quantum circuits and universal gates
- Phase kickback: Deutsch-Jozsa's algorithm
- Amplitude amplification: Grover's search algorithm
- Quantum Fourier transform: Shor's factoring algorithm

Quantum error correction

- Decoherence
- Classical error correction
- 3-qubit repetition code
- Shor's 9-qubit code
- Fault tolerance (basics)

Objectives (and/or specific learning outcomes)

The final objectives are

- to familiarise the students with the basic properties of quantum information, in particular how it differs from classical information and how it can be processed keeping quantum coherence;
- to expose how these properties can be exploited in different communication and computation applications, analyzing in particular the notion of quantum algorithms;
- to confront the students with current challenges in the field of quantum information and computation, both from a physics and computer science perspective.

Learning outcomes:

At the end of the course students are able to

- understand the basics of quantum information theory and its main applications;
- solve simple problems in quantum information and computation;
- design and analyse simple quantum algorithms using basic tools such as phase kickback and amplitude amplification.

Teaching method and learning activities

- Theory courses
- Exercice sessions

References, bibliography and recommended reading

- Michael A. Nielsen and Isaac L. Chuang. Quantum Computation and Quantum Information. Cambridge University Press, 2000
- John Preskill. Lecture notes for the course "Physics 219/ Computer Science 219" at Caltech. See in particular chapter 6 for quantum computation: http://www.theory.caltech.edu/~preskill/ph219/index.html#lecture
- David Mermin. Quantum Computer Science; An introduction. Cambridge Univ Press, 2007

Course notes

Université virtuelle

Other information

Place(s) of teaching

Solbosch

Contact(s)

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Evaluation method(s)

Oral examination

Evaluation method(s) (additional information)

Final assessment: open book oral exam

Determination of the mark (including the weighting of partial marks)

The oral exam is graded on a total of 20.

Main language(s) of evaluation

English

Programmes

Programmes proposing this course at the Brussels School of Engineering

MA-IRIF | Master of science in Computer Science and Engineering | finalité Professional/unit 1 and finalité Professional/unit 2 and MA-IRPH | Master of science in Physical Engineering | finalité Professional/unit 2

Programmes proposing this course at the faculty of Sciences

MA-INFO | Master in Computer science | finalité Professional/unit 2 and MA-SECU | Master in cybersecurity | finalité Cryptalalysis and Forensics/unit 2