EPFL

QUANT-400

# Introduction to quantum science and technology

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| Cursus | Sem. | Type |
|---|---|---|
| Minor in Quantum Science and Engineering | H | Opt. |
| Quantum Science and Engineering | MA1, MA3 | Obl. |

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|---|---|
| Language of teaching | English |
| Credits | 5 |
| Session | Winter |
| Semester | Fall |
| Exam | Written |
| Workload | 150h |
| Weeks | 14 |
| **Hours** | **4 weekly** |
| Lecture | 3 weekly |
| Exercises | 1 weekly |
| **Number of positions** | |

## Summary

A broad view of the diverse aspects of the field is provided: quantum physics, communication, quantum computation, simulation of physical systems, physics of qubit platforms, hardware technologies. Students will grasp the field as a whole and better orient themselves on specialized topics.

## Content

**Introduction *(2 weeks)***:

- Overview of the frontiers of quantum science, technology and applications.
- Introduction to qubits, quantum states, measurements, evolution. Axiomatic formulation.
- Illustration with two level systems, Bloch sphere, Spin, its manipulation in magnetic fields. Heisenberg and spin Hamiltonians, elementary gates. Coherence times.

**Communication, information and computation (5 weeks)**

- Quantum communication: QKD, dense coding, teleportation.
- Circuit model of computation.
- Introduction to algorithms (Deutsch-Josza, Simon or Shor, QAOA)
- Quantum simulation of physical systems (VQE, hybrid quantum-classical approaches)

**Physics of qubit platforms (3 weeks):**

- Introduction to qubit platforms
- superconducting qubits
- trapped ions, spin qubits (time permitting)

**Hardware technologies and applications (4 weeks):**

- Single electron transistors (SET) and fabrication technologies
- Single electron memories (SEM)
- Hybrid CMOS-SET for analog and sensing functions at cryogenic temperatures

- The quantum stack, Quantum-classical interfaces
- From fidelity to electronic circuit specifications
- Cryogenic electronics to control quantum systems

## Keywords

quantum bit, qubit, quantum information, quantum computation, algorithms, spin, quantum sensing, metrology, NISQ devices, cryogenic electronics, quantum-classical interface.

## Learning Prerequisites

### Required courses

- Linear Algebra
- Elementary physics classes

## Learning Outcomes

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

- Describe various frontier topics in quantum science and technology.
- Illustrate quantum principles for simple systems
- Recognize quantum computation models
- Explain the simplest primitive communication protocols
- Present current hardware technologies and their applications
- Design electronics for quantum systems

## Teaching methods

- Ex-cathedra lectures
- Exercices session

## Assessment methods

- Written exam

## Supervision

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|---|---|
| Assistants | Yes |
| Forum | Yes |

## Resources

### Bibliography

- The physics of information technology / Gershenfeld
- Quantum computation and quantum information / Nielsen and Chuang
- Quantum computer science: an introduction /Mermin
- Bharti, K., et al., 2022. Noisy intermediate-scale quantum algorithms. Rev. Mod. Phys. 94, 015004.

### Ressources en bibliothèque

- Quantum computation and quantum information / Nielsen and Chuang
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### Moodle Link

- https://go.epfl.ch/QUANT-400

### Prerequisite for

Classes in Quantum Science and Engineering