PHYS-541

Quantum computing

Savona Vincenzo

Cursus	Sem.	Type
Ing.-phys	MA1, MA3	Opt.
Minor in Quantum Science and Engineering	H	Opt.
Physicien	MA1, MA3	Opt.
Physics		Opt.
Quantum Science and Engineering	MA1, MA3	Opt.

Language of teaching	English
Credits	6
Session	Winter
Semester	Fall
Exam	Oral
Workload	180h
Weeks	14
Hours	**5 weekly**
Lecture	3 weekly
Exercises	2 weekly
Number of positions	

Summary

This course introduces quantum computing, starting with quantum mechanics and information theory. It covers the quantum circuit model, universal gates, foundational quantum algorithms, noise, quantum error correction, NISQ quantum algorithms, and an overview of recent progress.

Content

Introduction
- Crash course on quantum mechanics
- Quantum measurement and interaction with the environment
- Foundations of classical and quantum information theory

Quantum computing
- The quantum circuit model
- Universal quantum gates
- Quantum advantage and the Deutsch-Jozsa algorithm

Overview of quantum algorithms
- The quantum Fourier transform and Shor's factoring algorithm
- The quantum state amplification and Grover's database search algorithm
- The quantum phase estimation and linear system solving
- Digital quantum simulation and unitary time evolution

Noise in quantum hardware and the digital noise model

Quantum error correction
- The Shor quantum error correction code
- Stabilizer codes
- Fault-tolerant quantum computing and the threshold theorems

Hybrid quantum-classical algorithms for NISQ hardware
- The variational quantum eigensolver
- The quantum approximate optimization algorithm
- The variational quantum dynamics algorithms

Overview of recent progress in quantum computing and quantum algorithms.

Keywords

1. Quantum Mechanics
2. Quantum Computing
3. Quantum Information Theory
4. Quantum Circuit Model
5. Universal Quantum Gates
6. Quantum Algorithms
7. Quantum Error Correction
8. NISQ Hardware

9. Hybrid Algorithms
10. Recent Advancements

Learning Prerequisites

Required courses

Quantum Physics, Linear Algebra

Learning Outcomes

By the end of the course, the student must be able to:

- Apply the quantum circuit model
- Design simple quantum algorithms
- Formalize the quantum computing paradigm
- Assess / Evaluate the computational complexity of quantum algorithms
- Analyze the origin and extent of quantum advantage
- Discuss quantum error correction codes
- Explore the recent progress in the field
- Classify quantum algorithms

Teaching methods

Ex cathedra. Lecture notes available. Exercises and hands-on problems using the Qiskit platform

Assessment methods

Oral exam including the presentation of a project selected and carried out during the last weeks of the term

Resources

Bibliography

M. A. Nielsen & I. L. Chuang, Quantum Computation and Quantum Information (Cambridge, 2011)
John Preskill, Lecture Notes on Quantum Information and Computation

Ressources en bibliothèque

- Quantum Computation and Quantum Information / Nielsen & Chuang

Notes/Handbook

Lecture notes provided

Moodle Link

- https://go.epfl.ch/PHYS-541