Linnæus University

Course syllabus

Faculty of Technology

Department of Physics and Electrical Engineering

4FY590 Introduktion till kvantberäkning, 15 högskolepoäng
4FY590 Introduction to Quantum Computing, 15 credits

Main field of study
Physics

Subject Group
Physics

Level of classification
Second Level

Progression
A1N

Date of Ratification
Approved by Faculty of Technology 2022-02-07
The course syllabus is valid from autumn semester 2022

Prerequisites
General entry requirements for secondcycle studies and specific entry requirements:

- A bachelor in physics or engineering physics; or: a bachelor in chemistry, mathematics, or computer science with a good knowledge of basic quantum mechanics or equivalent.
- English 6

Objectives

Upon completion of the course, the student should

- be proficient with the mathematical tools and the basic principles of quantum mechanics (e.g., entanglement) that are essential to understand quantum computing.
- be able to explain the concepts of qubits and how to manipulate the states of qubits by quantum gates.
- be able to explain and compare the difference between classical and quantum information processing.
- be able to explain the basic structure of quantum algorithms based on the circuit model, and compute the outcome of basic quantum circuits.
- be able to explain what quantum advantage is expected from the quantum

algorithms addressed in the course with respect to their classical counterparts.
- be able to program simple quantum algorithms on a cloud quantum computer or a simulator.
- be able to calculate energies of molecules using a combination of quantum and classical computing.
- be familiar with simple realizations of solid-state-based qubits devices such as semiconductor quantum dot spin qubits and superconducting qubits.
- have acquired the background which can be useful to start a master thesis in the field of quantum computation.

Content

- History & overview: Classical vs quantum computing.
- Linear Algebra for quantum computing: Vector space, linear operators, inner product, eigenvectors and eigenvalues, singular value decomposition
- Quantum Mechanics for quantum computing: Quantum state, superposition, time evolution, unitary transformations, quantum measurements
- Qubits: Single qubit, two qubits, Bell state, entanglement, physical and logical qubits
- Quantum gates & Circuits: Pauli gates, Hadamard gates, controlled gates, swap gates, Toffoli gates, universal quantum gates, quantum circuit elements, basic quantum circuit design.
- Simple quantum algorithms: quantum parallelism, Deutsch-Jozsa algorithm, Simon’s algorithm
- Quantum algorithms: quantum Fourier transform, quantum phase estimation, Shor’s factoring algorithm, Grover’s search algorithm.
- Quantum simulation: Hamiltonian mapping, variational algorithms
- Quantum information: Shannon entropy, Von Neumann entropy, quantum teleportation, quantum cryptography.
- Quantum computing for quantum chemistry – Hamiltonian representation, principles of energy calculation
- Practical realizations of qubits: Molecular qubits, semiconductor qubits, photon qubits, ion-trap qubits, superconducting qubits, topological qubits.
- Decoherence and error correction: Density operator, mechanism of decoherence, bit-flip and phase-flip errors, No cloning theorem, stabilizer formalism, framework of error correcting codes.
- Recent progresses in the development of quantum computers.

Type of Instruction

The teaching consists of lectures and virtual labs. Students can also register for the “distance” version of the course and follow the course via the internet.

IT support and technical information: Email and web connection. Live and recorded lectures on the course homepage.

Examination

The course is assessed with the grades A, B, C, D, E, Fx or F.

The grade A constitutes the highest grade on the scale and the remaining grades follow in descending order where the grade E is the lowest grade on the scale that will result in a pass. The grade F means that the student’s performance is assessed as fail (i.e. received the grade F).

The examination is composed of two moments, each earning 7.5 credits:

1. Written problem sets during the course.
2. Final project at the end of the course, which the student will present in a written article and in an open seminar.

Repeat examination is offered in accordance with Local regulations for courses and examination at the first and second-cycle level at Linnaeus University.If the university has decided that a student is entitled to special pedagogical support due to a disability, the examiner has the right to give a customised exam or to have the student conduct the exam in an alternative way.

Course Evaluation

During the implementation of the course or in close conjunction with the course, a course evaluation is to be carried out. Results and analysis of the course evaluation are to be promptly presented as feedback to the students who have completed the course. Students who participate during the next course instance receive feedback at the start of the course. The course evaluation is to be carried out anonymously.

Other

Grade criteria for the A–F scale are communicated to the student through a special document. The student is to be informed about the grade criteria for the course by the start of the course at the latest.

Required Reading and Additional Study Material

- Quantum Computation and Quantum Information by Michael A. Nielsen & Isaac L. Chuang (10th Anniversary Edition)
- Lecture Notes distributed by the instructors.