

QUANTUM COMPUTING ALGORITHMS

Quantum phenomena provide computing and information handling paradigms that are distinctly different and arguably much more powerful than their classical counterparts. In the past quarter of the century, much progress has been made on the theoretical side, and experiments have been carried out in which quantum computational operations were executed on a small number of quantum bits. The NSF has declared this general area to be one of the 10 big ideas for future investments. In June 2018, the science committee of the House of Representatives unanimously approved the National Quantum Initiative Act (H.R. 6227), which has created a 10-year federal effort to boosting quantum science. Similar funding commitments have been made throughout the world.

This course provides an introduction to the theory of quantum computing and information. The covered topics include 1) the fundamental elements of quantum information processing (qubits, unitary transformations, density matrices, measurements), 2) entanglement based communications protocols (e.g., teleportation) and games (e.g., CHSH), the Bell inequalities, 3) quantum algorithms such as Shor's factoring and Grover's search, and 4) basic (quantum) error correction algorithms. The course material will be accessible to undergraduate and graduate students with a variety of backgrounds, e.g., electrical engineers, physicists, mathematicians, and computer scientists.

Learning Objective:

The students will learn the fundamentals of quantum information science, as well as a selected number of more advanced topics of their individual interests.

Instructor: Emina Soljanin (contact info on the web page, office hours by appointment).

Class time and place: M & W, 3:00 – 4:20 PM, on Webex

Prerequisites: Calculus, linear algebra, and probability at an undergraduate level as well as familiarity with complex numbers are required. Prior exposure to quantum mechanics and information/coding theory is helpful but not essential.

Course notes: given per week in separate documents on the class (Sakai) web page.

Recommended reading:

- N. D. Mermin, *Quantum Computer Science: An Introduction*, Cambridge Univ. Press (2007).
- J. D. Hidar, *Quantum Computing: An Applied Approach*, Springer (2019).
- L. Susskind and A. Friedman, *Quantum Mechanics: The Theoretical Minimum*.
- J. Preskill, *Lecture Notes for Physics 229: Quantum Information and Computation*.
- F. W. Byron and R. W. Fuller, *Mathematics of Classical and Quantum Physics*.

Grading: (weekly) quizzes 60%, final take-home exam 20%, project 20%.

Remarks on the topics: Many topics outlined above are typical for a quantum information science course at an advanced-undergraduate/graduate level. Such courses have been taught at several universities for many years, at ECE, CS, and Physics departments. The course usually covers selected topics of current interest as well. We encourage students to choose their project topics according to their own (research) interests.

Comparison with the Spring course: Both courses start by providing answers to the three essential questions that any newcomer to quantum computing needs to know: How is quantum information represented? How is quantum information processed? How is classical information extracted from quantum states? The Fall course then covers selected quantum algorithms. After the initial topics, the Spring (systems) course moves to selected topics in quantum computing, communications, and multi-particle systems.